# Weighted Overlay Analysis of Geoinformatics in the Exploration of Groundwater

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***Abstract:*** In our country a considerable part of the Agricultural production depends upon the availability of groundwater. So, exploration of groundwater has got an importance. Groundwater occurrence being a sub-surface phenomenon, its identification and location is based on direct or indirect analysis. Directly it can be observed by terrain features like geological and geomorphic features and their hydrologic characters. In modern techniques GIS tool, remote sensing data were used to prepare and analyse digital layers of lithology, geological structures, drainage and topography to detect the most important promising sites for groundwater exploration. An integrated approach including studies of lithology, drainage and slope have been taken up using GIS techniques. A separate map of existing groundwater levels is integrated with the generated maps to calculate the zones of groundwater. A case study of Beemunipadu, Guladurthi, Kampamalla, Pottipadu of Koilakuntla mandal of Kurnool District is made to detect the ground water zones by using GIS and Remote Sensing applications. The study showed that Remote Sensing and GIS provided efficient tools for mapping promising sites for groundwater exploration. However, the data of groundwater wells would contribute to refining the final locations of most promising sites.

***Index Terms* – Geoinformatics, Groundwater, Integration, Weighted Overlay Analysis**

## I. INTRODUCTION

Groundwater is one of the most valuable natural resources which contribute significantly in total annual supply. It supports human health, economic development (domestic, agriculture, industrial purpose) & ecological diversity. Because of its several inherent qualities like increase in population, advanced irrigation practices & industrial usages it has become an immensely important and dependable source of water supplies in all climatic region including both urban and rural areas of developed and developing countries. Groundwater is a form of water occupying all the voids with in a geological stratum. The ground water occurrence in a geological formation and scope for its exploration primarily depends on the formation of porosity. High relief and steep slopes impact higher runoff while topographic depressions increase infiltration. An area of higher drainage density also increases surface runoff, while topographical depressions increase infiltration, surface water bodies like river, ponds, etc., can act as recharge zones. Groundwater is a significant natural resource in percent day, but of limited use due to frequent failures in monsoon, undependable surface water, rapid urbanization and industrialization have created a major risk to this valuable resource. This alarming situation calls for a cost and time effective technique for proper evaluation of groundwater resource and management planning. A groundwater developing program requires a large volume of data from various sources. Hence, identification and quantization of these features are important for generating groundwater potential zones of study area. Despite the extensive research and technological advancement, the study of groundwater has remained riskier, as these is no direct method to facilitate observation of water below the surface. It can infer indirectly by studying the geological and surface parameters. The GIS and Remote sensing system tool can open new path in water resources studies. Analysis of Remote sensing data along the survey of India topographical sketch and collateral information with necessary ground truth verification help in generating the baseline information for Groundwater targeting.

### 1.1 Remote Sensing and Geographic Information System

Remote sensing is the acquisition of information about an objector phenomenon without making physical contact with the object and thus in contrast to on-site observation. Remote sensing is used in numerous fields, including geography, land surveying and most Earth Science disciplines and oceanography, it has military intelligence, commercial, economic, and humanitarian applications. GIS can refer to a number of different technologies, processes, and methods. It is attached to many operations and has many applications related to engineering, planning, management, transport, insurance, telecommunications, and business. For that reason, GIS and location intelligence applications can be the foundation for many location-enabled services that rely on analysis and visualization. GIS can relate unrelated information by using location as the key index variable. Rapid and advances in the development of Geographical information system 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. In recent years, extensive use of satellite data along with conventional maps and rectified ground truth data has made it easier to establish the base line information for groundwater potential zones. Remote sensing not only provides a wide range scale of the space-time distribution of observations, but also saves time and money. To understand groundwater prospects of an area, integration of different thematic layers is required. The use of remote sensing and GIS tools to extract detailed features of Drainage, Slope, Geomorphic, Piezometric levels in a part of Kurnool district in Koilkuntla mandal for groundwater potential zones.

## II. STUDY AREA AND OBJECTIVES

The study area consists of four villages namely Bheemunipadu, Kampamalla, Gulladurthi and Pottipadu. Location map of the study area is given in the Figure 1.

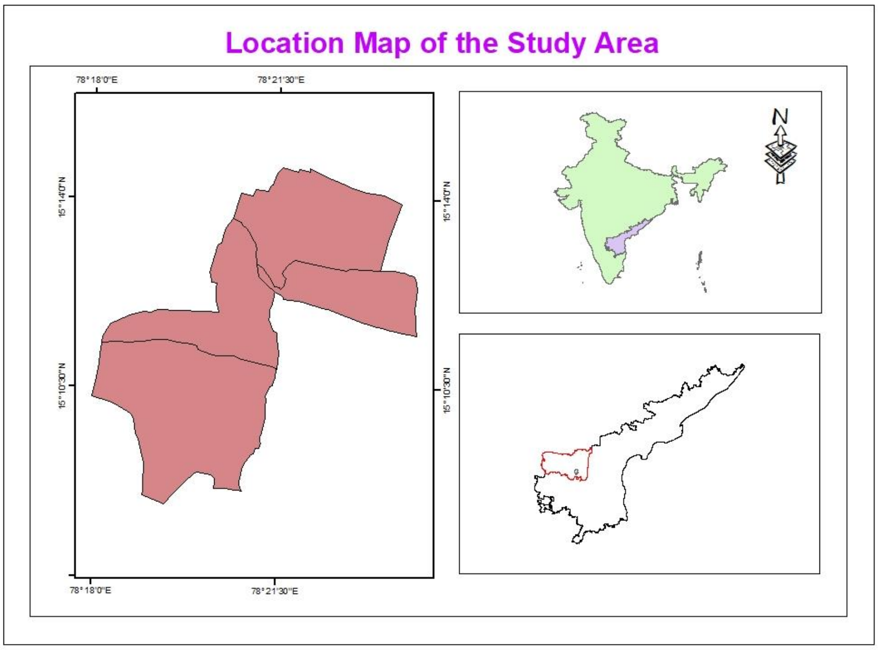


Figure. 1 Location Map of the Study Area

### 2.1 Bheemunipadu

According to Census 2011 information the location code or village code of Bheemunipadu village is 594510. It is located in koilkuntla Tehsil of Kurnool dist. in AP. It is situated 5KM away from koilkuntla and 100KM away from Kurnool. The total Geographical area of village is 1492hectares. It has total population of 2,311peoples. There are about 649 houses. It is located at latitude of 15.2190058and longitude of 78.360756.

### 2.2 Kampamalla

According to Census 2011 information the location code or village code of Kampamalla village is 594511. It is located in koilkuntla Tehsil of Kurnool dist. in AP. It is situated 9KM away from koilkuntla and 104KM away from Kurnool. The total Geographical area of village is 796hectares. It has total population of 1,563 peoples. There are about 400 houses. It is located at latitude of 15.8281257 and longitude of 78.0372792.

### 2.3 Gulladurthi

According to Census 2011 information the location code or village code of Gulladurthi village is 594508. It is located in koilkuntla Tehsil of Kurnool dist. in AP. It is situated 10KM away from koilkuntla and 105KM away from Kurnool. The total Geographical area of village is 2241hectares. It has total population of 3,528 peoples. It is located at latitude of 15.5508726 and longitude of 77.9310283.

### 2.4 Pottipadu

It is located in koilkuntla Tehsil of Kurnool district in AP. It is situated 8KM away from koilkuntla and 90KM towards south from Kurnool. It is located at latitude of 15.1871211 and longitude of 78.3564887.

### 2.5 Main Objective of the study area

The primary objective of the study is to contribute towards systematic groundwater studies utilizing Remote Sensing and Geographic Information systems in the exploration of Groundwater potential areas using weighted overlay analysis method.

### 2.6 Hydrogeology

Groundwater occurs in all geological formations in Kurnool district. Mainly there are three types of Hydrogeological conditions in the district, namely Crystalline aquifers, Consolidated Sedimentary Formation and Aquifer Parameters

#### 2.6.1 Crystalline aquifers

The crystalline rocks develop secondary porosity through fracturing and subsequent weathering over ages and become water bearing. Movement of groundwater is controlled by degree of inter-connection of secondary porosity and voids. The depth of weathered zone ranges from few centimetres to 18 m below ground level. Groundwater occurs under unconfined conditions in shallow weathered zones and under semi-confined conditions in joints, fissures and fractures. Occurrence of joints and fissures extends down to depth ranging from 20 to 100 m below ground level. The shallow aquifers are developed through large diameter irrigation wells and domestic wells. The depth of irrigation wells ranges from 4 to 26 m below ground level. Irrigation wells sustain pumping of 2 to 4 hours per day during summer.

#### 2.6.2 Consolidated Sedimentary Formation

Ground water occurs in the aquifers of Kurnool formations in Panyam Quartzite under unconfined and semi-confined conditions in weathered zone, sheared zones, joint planes and bedding contacts. The depth of dug wells varies from 7-13 m below ground level, with extension bores down to a maximum depth of 15 m. The yield of wells ranges from 30 to 100 cubic meters per day. In Koilkuntla limestone, ground water occurs under unconfined conditions in top weathered zones and karstified horizons. Ground water occurs under unconfined condition in Nandyal shales down to a limited depth of 30 m below ground level. The thickness alluvial aquifers varies from <1 to 8.0 m and depth to water ranges between 1.0 and 5.3 m below ground level.

#### 2.6.3 Aquifer Parameters

Transmissivity of the aquifers in granitic gneisses in western part of the district in Vedavati River Basin ranging from 585 to 1370 square meters per day and in Tungabhadra canal command area it is varying from 1 to 210 square meters per day. The storability is in the order of 2.76 x 10^-2 to 1 x 10^-6. The specific capacity of wells varied from 5.92 to 49.78 lpm/m of draw down.

## III. METHODOLOGY

The proposed methodology of study involved various activities such as base map preparation, Digitization and image processing using software and interpretation of the outputs. First stage includes development of spatial data base by using survey of India (SOI) toposheet on a 1:50000 scale and Google earth satellite (landsat) data. GIS and remote sensing technology is applied to prepare various thematic maps with reference to groundwater like drainage density, and stream length. Additionally, the Land Utilization Survey Database, geologic maps and on site investigation are adopted to quantitatively and qualitatively describe the hydro-geo-logical conditions of the area. In the second stage, digital image processing of the satellite data is done for geo-referencing & geometric correction. This is followed by creation of different thematic layers using supervised classification technique. It is then followed by creation of other important data which is used to determine the ground water potential at the later stage like geo-morphological map, geology map, piezometric level map, slope map and drainage density map. In the third stage all above themes are further processed and analysed in overlay and ranking is given to evaluate suitable groundwater potential zone. All the thematic layers will overlay by using GIS to find the final integrated output of groundwater potential zones in the present study, geomorphology, slope, drainage density, geology and piezometric levels are considered for the identification of groundwater potential. Detailed methods are shown in given Figure 2.

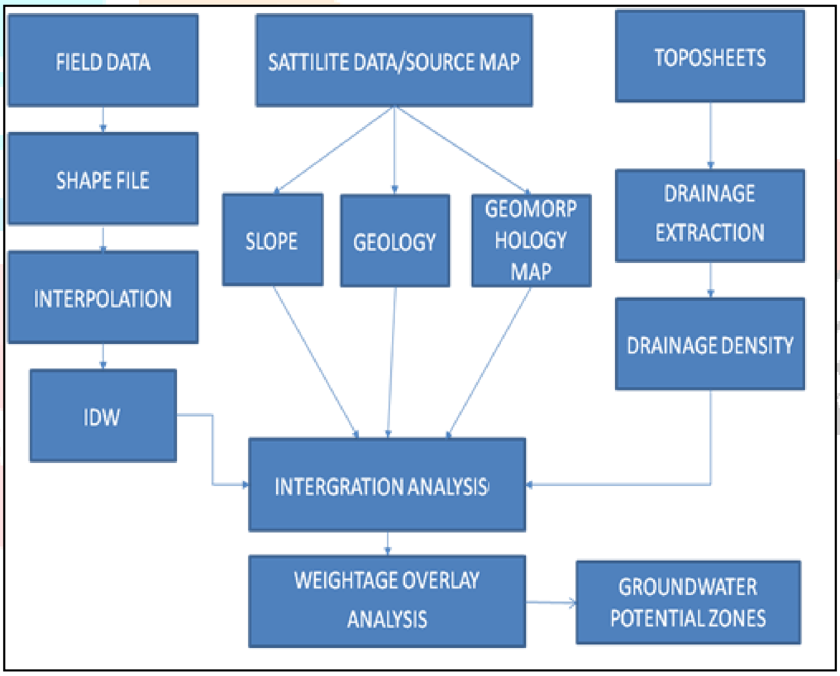


Figure. 2 Methodology flowchart of the Study area

### 3.1 Drainage Density

Drainage density is the total length of all the streams and rivers in a drainage basin divided by the total area of the drainage basin. It is a measure of how well and how poorly a watershed is drained by stream channels. Drainage density indicates closeness of spacing of channel as well as the nature of surface material. High drainage density is the resultant of weak or impermeable subsoil material, sparse vegetation and mountainous relief. Low drainage density is the resultant of highly permeable subsoil material under dense vegetative cover and where relief is low. The drainage density characterizes the runoff in an area or in other words, the quantum of relative rainwater that could have infiltrated. Hence lesser the drainage density, the higher is the probability of recharge or potential groundwater prone. The entire drainage map is divided into 5 classes as in table1, which is obtained by using tool GIS. Resulted map can be seen in the given Figure 3 and zones are described with ranges in the given table 1.

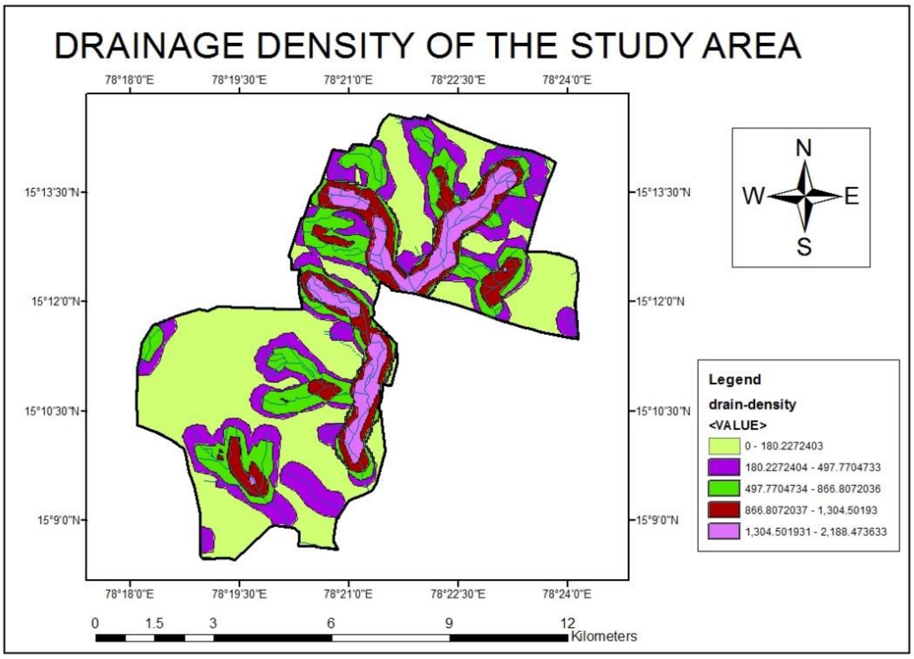


Figure. 3 Drainage density map of the study area

Table.1 Drainage Density ranges

| Class | Drainage Density Range | Drainage density category |
|---|---|---|
| 1 | 0 - 180.22724 | Very good |
| 2 | 180.22724 - 497.770473 | Good |
| 3 | 497.770473 -866.807204 | Moderate |
| 4 | 866.807204 -1304.50193 | Poor |
| 5 | 1304.50193-2188.473633 | Very Poor |

### 3.2 Piezometric Levels

Piezometers are placed in boreholes to monitor the pressure or depth of groundwater. The levels of study area with their location are added to the shape file in Arc GIS. The piezometric level map was prepared by using IDW method in Arc GIS. Inverse Distance Weighted is a type of deterministic method for multivariate interpolation with a known scattered set of points. The assigned values to unknown points are calculated with a weighted average of the values available at the known points. The map is then divided into 5 classes which gives the data about the availability of groundwater in different stages. Details can be seen in the given Figure 4 and ranges are mentioned in the Table 2.

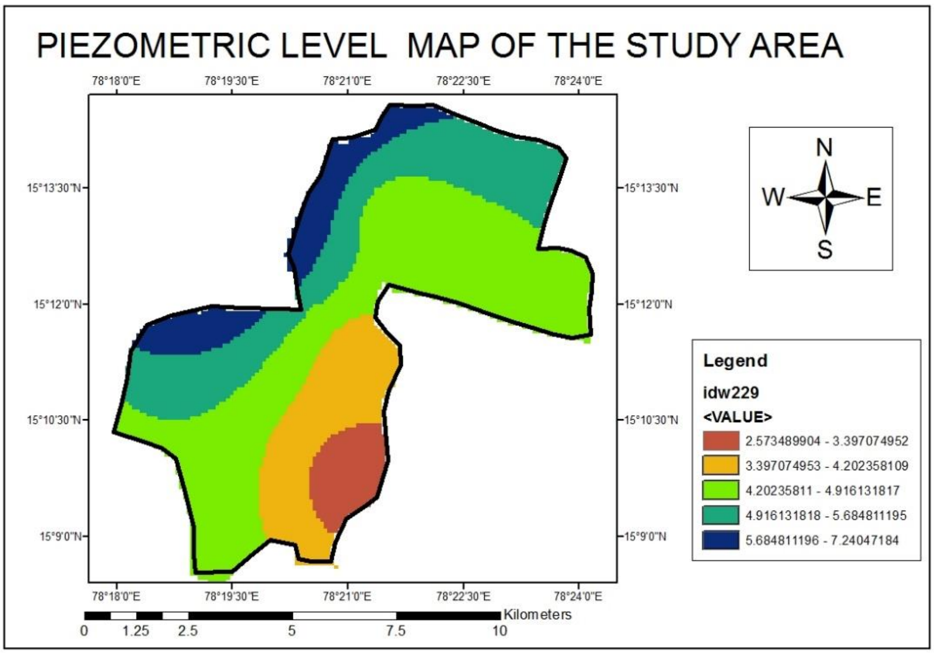


Figure. 4 Piezometric depth map of the study area

Table.2 Depth ranges

| Class | Depth ranges (m) | Categories |
|---|---|---|
| 1 | 2.473833 - 4.373362 | Very good |
| 2 | 4.373362 - 5.730169 | Good |
| 3 | 5.730169 - 7.539244 | Moderate |
| 4 | 7.539244 - 9.800589 | Poor |
| 5 | 9.800589 - 14.006689 | Very Poor |

### 3.3 Geomorphology

Geomorphology is the study of the landform of the earth, its description and genesis. It is a branch of earth science, which has grown after the advent of aerial photographs and satellite data. Geomorphology, along with information on soil, water and vegetation has become one of the essential inputs in planning for various developmental activities. Geomorphology of an area depends upon the structural evolution of geological formation. Geomorphology reflects various land form and structural features. Many of the features are favourable for the occurrence of groundwater and classified in terms of groundwater potentiality. The geomorphic units of the basin can be divided into pediment-pediplain complex, water bodies, fluvial origin and denudational origin. Among these water bodies are good in groundwater potential. The present study follows the classification of geomorphology by National Remote Sensing Centre. Based on ground truth verification, the geomorphology of the study area has shown in Figure 5 and has been classified into three categories as shown in Table 3.

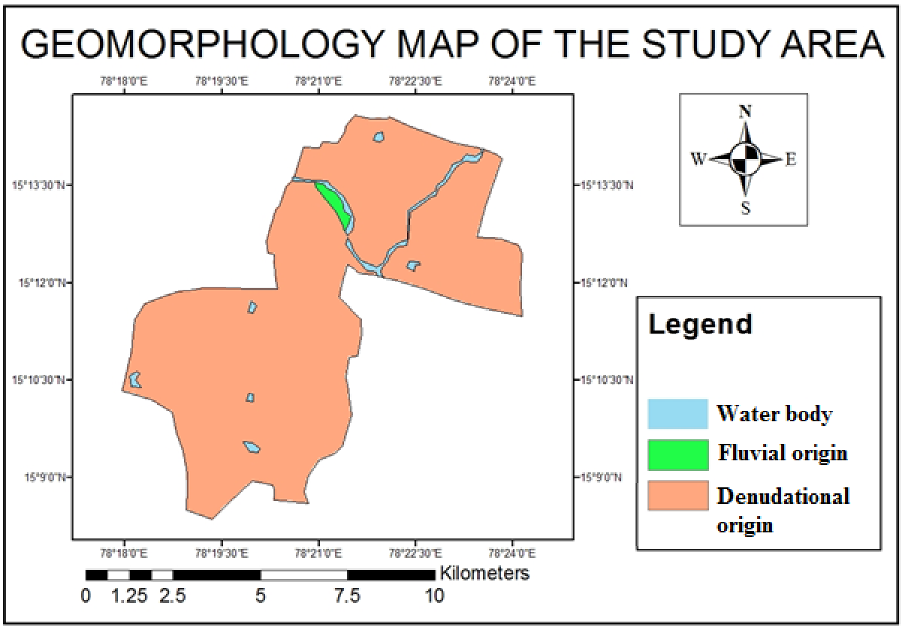


Figure. 5 Geomorphology map of study area

Table.3 Geomorphological units

| Class | Geomorphic units | Category |
|---|---|---|
| 1 | Water body | Very Good |
| 2 | Fluvial origin | Good |
| 3 | Denudational origin-Pediment-Pediplain complex | Moderate |

### 3.4 Slope

Slope is one of the important terrain parameters which are explained by horizontal spacing of the contours. In general, in vector form closely spaced contours represent steeper slopes and sparse contours exhibit gentle slope where as in the elevation output raster every cell has a slope value. Here, the lower slope values indicate the flatter terrain and higher slope values correspond to steeper slope of the terrain. In the study area slope map is generated using the data and google earth source, and classified into 5 categories. Details are show in the Figure 6 and categories are mentioned in the Table 4.

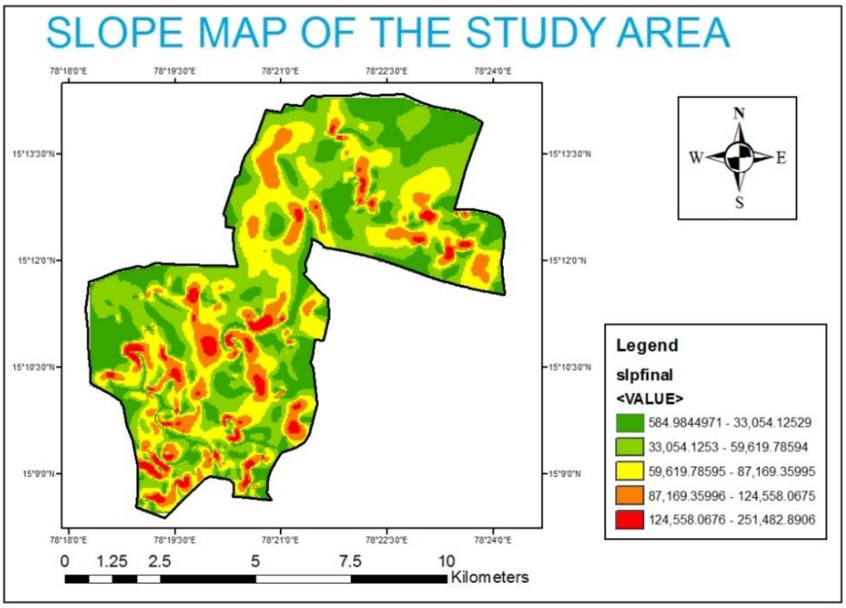


Figure. 6 Slope map of the study area

Table.4 Slope Categories

| Class | Slopes (degrees) | Category |
|---|---|---|
| 1 | 75.524841 - 80.402818 | Very Poor |
| 2 | 80.402818 - 87.776504 | Poor |
| 3 | 87.776504 - 89.307961 | Moderate |
| 4 | 89.307961 - 89.761727 | Good |
| 5 | 89.761727 - 89.988609 | Excellent |

### 3.5 Geology

Geology describes the structure of the earth beneath its surface, and the processes that have shaped that structure. The geology of study area is completely Kurnool sedimentary formation. The district is situated within the stable shield of Indian Peninsula. Find the geology map in the given Figure 7.

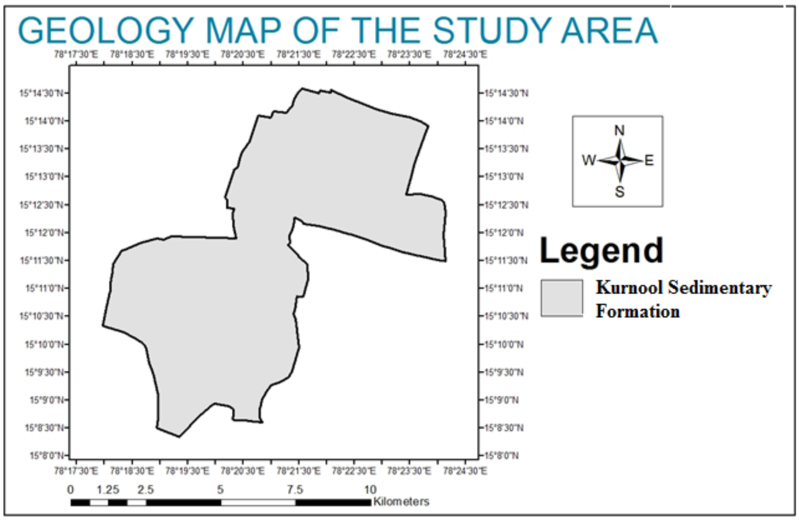


Figure. 7 Geology Map of the study area

## IV. ASSIGNING RANK AND WEIGHT

The groundwater potential zones are obtained by overlaying all the thematic maps in terms of weighted overlay method using the spatial analysis tool in ArcGIS 10.1. During the weighted overlay analysis, the ranks have been given for each individual parameter of each thematic map and the weight is assigned according to the influence of the different parameters. All the thematic maps are converted into raster format and superimposed by weighted overlay method. Thematic maps are integrated with one another through GIS integration. For assigning the weight, the piezometric level map was assigned higher weight, whereas the slope, geomorphology, drainage density and geology were assigned lower weight. After assigning weights to different parameters, individual ranks are given for sub variable. In this process, the GIS layer on piezometric level map, geomorphology, geology, slope and drainage density were analysed carefully and ranks are assigned to their sub variable. The minimum value is given to the feature with highest groundwater potentiality and the maximum given to the lowest potential feature. The landforms such as water body and fluvial origin are given highest rank and lower value is assigned for pediplain. As far as slope is concerned, the lower rank value is assigned for gentle slope and highest rank value is assigned to higher slope. The lower rank factors are assigned to lower drainage density because the low drainage density factor favours more infiltration than surface runoff. Higher value followed by higher drainage density. Low depth of piezometric level is given lower rank and higher depth of piezometric level is given higher rank. In geology, the district is covered with Kurnool - sedimentary formations, it is given as good. Final integrated map is shown in the given Figure 8 and categories are mentioned in the Table 5 and Table 6.

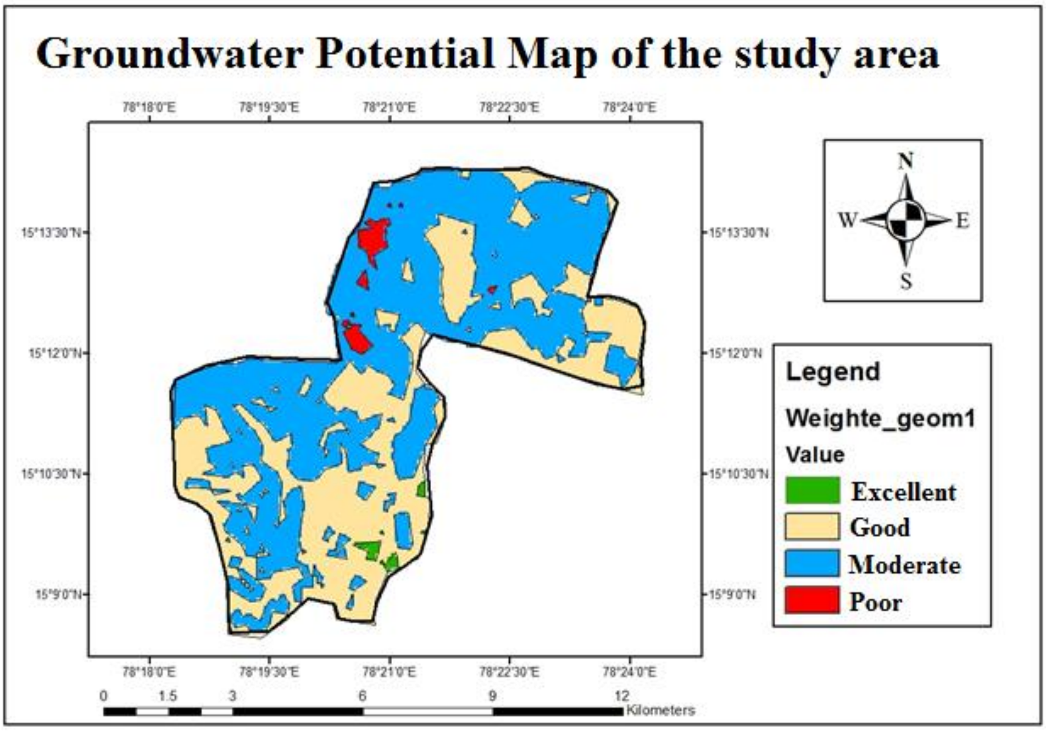


Figure. 8 Groundwater potential zones map of study area

Table.5 Parameter categories with percentage of weightage

| PARAMETER | CLASSES (or) RANK | DESCRIPTION | GROUNDWATER PROSPECT | WEIGHT (%) |
|---|---|---|---|---|
| Piezometric Level | 1 | 2.473833 - 4.373362 | Very Good | 30 |
| | 2 | 4.373362 - 5.730169 | Good | |
| | 3 | 5.730169 - 7.539244 | Moderate | |
| | 4 | 7.539244 - 9.800589 | Poor | |
| | 5 | 9.800589 - 14.006689 | Very Poor | |
| Drainage density | 1 | 0 - 180.22724 | Very Good | 20 |
| | 2 | 180.22724 - 497.770473 | Good | |
| | 3 | 497.770473 - 866.807204 | Moderate | |
| | 4 | 866.807204 -1304.50193 | Poor | |
| | 5 | 1304.50193 - 2188.473633 | Very Poor | |
| Slope | 1 | 75.524841 - 80.402818 | Very Good | 20 |
| | 2 | 80.402818 - 87.776504 | Good | |
| | 3 | 87.776504 - 89.307961 | Moderate | |
| | 4 | 89.307961 - 89.761727 | Poor | |
| | 5 | 89.761727 - 89.988609 | Very Poor | |
| Geomorphology | 1 | Water body | Very Good | 20 |
| | 2 | Fluvial origin | Good | |
| | 3 | Denudational origin-Pediment-Pediplain complex | Moderate | |
| Geology | 2 | Kurnool-sedimentary formation | Good | 10 |

Table.6 Groundwater potential zones of the study area

| S.NO | Potential Zones | Area(km) | Area (%) |
|---|---|---|---|
| 1 | Excellent | 0.5332 | 0.5175 |
| 2 | Good | 41.002 | 39.787 |
| 3 | Moderate | 60.028 | 58.250 |
| 4 | Poor | 1.0248 | 0.9944 |

## V. CONCLUSIONS

In this present study, it can be concluded that the Kurnool region of Andhra Pradesh state is found to be utilizing surface water more than ground water. The successful use of the remote sensing data on GIS platform has helped in obtaining detailed scenario of groundwater situation in the study area. Geographical information system and remote sensing has proved to be powerful and cost effective method for determining groundwater potential in study area. The study reveals that integration of five thematic maps such as drainage density, slope, geology, geomorphology and piezometric levels gives firsthand information to local authorities and planners about the areas suitable for groundwater exploration. The given study area is classified in to excellent, good, moderate, poor groundwater potential zones. The Potential zone map could be used for various purposes like irrigation, drinking and management of groundwater etc. Various algorithms which were essential for the hydrological application was used in ArcGIS which were useful in creating study area boundary and drainage density maps. The very poor zone was indicating the least favourable area for groundwater prospect whereas excellent zone indicates the most favourable area for ground water prospect. The results which were secured from the integration of various thematic maps shows that the study area falls in the range of good to moderate which accounts 97% of the study area. Finally, by this study we conclude that area like Gulladurthi is good in groundwater prospect, Bheemunipadu, Kampamalla, Pottipadu have moderate groundwater prospect.

## VI. ACKNOWLEDGMENT

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## REFERENCES

**[1]** Basavaraj Hutti and Nijagunappa, R. 2011. Identification of groundwater Potential Zone using Geoinformatics in Ghataprabha basin,North Karnataka,India. International Journal of Geomatics and geosciences,V 2, 0976-4380.

**[2]** Deepesh M, Madan K, Jha, Bimal C., 2011 Assessment of groundwater potential in a semi-arid region of India using remote sensing, GIS and MCDM techniques. Water Resource Manage 25:1359-1386.

**[3]** Kavitha Mayilvaganam, Mohana Perumal, Naidu KB, 2011 Delineating groundwater potential zones in Thurinjapuram watershed using geospatial techniques, Indian Journal of Science and Technology 4(11):1470-1476.

**[4]** Krishnamurthy, J. Venkatesa, K. N., Jayaraman, V. And Manivel, M., 1996 An approach to demarcate groundwater potential zones through remote sensing and geographic information system. International Journal of Remote Sensing 17,1867-1884.

**[5]** Murthy KSR, Amminedu E, Venkateswara Rao. V, 2003 Integration of Thematic Maps through GIS for Identification of Groundwater Potential Zones. Journal of Indian Society of Remote Sensing, V.31, No.3.

**[6]** Murugesan B, Thirunavukkarasu R, Senapathi V, Balasubramanian G. 2012 Application of remote sensing and GIS analysis for groundwater potential zone in kodaikanal Taluka, South India. Earth Science 7(1): 65-75.

**[7]** Muthukumar M, Ramasamy SM, 2014, Remote Sensing Revealed Anomalies in the Flood Plains of Asian Rivers and Their Significance, International Journal of Science and Research, Volume 3 Issue 9, 451-454.

**[8]** Nagamani K, Mohana P, Santhanam K, 2018 Sustainable Development and Management of Surface and Groundwater in Cooum Sub Basin of Chennai Basin Using Remote Sensing and GIS, Rasayan J. Chem, 11 (2), 620- 633.

**[9]** Prabir Mukherjee, Chander Kumar Singh and Saumitra Mukherjee. 2011 Delineation of Groundwater Potential Zones in Arid Region of India, A Remote Sensing and GIS Approach. Water Resource Manage 26:2643–2672.

**[10]** Preeja K. R, Sabu Joseph, Jobin Thomas and Vijith H, 2011 Identification of Groundwater Potential Zones of a Tropical River Basin (Kerala, India) Using Remote Sensing and GIS Techniques. Journal of Indian Society of Remote Sensing. 39(1):83-94.

**[11]** Sunandana Reddy M, Sada Sivudu J, Rajesh P, 2018 Application of Geo-Spatial Technologies in Identification of Groundwater Potential Zones, Int. Journal for Science and Advance Research in Technology, 4 (1), 230-235.

**[12]** Sunandana Reddy Machireddy, Venkata Rami Reddy Pesala, 2017 Geospatial Technology based Water Harvesting Models for Drought Prone Area, Int. Journal for Modern Trends in Science and Technology, 3 (8), 216 – 224.

**[13]** Sunandana Reddy Machireddy, 2015 Optimal Land Use Planning by using GIS, Int. Journal of Advanced Research Foundation, 2 (1), 44-49.

**[14]** Waikar. ML And Chandakar.GT, 2014 Estimation of Curve Number for Asna River Basin Using Remote Sensing and GIS. International Journal of emerging technologies and applications in engineering, technology and sciences Vol.7 pp36-40, ISSN : 0974-3588.

**[15]** Yeshodha. L, Rajkumaraand. HN, Arunachalam. S, 2010 Modelling of Groundwater Potential Zone Using Remote Sensing and GIS, Krishnagiri District,Tamil Nadu, India. J Environmental Research and development, V.5, No.1.