Geospatial Technologies in the extraction of Groundwater Potential Zones

A case study of Nandyal Mandal, Kurnool District of Andhra Pradesh, India

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Abstract*: The utmost source which is contributing to the supply of water to the society is groundwater. Depletion of under groundwater is enormously caused by eruptive growing rate of human population along with needs in the form of industrial and urbanized growth, indigent practices in irrigation methods and deforestation. As surface fresh water is very limit, water demand is drastically increasing for the needs. In this connection, there is immense predominant for the natural source called groundwater. It is mandatory for the communities not only to targeting the resource called groundwater but also to provide remedial measures to replenishment the groundwater. Enormous investigations are in the process globally, to meet the requirement to compensate resource for the needs in all aspects. Geospatial techniques are playing vital role in the extraction of groundwater resources by means of spatial and temporal data variations along with its integration analysis in the form of separable layers to derive the solutions. In this connection, Nandyal mandal of Kurnool is selected to demarcate the potential zones of groundwater by using this geospatial technology. The main motto of the research work is to identify the effective potential groundwater zones by applying methods and integration techniques of Geographic Information System and remote sensing. This gives more information for the planning and management of the ground water. By employing geospatial technologies, the integrated composite output for potential zones is demarcated with help of key parameters such as drainage, lineament, slope, geology, geomorphology, land use land cover and existing groundwater levels. All these thematic layers are extracted by using the satellite data and other available sources by using remote sensing and GIS. All these themes are demarcated using basic elements to identify the respective classes. Proper weightages are assigned to each class of all themes in the form of separate category based on importance of weightage from excellent to poor based on suitability to avail the groundwater sources. This process is applied for the considered themes and is reclassified based on results. It is then integrated with weighted overlay operation in ARCGIS environment. Appropriate weightage percentages which are equal to 100%, are given prior to overlay analysis of hydrology tools of ArcGIS. Various zones like excellent, very good, good, moderate, poor are categorized for the integrated potential zones of groundwater source. The use of suggested methodology is applied and demonstrated for a selected case study area in Nandyal Mandal of Kurnool District of Andhra Pradesh, India. Integrated output layout will be effectively useful in the demarcation of potential resource zones. This demarcation area zone system is not only to identify the zones but also helpful in the replenishing the resources of the study area. The digital elevation model is also used to extract slope and drainage themes of the study area. The groundwater potential zones were obtained by overlaying all the thematic maps in terms of weighted overlay analysis method using the spatial analysis tool in ArcGIS 10.1. This ground water potential information will be useful for effective identification of suitable locations for extraction of such groundwater.

***Keywords*: Groundwater Potential Zones, Weighted Overlay Analysis, Integration, Geospatial Technology**

(Article history: Received: March 2022 and accepted May 2022)

I. INTRODUCTION

A. General

Water, which is utmost one of the most predominant resource which is available naturally in the form of sub surface and surface water. All the human being are mostly depends on water sources to meets the demands including domestic, industry, sector of agriculture and other for other activities. Hence this natural resource plays vital predominant role in the activities of the whole globe. The evolution and growth of the nations, are highly depending on the adequate availability and proper utilization of this resource [1]. In both timely and space, water is expensive valuable resource which may be abundant, scare and unbalanced some time depending upon the climate and aquifer system of the nature. Groundwater constitute the abundant handy freshwater resources of the total earth. Many human beings are utilizing on this groundwater to meet the all water requirements including drinking water. This source is very admired resource of water for the many nations. Groundwater seems fresh water due to the natural geological layer which are acting as filters to filter the groundwater form the pollution hazards [2-3].

Inadequate comprehension and over exploitation of resource called groundwater to meet the needs, unable to protect and control the needs of groundwater to compensate according to requirements. Especially in Indian sub-continent, the utilization of groundwater has drastically increased in recent decades because of urban and industrial development. It is to be properly managed by proper measures and controls to extract the groundwater and replenish properly with suitable measures to improve the resource. Policy makers and communities should protect groundwater by means of crating awareness on the surface hydrological cycle as it is the main source. Hence, availability of source can effectively have extracted and refilled the gap to improve the groundwater through recharge structures. It improves the scope of development in the agriculture and industrial sectors of the nations.

B. Remote sensing

Remote sensing along with GIS is a technology effectively used to extract the earth's information including sub surface details without into the field. By advent of various analysis tools like hydrology and spatial analysis tools of spatial analysis of GIS, today it is an excellent tool in the water resource management even with complete information of groundwater zones. This geospatial technology is an emerged tool in the development and planning of any earth resources. Space technology is unique due to its synoptic, temporal, systematic, swift and spatial accuracy in the different band wavelength EMR spectrum regions to cover vast area from single point of view in the management of natural resources.

This spatial technology has its own approach in the fields of mapping of geological formations, study of landforms, exploration of minerals, etc. to make effective studies, processing models, mitigation processes with helps in the management of natural resources. In the present case project, Indian Remote Sensing satellite images have analyzed by the techniques of interpretation analysis to extract the information from the images related to each theme.

Unified RS and GIS approach furnishes efficient value in resource inventory along with resource comprehension, mapping of land and techniques for governing and ecological for the evaluation of work. Hence, an integrated geospatial analysis can furnish the pertinent plan of action for the confluent investigation of huge amount of data and techniques for decision making underground water exploration [4-5] with help of key parameters in the shape of separate layers. These layers are enabling the spatial tool to make integrated output through the spatial analysis effectively.

II. LITERATURE REVIEW

Various researchers and authors have studied the groundwater location and demarcation by applying remote sensing and GIS techniques across the globe. Much identification is followed in the present work and which are referred under references. Couple of articles are highlighted here which are recently published.

Kesana Sai Teja, Dinesh Singh did Identification of Groundwater Potential Zones using Remote Sensing and GIS, for Mangalagiri Mandal on April 2019. Thematic maps are prepared and overlayed for getting groundwater potential zones. These studies demonstrate that the areas to construct artificial recharge structures to enhance groundwater levels in the point of view of groundwater use for future generations.

Adity Nilawar did Identification of Groundwater Potential Zone using Remote Sensing and GIS Technique for Parbhani district of Maharashtra on 5 may 2014. The study reveals that integration of six thematic maps and weighted overlaying gives firsthand information to local authorities and planners about the areas suitable for groundwater exploration.

P. Venkateswara Rao and M. Subrahmanyam did integration of GIS and Remote Sensing in Groundwater investigation, for Visakhapatnam district on 5 september2020. Integrated Remote Sensing and GIS techniques are very efficient for groundwater exploration studies in terms of time and labor. A total of nine thematic layers were integrated with weighted overlay analysis in Arc GIS to generate a groundwater potential zone. The study area belongs to an area with poor electricity facility, it is also recommended to drill the bore wells at good potential zones and fitted with solar-based pumps for enhancing the small to medium agricultural practices and to generate income to the local people. This will also help in reducing the migration of people to the urban areas.

III. STUDY AREA AND DATASETS USED

A. Area Location Details

Nandyal mandal of Kurnool District, Andhra Pradesh, India is selected to demarcate the potential groundwater zones. Geographically Nandyal mandal is located between the latitude from 15° 21' to 15°36' N and the longitude from 78° 20' to 78°34' E. Area of Nandyal mandal is 403.7 sq.km. Elevation of Nandyal mandal is +216.00 m above MSL. Total population of the Nandyal mandal is 2,14,175, spreading across 17 villages. Nandyal is surrounded by hills with the Kundu River on its west, the dense forest of Nallamala Hills to the east and granite mines to the south.

The mandal is wealthy in water supply from reservoirs through canals. There is fair climate throughout the year. However, summer can be hot. The average temperature is around 28°C. Location map is given in the below figure (Fig.1).

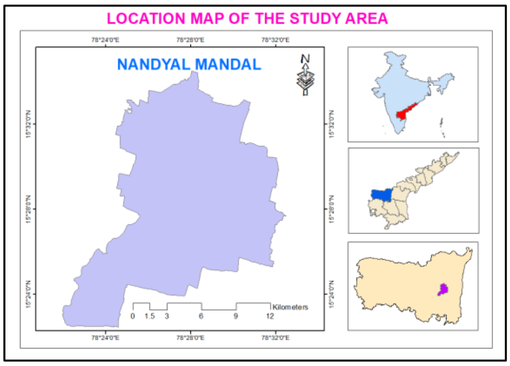

Fig. 1. Location Map of the study area

B. *Datasets Used*

Different types of datasets collected for the purposes of demarcation of features of the present study area, such as satellite data, SRTM data, Secondary ancillary data earth data.

1) Satellite Data

To interpret the features of different themes, Landsat-8 satellite image is used. Satellite image consists of band regions from 1 to 11 bands including thermal. Apart from the thermal bands, the resolution of data is 30 m resolution. This resolution is more fit to interpret data for the theme feature extraction. All the required wavelength bands of visible and infrared region are superposed to make composite false color image from image analysis technique of GIS. The Landsat-8 image of April 2015, which is downloaded from earth explorer of USGS.

2) SRTM Data

The Shuttle Radar Topographic Mission data of 1 arc sec spatial resolution data is downloaded from earth explorer of USGS. The same data is used to develop elevation model for the study area. Using this SRTM data, the thematic maps called slope and drainage were extracted with help of geospatial technology [6].

3) Secondary data

Secondary ancillary data is considered from district profile reports and some of the themes including geology were inter checked with Bhuvan data of Department of Space, Govt. of India. Groundwater depth levels were collected from the field with help of farmers and other communities.

IV. METHODOLOGY

This section highlights the methods which are adopted to demarcate the potential groundwater zones by applying geospatial technologies by means of integration of various themes of the study area [7-8]. The description of methodology is shown in the given flowchart (Fig. 2).

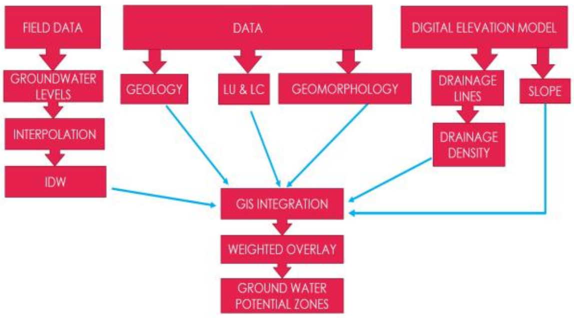

Fig. 2. Methodology Flowchart

A. *Digital Elevation Model*

Filled SRTM data is considered as input data for the extraction of different themes like slope and drainage. Slope categories in percentage were demarcated using contours of the study which were derived from elevation model using ArcMAP. Drainage density was created using line density for the drainage lines which were again extracted from the hydrology tools of spatial analysis of ArcGIS by considering DEM as input data.

B. *Secondary Data*

Groundwater levels were collected from the field with help of existing agriculture bore wells and inputs from the farmers along with relevant data which is useful in the finding groundwater levels. Depth information was collected along with location details like latitude and longitude of individual point location. These data were used as input to derive depth zone map. District profile reports were also considered to extract information related to the study area. Geological and geomorphological details are collected to cross check with the derived outs from satellite image. Bhuvan data is also considered to check the consistency with derived themes from satellite data.

C. *Satellite data*

Landsat-8 satellite 2015 data was used to capture the features of individual themes. All the themes like geomorphology, geology, land use / land cover are extracted using interpretation techniques from satellite image. All the thematic layers were interpreted and converted into raster output based on weightage given with respect to groundwater suitability [9-11].

V. PREPARATION OF THEMATIC MAPS

A. *Drainage Map*

Basin of drainage is a naturally drain unit of discharge towards a point. Drainage network map is extracted from SRTM elevation data using flow direction and flow accumulation tools of hydrology tools of spatial analysis of ArcMAP. Map algebra tool was used to make the drainage network in connection with map scale [12]. Derived raster lines were converted into lines. Extracted drainage map is shown in the given figure (Fig. 3).

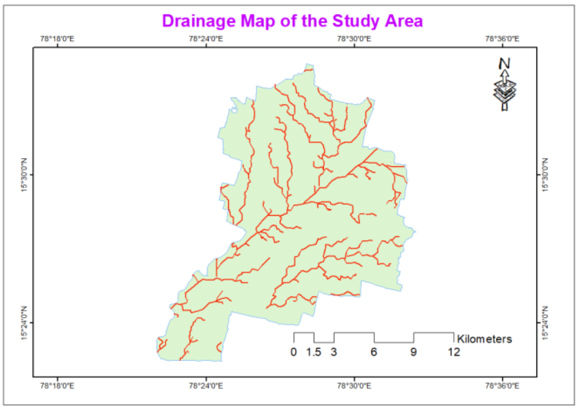

Fig. 3. Drainage Map

Density of drainage lines are depending upon the basin's physical and climate characteristics of the basin. It mainly comprises rivers, streams, water bodies and ponds etc., Drainage density of the area was created using line density which the weightage of the line segment with respect to total area. The higher the density, the high preference of charge. The drainage density map is categorised as very good, good, moderate, poor, very poor. Density map is depicted in the given figure (Fig.4). Percentages of density values are tabulated in the below table (Table I).

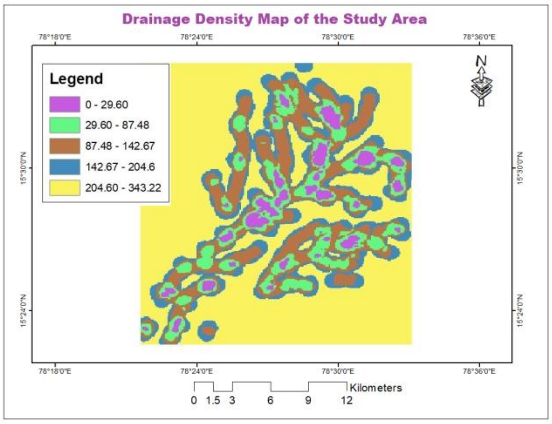

Fig. 4. Drainage Density Map

TABLE I. DRAINAGE DENSITY PERCENTAGES

S.No	Drainage Density	Percentage (%)	Class	Prospect
1	0 -29.611	8.62	1	VERY GOOD
2	29.611 – 87.489	16.867	2	GOOD
3	87.489 – 142.675	16.08	3	MODERATE
4	142.675 – 204.59	18.04	4	POOR
5	204.59 – 343.228	40.39	5	VERY POOR

B. *Slope Percentages*

Region's slope is utmost influencing factor of groundwater recharge. Sub surface as well as surface drainage system of precipitation is influenced by slope. Slope categories are estimated as percentages and are saved as raster form. Groundwater potential is low, if the slope of the area is high which leads to low infiltration and more favor if the slope percentage is low, leads to high infiltration. Slope map is generated from SRTM elevation data [12]. Filled elevation was used to generate contours and contours are base information to derive slope map. Slope map details are shown in the below figure (Fig. 5).

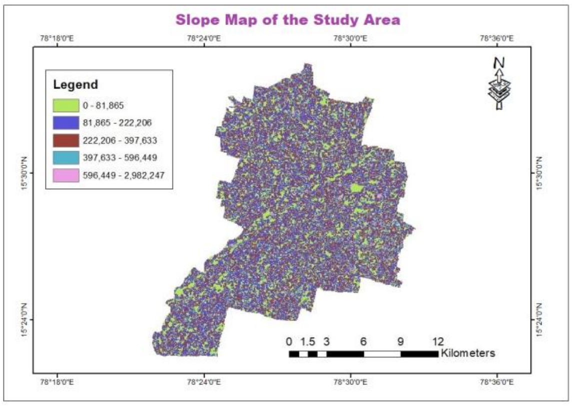

Fig. 5. Slope Categories Map

C. *Geology Map*

Lithology plays vital role in the groundwater occurrence and movement. The main portion of the study consists of prominently of limestone and shale of Cuddapah group of rocks. The Kunderu geological classes are the latest of Kurnool Group consists of Koilkuntla layers at low and Nandyal shale on to open. Geological types of demarcated with prior knowledge on the area through satellite image. Same is verified with secondary data and also cross checked with the layers of Bhuvan. Detailed geology map is shown in the given figure (Fig. 6). Geological classes are tabulated in the given table (Table II).

TABLE II. GEOLOGY CLASSES PERCENTAGES

S.NO	CLASS	AREA Sq.km	PERCENT (%)	PROSPECT
1	SHALE	222.92	55.17	VERY GOOD
2	LIME STONE WITH SHALE	5.93	1.46	MODERATE
3	LIME STONE	175.21	43.37	GOOD

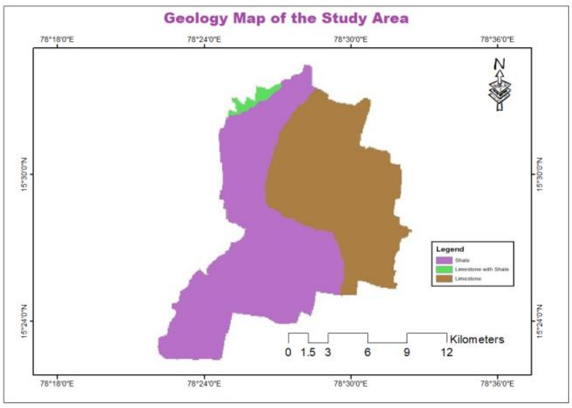

Fig. 6. Detailed Geology Map

D. Geomorphology Map

In simple words, geomorphology is nothing but study of landforms of the earth's surface. Various geomorphological major groups were captured from satellite image with help of bhuvan data. Geomorphological details are also major concerns in the identification of groundwater. Major units of the geomorphology are fluvial land forms, denudational land forms and water bodies. All these classes are favorable for the groundwater targeting of the study area. The details classes are depicted in the below figure (Fig. 7). Geomorphological classes are tabulated in the table (Table III).

TABLE III. GEOMORPHOLOGY CLASSES PERCENTAGES

S.NO	CLASS	AREA Sq.km	PERCENT (%)	ZONE
1	WATER BODY	70.38	17.42	VERY GOOD
2	FLUVIAL	31.71	7.85	MODERATE
3	DENUDATION	301.97	74.73	POOR

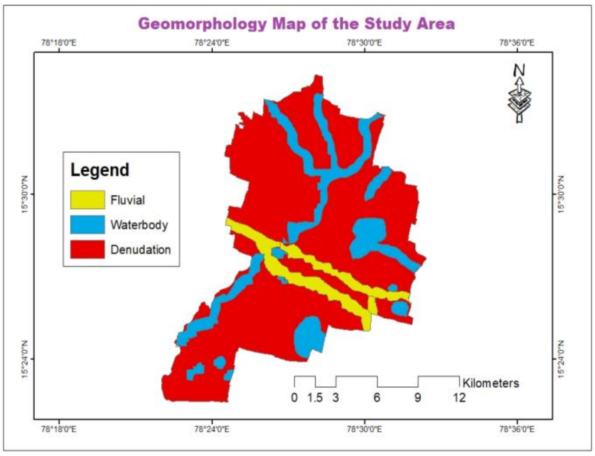

Fig. 7. Geomorphology Map

E. Land Use / Land Cover

In the improvement of groundwater zones, land use and land cover plays a vital part which can be effectively captured by using interpretation techniques of geospatial technology [13]. Proceedings of hydro geology like discharge, evaporation and percolation characteristics are controlled by the land cover and land use system of the study area. Infiltration capacity is being increased due to runoff reduction and surface roughness which are provided by means of surface cover. Various covers due to change of land are suggested like water bodies, soil area, vegetation etc., in the form of land cover.

Land use / land cover map is derived from the Landsat-8 satellite image. Composite image is classified using image analysis. To extract the cover classes unsupervised classification and assigned appropriate classes to the derived classes. Separate classes are assigned in the form of another field in the attribute filed and displayed based on the class. This output is converted into vector from raster data. Dimensions are assigned in the polyconic projection system. Landsat-8 satellite image is shown in the below figure (Fig. 8). Details are tabulated in table (Table IV).

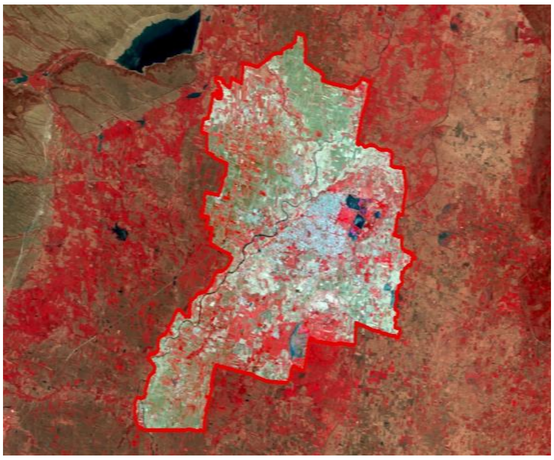

Fig. 8. Landsat-8 Satellite Image

TABLE IV. LU / LC CLASSES PERCENTAGES

S.NO	CLASS	AREA Sq.km	(%)	Zones
1	WATER BODIES	13.07	3.23	VERY GOOD
2	AGRICUL TURE	224.896	55.65	GOOD
3	FOREST LAND	33.976	8.40	MODER ATE
4	BARREN LAND	42.386	10.49	POOR
5	SETTLEM ENT	89.716	22.20	VERY POOR

Extracted macro level classes of LU / LC are Built-up area, Agricultural land, forest area, waster land and water bodies. All these categories are assigned suitability ranges in lien with water resource facility. Top priority was given to water bodies and next ordered with forest area and agricultural land. Least preference was given to waste land due to less vegetation cover. Weighted categories are assigned in separate field and displayed classification, which is mentioned in the below figure (Fig. 9).

F. Groundwater Levels

Groundwater existing depth levels were collected mainly through bore wells and open wells, by field observation. Groundwater levels were available at different quantities at various locations. Individual depth from surface levels were collected along with its latitude and longitude. Collected data from field data, which are from the main sources like agriculture and drinking purpose facilities. The groundwater is the major resource for drinking and for agriculture fields. This data was used for the preparation of groundwater depth levels for the study area by using Inverse Distance Weighting method. Depth location filed point data was imported into ArcMAP and generated groundwater levels zones using interpolation technique of GIS.

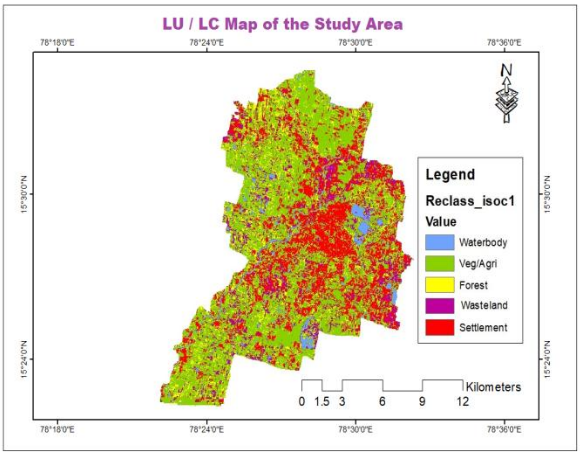

Fig. 9. LU / LC Map

Interpolation is a method to assign values to the total area based on known point location values. Now, groundwater depth field information is converted as continuous surface raster data using Inverse Distance Weighting method of spatial analyst tools of GIS [14]. Total area raster output was converted into five zones. If groundwater depths are very less from the surface, it is intimation that the zone will be the excellent zone for the case of groundwater. Map is depicted in the below figure (Fig.10). Depth ranges are shown in table (Table.5).

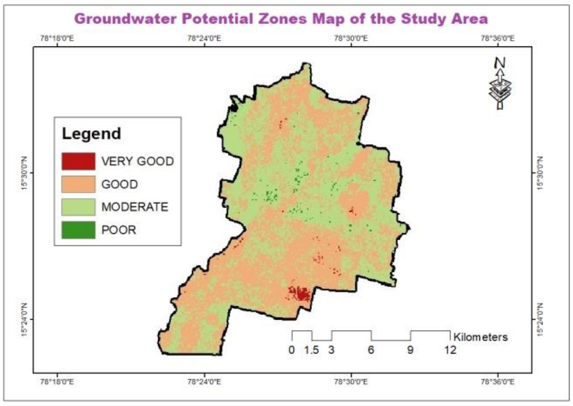

Fig. 10. Groundwater Depth Levels Map

TABLE V. GROUNDWATER RANGES PERCENTAGES

S.NO	DEPTH RANGE	AREA Sq.km	PERCENT (%)	ZONES
1	9.155 – 22.559	124.804	30.887	VERY GOOD
2	22.559 – 35.963	123.855	30.900	GOOD
3	35.963 – 49.366	104.81	25.939	MODERATE
4	49.366 – 62.770	34.114	8.442	POOR
5	62.770 – 76.173	16.477	4.074	VERY POOR

VI. INTEGRATION OF THEMATIC LAYERS USING GIS WEIGHTED OVERLAY ANALYSIS

Potential groundwater zones were demarcated by integrating all the themes using weighted overlay analysis method of spatial analysis using ArcGIS software.

Before integration analysis, suitable weightages were assigned to each theme according to the influencing factors related to groundwater system. Raster themes are reclassified based on common weightage system and categorized like using code. Similarity is maintained in all the themes. Weightage overlay analysis of spatial analysis was used to superimpose Reclassified raster images. Uniform weightage is chosen to make all themes percentages. All the percentage weightages made equal to 100% to run the overlay analysis method to generate integrated output [15-17].

Based on the groundwater potentiality, each class of the layers was roughly placed into one of the following group's viz., Excellent, Very good, Good, Moderate and Poor. Suitable weighted on a scale of "0-5" has been given to each class of a particular thematic layer based on their contribution towards ground water potentiality.

The potential groundwater zones were obtained by integrating the themes by means of weighted overlay analysis of spatial analyst tool of GIS. Finally, four zones were derived likely very good, good, moderate and poor. When compare to the total area, there are two major classes called good and moderate zones are predominantly occupied in the Nandyal Mandal of Kurnool District of Andhra Pradesh. 1.83 % of study area is demarcated as very good potential zone, 49.12 % of area is derived as good, 47.46 % of the study is covered as moderate and 1.58 % is as poor. Derived potential map is depicted in the below figure (Fig.11). GWPZ are tabulated in the below table (Table.6).

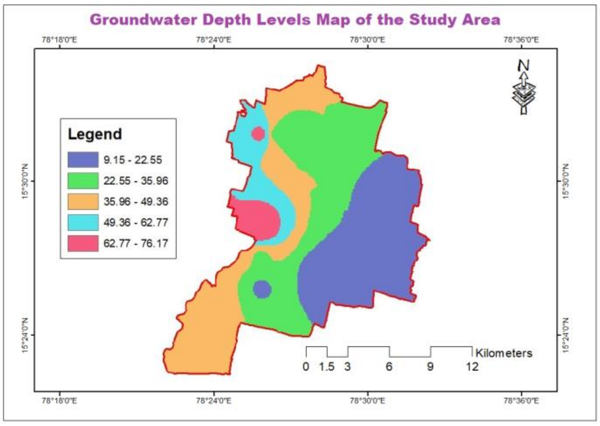

Fig.11. Groundwater Potential Zones Map

TABLE VI. GROUNDWATER POTENTIAL ZONES PERCENTAGES

PERCENTAGE OF ZONES AREA				
S. No.	**NAME OF ZONES**	**VALUE**	**AREA (sq.km)**	**PERCENTAGE (%)**
1	VERY GOOD	1	7.415	1.83
2	GOOD	2	198.471	49.119
3	MODERATE	3	191.79	47.466
4	POOR	4	6.378	1.578

VII. CONCLUSIONS

The applications of technology have assists in gaining elaborate schema of circumstances of groundwater in the present study area where need of groundwater utility is to be improved. Majority of the communities of the mandal are depending on groundwater sources for their needs like drinking, industry and for irrigation.

Numerous innovations which are required to understand the hydrological scenarios of the study were analyzed and implemented in ArcGIS environment to derive the solutions for the demarcation of potential zones by means of capturing various themes like drainage pattern and density, interpolation, integration to generate fruitful results. Potential underground water zones were demarcated through the integration analysis by overlaying different thematic layers called drainage density, slope, geology, LU / LC, groundwater levels and geomorphology using IDW method of spatial analysis techniques of GIS. Integrated output raster with potential zones are categorized from very good to poor in the form of four classes which are very good, good, moderate and poor.

Nandyal mandal is predominantly covered with the potential zones of good and moderate only. Zones with very good is very less when compare to the good and moderate. The least zone called poor is very limited in the form of too small patches, which can be almost negligible. Due to the sedimentary geological classes and various branch canals, availability of groundwater is sufficient to meet the demands of the communities of the study area.

From the study, groundwater potential zones were effectively demarcated with the technology of geospatial. These zones information is highly useful for the communities to take decision policy for the sustainable development in the study area [18-19]. To meet the water demand, according to the availability of groundwater resources, further mechanism can be developed to utilize cost effectively and awareness can also create among the people of the study area to utilize properly from the available zones and to provide provision to replenish the sources to fill the gaps. Further investigations may be required to suggest artificial recharge structures to improve the groundwater. It can be again effectively investigated by using applications of remote sensing and geographic information systems. With the advent of various specialties of the GIS tools like layer based system, integration, interpolation, spatial analysis, derivation of information using DEM etc., are helping to keep the GIS tool in the top to use in the water resource management when compare to other ordinary mapping software.

ACKNOWLEDGMENT

Authors would like to thank the management of Rajeev Gandhi Memorial College of Engineering and Technology and stake holders of the Civil Engineering Department for providing facilities to do such project works and to support and encourage the students in all the aspects. We also extend our acknowledgement to the other personalities who helped in this research work.

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