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# GIS and Remote sensing Approach in Identifying Ground Water Recharge Zones of Cheriyal Watershed

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## ABSTRACT

India has been bestowed with substantial water resources. Ground water, which is the source of more than 85 percent of rural domestic water requirements of the country, is depleting fast in many areas due to its large-scale withdrawal. Present study was conducted in a watershed to identify the ground water recharge zones and suitable structures using Remote Sensing coupled with Geographical Information System and Analytical Hierarchy Process. The parameters such as Geology, Geomorphology, Soil type, Land use, Lineament, Elevation, Slope and Ground water table depth were selected that are closely linked to surface and ground water availability. A base map of watershed was prepared by digitizing the boundary in bhuvan. The satellite images DEM 30 m, LISSIII 25 m and field inputs were used to derive different thematic maps. Multi criteria decision making was applied to all the parameters in thematic maps by assigning ranks from 1 to 5 scale and reclassified depending on its influence on the storage and movement of groundwater. The pair wise comparison for 6 layers were given based on the comparison between the layers and their relative importance towards groundwater prospects and a 6×6 matrix was formed. Based on the comparison matrix the reclassified maps were multiplied with normalized weights and added up in raster calculator to get the final suitability map. From the analysis it was found that 5.70 Percent area is highly suitable for recharge and 60.58 Percent of area was moderately suitable and 33.71 Percent was less suitable for recharge.

**Key Words:** AHP, GIS, Remote sensing, Recharge zones.

## INTRODUCTION

Water is a precious and valuable resource for the whole world. Over the years the unscientific use of water has led to a situation of uncertainty and stress for water resources. This alarming situation calls for a cost and time effective techniques for evaluation of surface and ground water resources and management planning. Water being by far the biggest and most vulnerable of all, then the consequences is far reaching and devastating. In recent times, many researchers such as Mishra *et al* (2010) and Jyoti Sarup *et al* (2011) have used the approach of remote sensing and GIS for identification of ground water potential zones and exploration of ground water with locating the artificial recharge sites. Balchandar *et al* (2010) and Kumar *et al* (2011) used the remote sensing and GIS techniques for generation of ground water recharge zones map for the improvement and development of ground water for the region.

Integrated approach of remote sensing and GIS can provide the appropriate platform for convergent analysis of divergent datasets for decision making in not only mapping and planning of groundwater resources but also management of groundwater resources for its efficient and cost effective use for a region or state. This study was aimed to develop and apply integrated method for combining the information obtained by analyzing multi-source remotely sensed data in a GIS environment for better understanding the groundwater resources in Cheriyal watershed.

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## Study Area

Cheriyal village is located in Telangana state of India with an area of 11.29 km$^2$. It is located between 78°9'36" and 78°7'48"E longitude and 17°31'48" and 17°34'48"N latitude. The main river is Manjeera. Rainfall occurs from July to September under the influence of south-west monsoon, with an average annual precipitation of 930 mm.

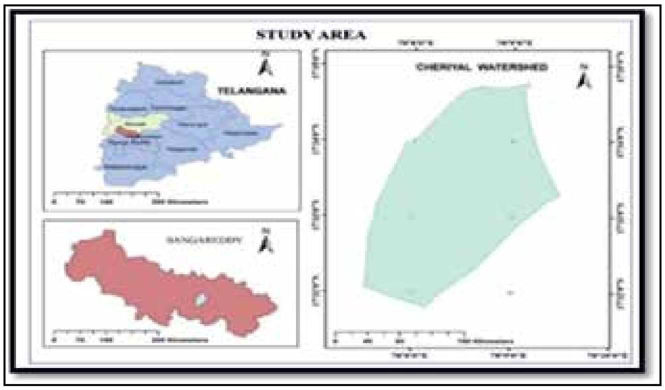


Fig.1 Location of the watershed

## MATERIALS AND METHODS

### Data Collection

A basic Preliminary survey was conducted in watershed to gain basic understanding on status of ground water. The survey involved in meeting the villagers and collecting basic information on land use, source of water for irrigation, no. of bore wells and cropping pattern to explore the prospects of ground water development. Selection of proper sites for ground water recharge needs information on land use/land cover, soil type, geomorphology, drainage density and other related parameters.

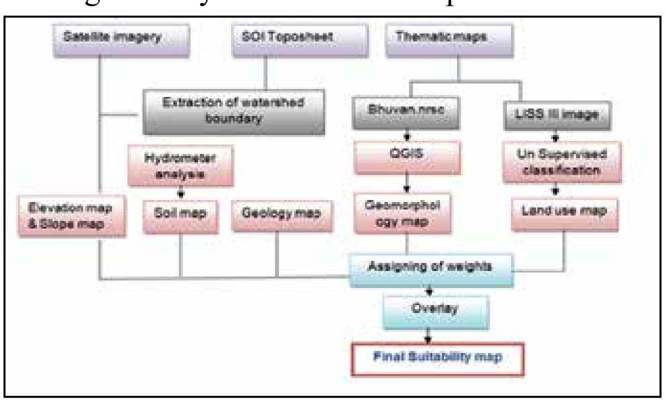


Fig.2 Methodology Flowchart

## Preparation of Thematic Maps

### Base map

Base map provides background details necessary to orient the location on the map. Base map was prepared from polygonal digitizing of Cheriyal watershed boundary in bhuvan and exported to Arc GIS 10.3.

### Elevation map

Elevation map of the study area derived from Cartosat DEM after clipping with boundary. The highest elevation in the watershed is at South side i.e., about 503 m and reduced towards north.

### Slope

The slope of an area is important parameter that defines recharge capability. The slope of the area is more at central part of study site due to mining or some excavation. The derived map was classified into gentle (0-5%), moderate (5-10%) and strong (>10%) slope as shown in Fig.4. The steep slope area is considered as poor in terms of recharge and given less importance because of higher runoff potentiality in that area given in Table 1.

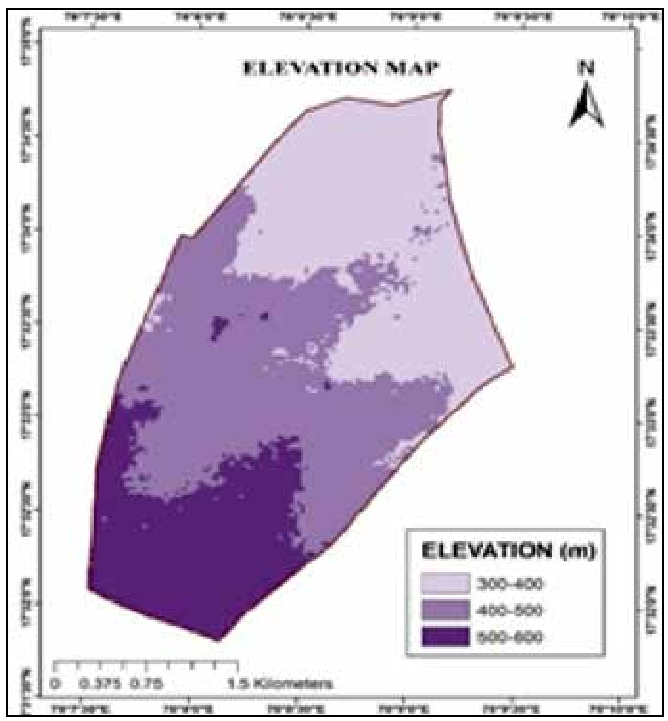


Fig.3 Elevation map

**Table 1. Ranking and calculated normalized weights for different parameters.**

| Sr No. | Parameter | Class | Recharge prospect | Rank | Normalized weight |
|---|---|---|---|---|---|
| 1 | Geomorphology | Water bodies | Very good | 5 | 0.500 |
| | | Anthropogenic | good | 4 | 0.400 |
| | | Denduational | Very poor | 1 | 0.100 |
| 2 | Land use land cover | Agricultural land | Very good | 5 | 0.333 |
| | | Water bodies | good | 4 | 0.266 |
| | | Fallow land | moderate | 3 | 0.200 |
| | | Scrub land | poor | 2 | 0.133 |
| | | Settlings | Very poor | 1 | 0.066 |
| 3 | Slope (%) | Gentle (0-5) | Very Good | 5 | 0.555 |
| | | Moderate (5-10) | Moderate | 3 | 0.333 |
| | | Strong (>10) | Very poor | 1 | 0.111 |
| 4 | Elevation (m) | 300-400 | Very Good | 4 | 0.444 |
| | | 400-500 | Moderate | 3 | 0.333 |
| | | 500-600 | Poor | 2 | 0.222 |
| 5 | Drainage density ($D_d$) | 0-1.2 | Very good | 5 | 0.333 |
| | | 1.2-2.4 | Good | 4 | 0.266 |
| | | 2.4-3.6 | Moderate | 3 | 0.200 |
| | | 3.6-4.8 | Poor | 2 | 0.133 |
| | | 4.8-6 | Very poor | 1 | 0.066 |
| 6 | Geology | Banded granite | moderate | 3 | 1.00 |
| 7 | Soil texture | Sandy loam | Good | 4 | 0.444 |
| | | Sandy clay loam | Moderate | 3 | 0.333 |
| | | Sandy clay | Poor | 2 | 0.222 |
| | | Clay loam | Poor | 2 | 0.222 |
| | | Clay | Very poor | 1 | 0.111 |

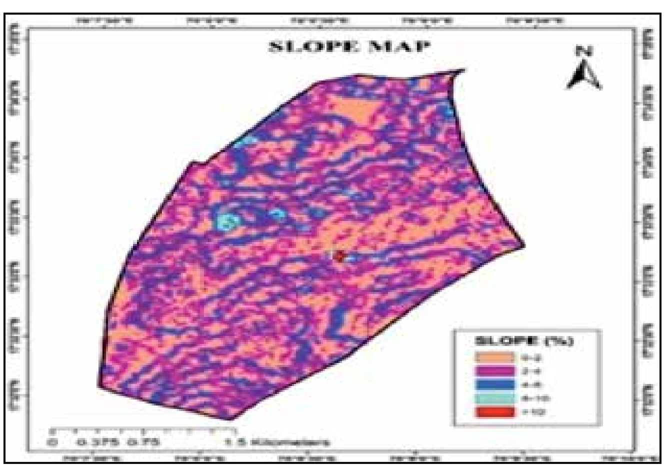


Fig.4 Slope map

**Drainage density**

Drainage density is an expression that provides a quantitative measure of length of stream with a square grid of the area in terms of km/km$^2$. Areas having high density are not suitable for groundwater development because of the greater surface runoff. Drainage map was generated from Cartosat DEM (30 m) using the raster calculator tool, which was then converted to vector and further the drainage density (km/km$^2$) map was prepared with 'line density' analysis tool. Study area was found to have 5$^{th}$ order of drainage and drainage densities was found between 0-6 km/km$^2$.

**Table 2. Pair-wise comparison matrix.**

| | GM | SLP | DD | LULC | SOIL | ELEV | Normalized Weight |
|---|---|---|---|---|---|---|---|
| GM | 1 | 2 | 2 | 4 | 3 | 7 | 0.3753 |
| SLP | 1/2 | 1 | 2 | 3 | 3 | 1 | 0.2053 |
| DD | 1/2 | 1/2 | 1 | 3 | 5 | 1/6 | 0.1316 |
| LULC | 1/4 | 1/3 | 1/3 | 1 | 2 | 9 | 0.1268 |
| SOIL | 1/3 | 1/3 | 1/5 | 1/2 | 1 | 4 | 0.0847 |
| ELEV | 1/7 | 1 | 6 | 1/9 | 1/4 | 1 | 0.0763 |

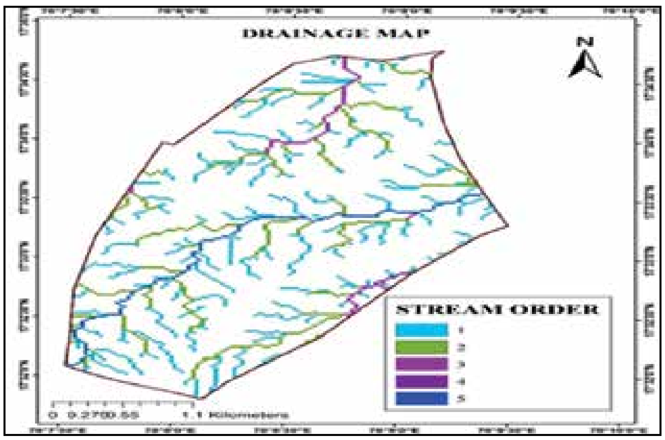


Fig.5 Drainage map

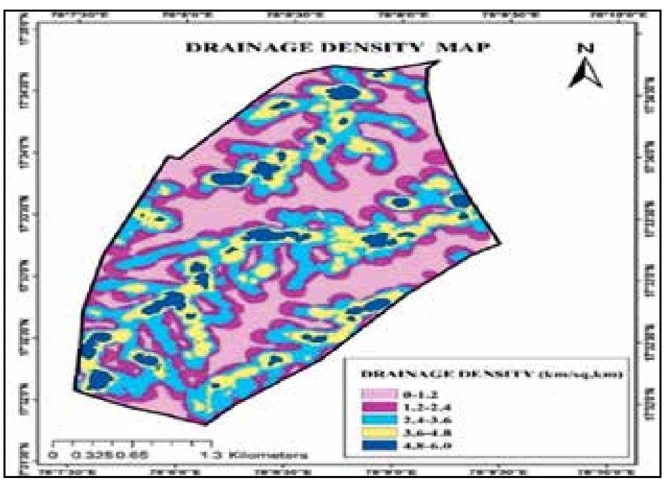


Fig.6 Drainage Density map

## Geomorphology map

Geomorphology map was obtained from Bhuvan ISRO's portal and imported in QGIS. Then map is exported and clipped to study area and digitized in Arc GIS 10.3.Denduational pediment complex was predominant in this area .Anthropogenic type was found in some places.

## Land use and land cover map

Land use and land cover map **(**LULC) features control the occurrence of groundwater and also causes for infiltration for recharge, with variety of classes among itself. It was prepared from Resource sat LISS III satellite image using unsupervised classification in ERDAS Imagine 2015. Study area is comprised of water bodies, settlings, scrub land, fallow land and agriculture land.

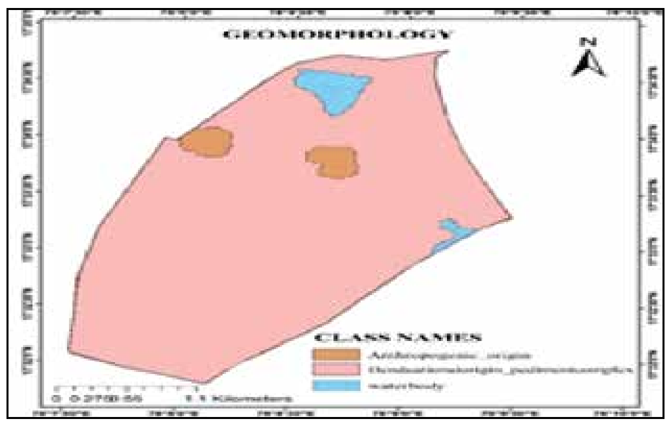


Fig.7 Geomorphology Map

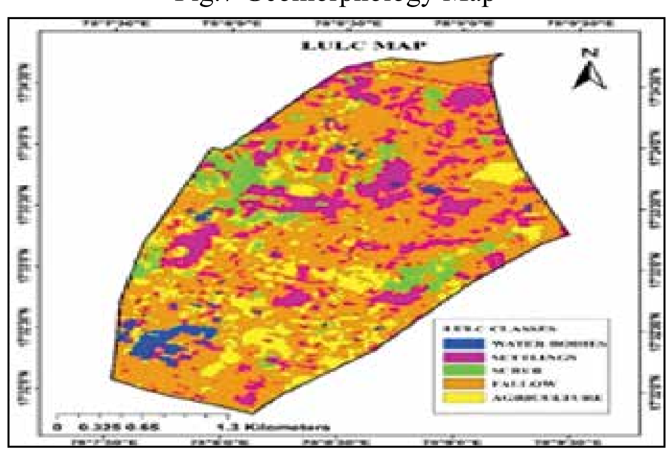


Fig.8 LULC Map

### Geology map

Geological set-up of an area plays a vital role in the distribution and occurrence of groundwater. Geology map obtained from GW department was geo-referenced and clipped to study area in. It has only banded gneiss granite type of rock structure all-over the area.

### Soil texture map

As type of soil texture varies, the groundwater recharge capability varies. Soil samples were collected from study area and hydrometer analysis is done to know the soil texture. Using IDW tool in Arc GIS, soil texture map was prepared. Sandy loam. Sandy clay loam, sandy clay, clay loam and clay soils are present in Cheriyal. Sandy clay and clay loam are predominant about 787.6513 ha and clay occupies about 258.2704 ha.

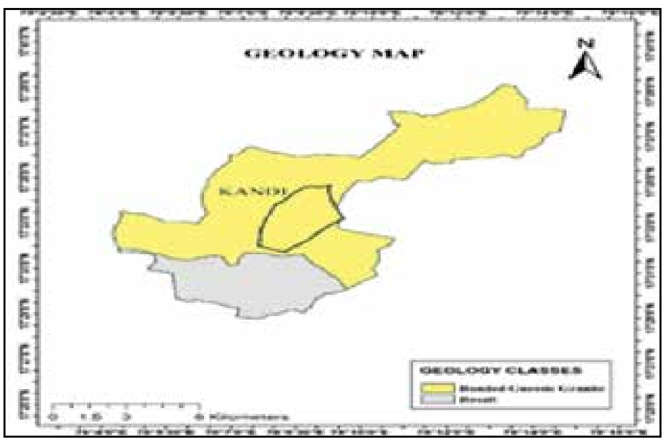


Fig.9 Geology Map

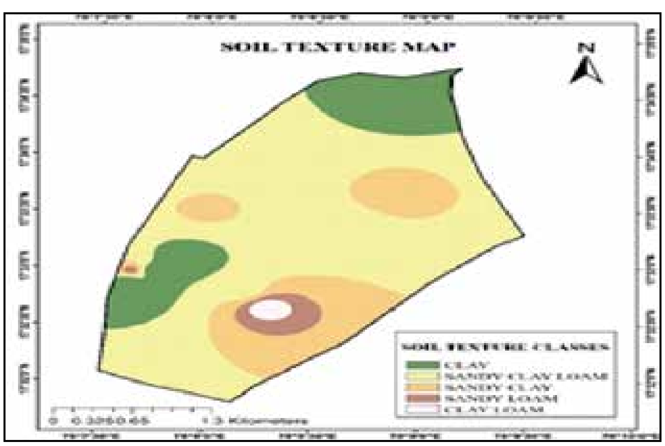


Fig.10 Soil Texture Map

### Multi criteria decision making (AHP)

Analytic Hierarchy Process (AHP) analyzer is online tool that facilitates the group decision making by pair wise comparison based on expert judgment values. The basic of AHP was developed by Dr. T.L. Saaty and other professors .It can be used for Project Prioritization, Priority Setting, Research Project Monitoring and Evaluation (PME) and also for Technology Valuation and Technology Management.

All the thematic maps were reclassified and assigned ranks on the scale 1 to 5 to each sub class depending on its influence on the storage and movement of groundwater. In this ranking 1 given for very poor and 5 scale is for very good in terms of groundwater Recharge. The Normalized weights were assigned to various thematic layers using Analytic Hierarchy Process which include geomorphology, land use/land cover, soil, drainage density; slope, elevation provides certain clue for the occurrence of groundwater. Based on the comparison matrix the reclassified maps were multiplied with normalized weights and added up in raster calculator to get the final suitability map.

## RESULTS AND DISCUSSION

From the study it was found that the slope of Cheriyal watershed ranging between 0 to 19%. The majority of the study area i.e., about 1118.779 ha is under low degree of slope (0-5%), this plain to gentle slope area characterized by very good category for groundwater recharge due to nearly flat terrain, and slow surface runoff allowing more time for rain water to percolate. The area with a steep slope is considered as poor groundwater recharge areas due to higher slope, higher runoff, and low infiltration**.**

The various land use classes in the area are agriculture, settlings, scrub, fallow and water bodies. Fallow land comprises about 60.70% (685.3ha), settlings 19.48% (220ha), agricultural land 11.86% (133.9ha), scrub land 5.81% (65.6ha) and water bodies 2.13% (24.1ha). The Geomorphology of the area comprises of anthropogenic origin, denduational pediment complex and water bodies. Denduational pediment complex has no property to store water. It comprises about 1064 ha (94.24%), anthropogenic origin about 33ha (2.92%) and water bodies which are good at ground water recharge comprises of 32 ha (2.83%) of total area. The drainage density map reveals a density value varying from 0 to 6 km/km$^2$. Low drainage density in the study area indicates less runoff and subsequently more chances for ground water recharge.

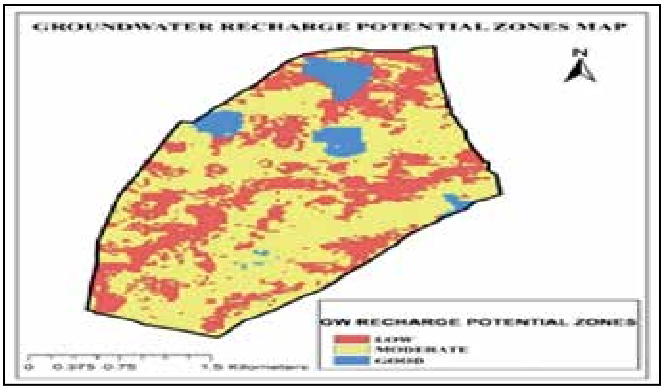


Fig.11 Ground Water Recharge Potential Map

From the analysis it was found that 5.70 per cent of area (64.248 ha) is suitable for recharge and 60.58 per cent of area (682.856ha) is moderately suitable and 33.71 per cent (379.94 ha) is less suitable for recharge.

The main suggested recommendations and location of different structures is shown in Fig.12.

### Boulder bund

These bunds are low cost small bunds across 1st to 3rd lower order streams. They may be made of dry stone masonry or boulders or even brushwood.

### Check dams

Check dams are engineered structures constructed across higher order (>3rd order) streams having minimum average area of 25 ha. These structures are constructed for checking the stream runoff during monsoon and for storage of rain water .Although these structures are constructed for the purpose of storage of water these may also help recharge of ground water reservoir located in the near vicinity.

### Recharge pit

Recharge pits are made either by constructing an embankment across a water course or by excavating a pit or the combination of both. These structures are recommended in single crop areas for providing irrigation to limited area during critical period.

### Injection wells

As the study area has no lineaments, recharge can be also done by injection wells. Injection wells are structures similar to a tube well but with the purpose of augmenting the groundwater storage of a confined aquifer by pumping in treated surface water under pressure.

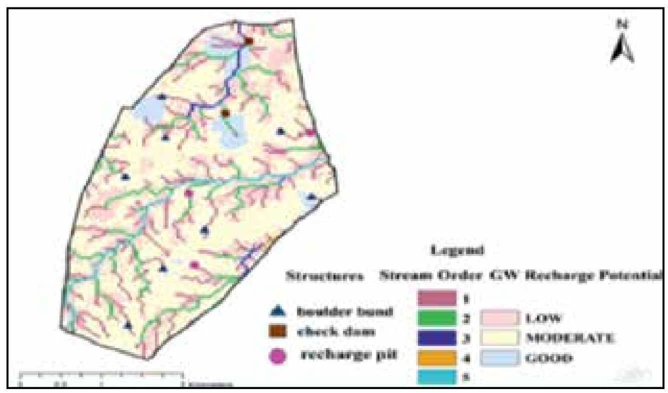


Fig.12 Map showing proposed recharge structures

## CONCLUSION

An integrated GIS technique for Ground water modeling is proved as efficient over manual methods in control of time and labor. Different thematic layers Elevation, Soil, Slope, Land use, Geology and Geomorphology maps were prepared using Arc GIS, Erdas and QGIS software. Weight factor was assigned for every thematic layer and their individual factor classes based on their significance in ground water recharging. The reclassified maps were overlaid for adding up of the cells and derived suitability map for Cheriyal watershed. The final delineated map integrated with stream order and slope map and 12 recharge structures were suggested at appropriate locations.

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