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DELINEATION OF GROUNDWATER POTENTIAL ZONES IN GREATER VISAKHAPATNAM MUNICIPAL CORPORATION (GVMC) AREA, ANDHRA PRADESH, INDIA. – A GEOSPATIAL APPROACH.

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ABSTRACT

Hydrogeomorphologic mapping coupled with hydrogeological investigations has been carried out to evaluate groundwater potential zones. The study area spread over 545 km^{2}in Greater Visakhapatnam Municipal Corporation (GVMC) in Visakhapatnam District, Andhra Pradesh. Thematic layers of Drainage, Geology, Geomorphology, Lineaments, LU/LC, Soils and Slopes have been generated by using toposheets (No. 65 O/2&3, O/5 and O/6), IRS-P6, LISS-III satellite imagery using remote sensing and GIS techniques. In this study an attempt has been made to discern various geomorphological landforms in relation to understand fluviatile activity in the area. The Slope map was derived from DEM through contour intervals and is classified. An attempt is made to classify various types of soils in the study area by field observations and on the base of satellite data.

The land use/land cover analysis has been carried out using ERDAS Imagine 9.1 software package. Twelve types of land use/Landover categories have been identified in the study area. Also the drainage pattern is observed as dendritic and barbed type of patterns.The groundwater potential zones are identified through GIS analysis using integrated overlay technique and have been classified in to five categories from very low to high.

Key words: Hydrogeomorphology, GVMC, Geology, Groundwater and GIS.

1. Introduction

Groundwater is one of earth's most vital renewable and widely distributed resources as well as an important source of water supply throughout the world. The quality of water is a vital concern for mankind since it is directly linked with human welfare. The importance of water quality in human health has recently attracted a great deal of interest. In developing countries like India around 80% of all diseases are directly related to poor drinking water quality and unhygienic conditions (Olajire and Imeokparia, 2001). In India, most of the population is dependent on groundwater as the only source of drinking water supply (Phansalkar et. al., 2005). The groundwater is believed to be comparatively much clean and free from pollution than surface water. Groundwater can become contaminated naturally or because of numerous types of human activities (Goulding, 2000). Contamination of groundwater can result in poor drinking water quality, loss of water supply, high clean-up costs, high costs for alternative water supplies, and/or potential health problems. A wide variety of materials have been identified as contaminants found in groundwater. These include synthetic organic chemicals, hydrocarbons, inorganic cations, inorganic anions, pathogens, and radio nuclides (Fetter, 1999).

The use of GIS technology has greatly simplified the assessment of natural resources and environmental concerns, including groundwater. In groundwater studies, GIS is commonly used for site suitability analyses, managing site inventory data, estimation of groundwater vulnerability to contamination, groundwater flow modeling, modeling solute transport and leaching, and integrating groundwater quality assessment models with spatial data to create spatial decision support systems (Engel and Navulur, 1999). Groundwater is a valuable natural resource that is essential for human health, socio-economic development, and functioning of ecosystems (Humphreys, 2009). In India severe water scarcity is becoming common in several parts of the country, especially in arid and semi-arid regions. Remote sensing and Geographic information system (GIS) has emerged as a powerful tool for storing, analyzing, and displaying spatial data and using these data for decision making in several areas including engineering and environmental fields (Burrough and McDonnell, 1998). GIS has been used in the map classification of groundwater quality, based on geology, geomorphology or landuse and landcover (Asadi et. al., 2007). In such studies, GIS is utilized to locate groundwater quality zones suitable for different usages such as irrigation and domestic (Yammani, 2007).

The Remote Sensing and GIS tools have opened new paths in water resources studies.Several researches have utilized the GIS technology and the remotely sensed derived data for water resources management, groundwater assessment and modeling.Hydrogeological applications such as groundwater for resources assessment, planning, soil erosion and urbandrainage system the remotely sensed data derivative has gained popularity with the advent of raster and vector GIS environment (Lyon, 2003). This study addresses the strategies for an integrated approach of remote sensing and GIS techniques to delineate groundwater prospective zones. The technique of integrated remote sensing and GIS has proved to be an efficient tool in groundwater studies (Murthy 2000). One ofthe greatest advantages of using remote sensing and GIS techniques for hydrological investigations and monitoring is its ability to generate information in spatial and temporal domain, which is very crucial for successful analysis, prediction and validation (Sarmaand Saraf, 2002). In recent years the importance of coupling remote sensing and GIS in groundwater potential assessment studies was realised by many workers like Vasanthavigar et.Al., (2011); Preeja et. al., (2011); for identification and location of groundwater resources using remote sensing data is based on an indirect analysis of some directly observable terrain features like geomorphology, geology, slope, lineaments, soils, land use/ land cover and hydrologic characteristics.

2. Location of the study area

The Visakhapatnam municipal corporation area was 120 Sq.km till January 2006 and now expanded to 545 Sq.km and renamed as Greater Visakhapatnam Municipal Corporation (GVMC). And comes under the Visakhapatnam District of Andhra Pradesh. The study area is covered in 65 O/1, O/2, O/3, O/5 and O/6 of Survey of India top sheets on 1:50,000 scales bounded between 17^0 32' and 17^0 52'northern latitudes and 83^0 04'and 83^0 24' eastern longitudes (Fig.1). For the convenience of administration GVMC area is divided into 70 wards, where the area of the ward is based on density of population.

3. Results and Discussion

3.1 Geological Studies

The Greater Visakhapatnam region comprises the Precambrian Meta sediments and intrusive Meta igneous bodies (Narasimha Rao, 1945). The high hill ranges namely the Kailasa to the North, the Yarada to the South and Narava to the West make the city area appear like an Amphitheatre. These are mainly composed of Garnet –Sillmanite – Biotite geneisses locally called as Khondalite (King, 1886). Apart from the Meta sediments the area is also marked by the occurrence of the Quaternaries such as the red sediments with calcium carbonate calcretes, dune sands, and beach sands with economically important black sands (Natarajan, et. al., 1979).

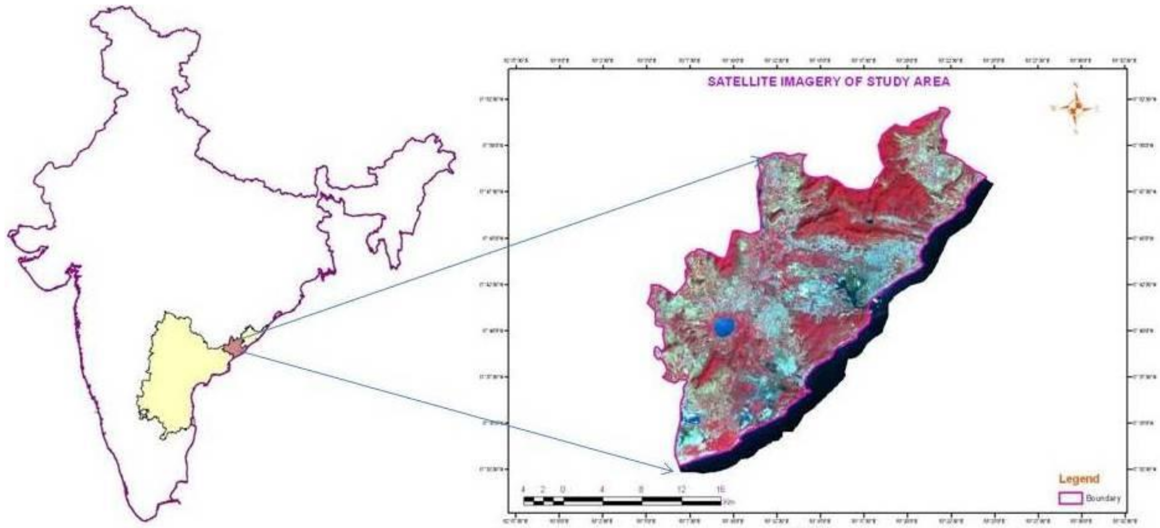

Fig.1: Location map of the study araea

It is composed of high-grade metamorphic rocks and igneous intrusive bodies. The order of abundance of rocks is Khondalite, Charnockite and Quartzite. The structural trend of these rocks is N-NE to S-SW and thus coincide the general trend of the Eastern Ghats (Chetty et. al., 2002). Khondalite is the major rock type in the area(Fig.2) and is composed of Quartz, Feldspar, Garnet, Sillimanite and occasionally Biotite and Magnetite with varying amounts of Graphite flakes (Krishna Rao, 1965). Quartzite bands associated with different gneisses occur in different regions of the study area. Charnockite is characterized by their intrusive relationship with the host khondalite suite of rocks. Compositionally, charnockites exhibit acidic, intermediate and basic compositions, which can be ascribed to the levels of mixing between the original melt and enclosing sediments during their formation.

In the study area, three types of soils are observed. Red soil is characteristically formed from the parent khondalite rock. Sandy soils (loamy soils) are confined along the seacoast. Marine soil is formed in the central part of the area. This might be deposited by marine action during geological past.

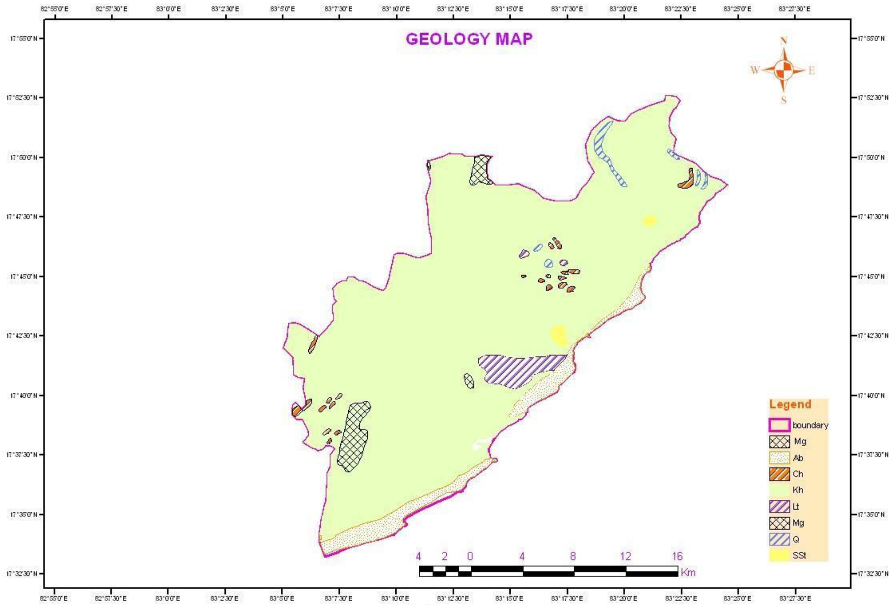

Fig.2: Geology map of the study area

3.2 Geomorphology

The word landform denotes the structure, process and stage that shape the earth surface features. Therefore, study of landforms help in understanding the material with which they are made up of, the processes responsible for their genesis and the stage of their evolution. In such a broader sense, the knowledge of landforms lends clues for the evaluation of resource potential, including the ground water in an area. Thus, geomorphology assumes significance in ground water studies. As such, the recent trends in groundwater exploration emphasize the geomorphic approach involving what is called “hydro geomorphic” mapping through remote sensing technique.The various geomorphological unitsdiscussed are the result of different geomorphologic processes especially the fluvial activities that have been operated inthe area (Harikrishna, K. et. al., 2013).

The Indian Remote sensing satellite IRS-P6, LISS III (March., 2012) digital data was analyzed through image processing software (ERDAS imagine 9.1) and Arc GIS 9.3 software. The various geomorphic features were delineated in online digitization. Field investigations were made for ground verification before finalizing the geomorphic map. In this study an attempt been made to discern different geomorphological landforms in relation to understand fluviatile activity in the area. In this study, 15 no’s of different landforms have been delineated by standard visual interpretation techniques. These are Denudation hills, Structural hills, Inselberg, Piedmont slope, Pediplane shallow, Marshy land, River alluvium, Pediplane moderate, Pediplane deep, Disected slope, Valley fill (Shallow) and Intermontane valley. Brief descriptions of these landforms are given below. It is shown Fig.3.

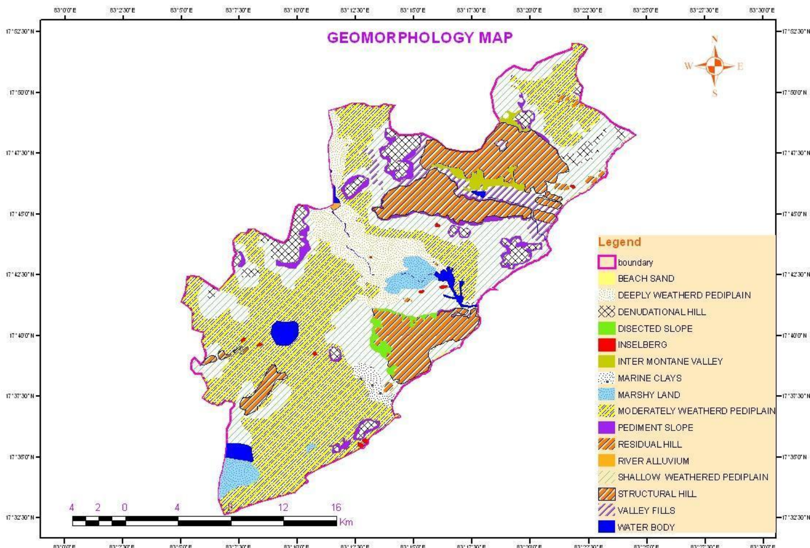

Fig.3: Geomorphology map of the study area

3.3 Lineament studies

Lineament is defined as a large scale linear feature, which express itself in terms of topography of the underlying structural features. The linear features can be measured and created quantitatively like measurements of other geological properties, but it is necessary to use formal static's that reflect the circular nature of the directional data. These provide the path way for ground water movement and are hydro-geologically very important. In the present study the lineaments are mapped from satellite imagery of IRS-P6, LISS-III digital data, which is shown in Fig. 4. High lineament density observed over the hill terrain. This can be ascribed to the hilly terrain is structurally controlled. Majority of the lineaments are disturbed due to various anthropogenic activities. A major lineament with the trend of E-W direction is parallel to the nearby denudational hill. This phenomenon reflects that the lineament area is a major valley, which is structurally controlled. A reservoir over this lineament was constructed at Mudasarlova with a view to supply water to the Visakhapatnam urban dwellers. Moderate to low lineament density are identified over the plains, which are characterized by urban sprawl. The major lineaments reflect structural instability and also these are occupied by major drainage. These lineaments can act as conduits and therefore unsuitable for landfill site.

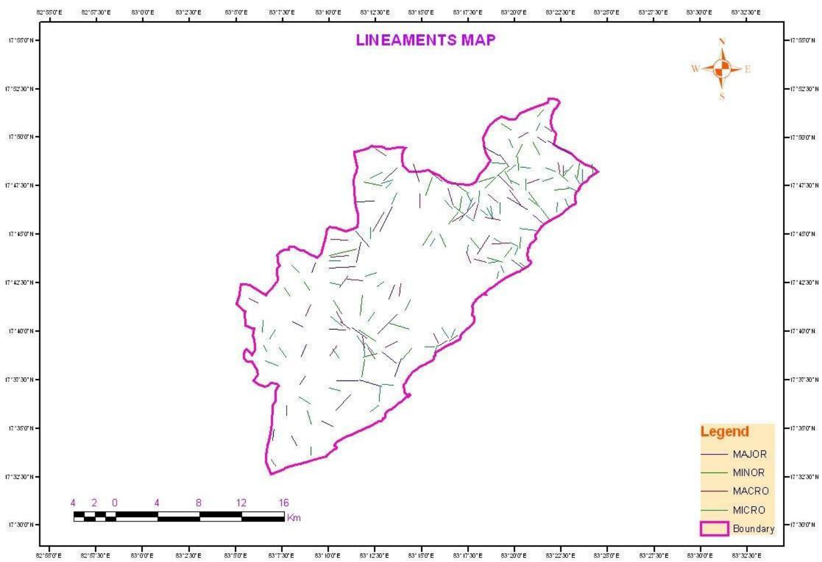

Fig.4: Lineament map of the study area

3.4 Slope Map

The slope map of the study area is generated by digitizing contours of 20 mts interval from the toposheets.The contour values are assigned under the ArcGIS 9.3, ERDAS Imagine 9.1 environment. This will be considered as the corresponding attributes of the slope. For general understanding the map has been divided into four categories of slope. The slope category gentle slope covers large area. This can be ascribed to plain land with nearly gentle slope. The second highest slope moderate slope which accounts 15% of the area. The other categories of slopes like moderately to steep slopes are not considered for analysis, and shown in Fig.5. The areas having gentle slope are the most suitable for constructing corridors.

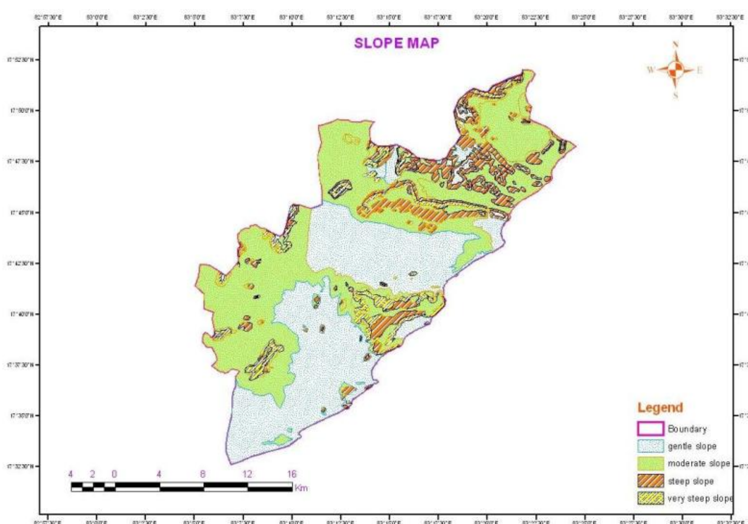

Fig.5: Slopemap of the study area

3.5 Soil

The term “soil” has specific connotation to different groups involved with soil survey and mapping (Lille sand and Keifer 1987). Soil is a major component of land system and an important ingredient of primary production system. The soil map helps to know the qualities and characteristics of soils of the area to understand their problems, potentials and management needs for their potential use. Traditionally, soil mapping is carried out by field traversing procedures which are tedious, slow, subjective and limited to accessible areas only. Application of remote sensing helps to overcome the shortcomings of the traditional system.Soil mapping is accomplished either by field survey or by application of aero-space remote sensing. Field survey methods are slow, tiresome and prone to subjectivity hazards. Present study area covers red clay soils, red loamy soils, red gravel clay soils, brown gravel soils and sandy soils. Red clay soils covers , red loamy soils and red gravel clay soils(Fig.6).

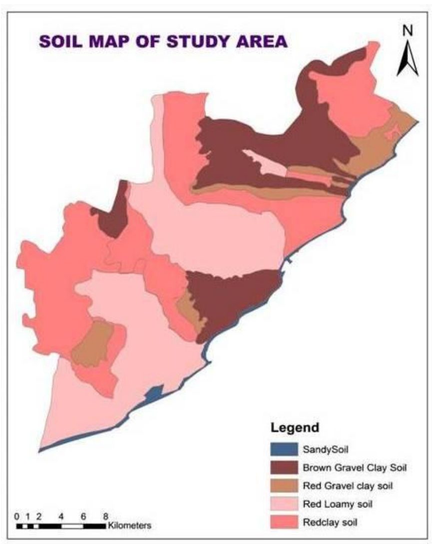

Fig.6: Soil map of the study area

3.6 Land use / Land cover studies

Land use describes how a piece of land is used whereas land cover describes the materials present on the surface (Sabin’s, 1987). Monitoring, mapping and assessment of land use/land cover in temporal sequence are essential for planning and development of land resources. A sudden change in land use/land cover may be indicative of change in terrain character. The land use pattern and land management of an area reveal indirectly the conditions of the people of the area their economic status and resources. Harikrishna, K.et. al., 2012 studied land use/land cover status of greater visakha municipal corporation.

The land use/land cover analysis has been carried out using ERDAS Imagine 9.1 software package. Considering different categories in the area twelve different training sites have been taken in the signature editor and supervised classification has been performed. The digital data of IRS-P6, LISS-III, and dated March 2012 have been used in the analysis.

The following in the description of land use / land cover citing the locations referring the toposheets. The present study area covers different types of land use/Land cover categories. Twelve types of land use/Landover categories have been identified in the study area. They are built up land, cropland, wastelands – barren/rocky, sandy area, fallow land and upland with or without scrub, deciduous forests, forest plantations, water bodies, deep waters and industrial area, reclaimed land and degraded forests(Fig.7). All the following categories are mentioned in table1.

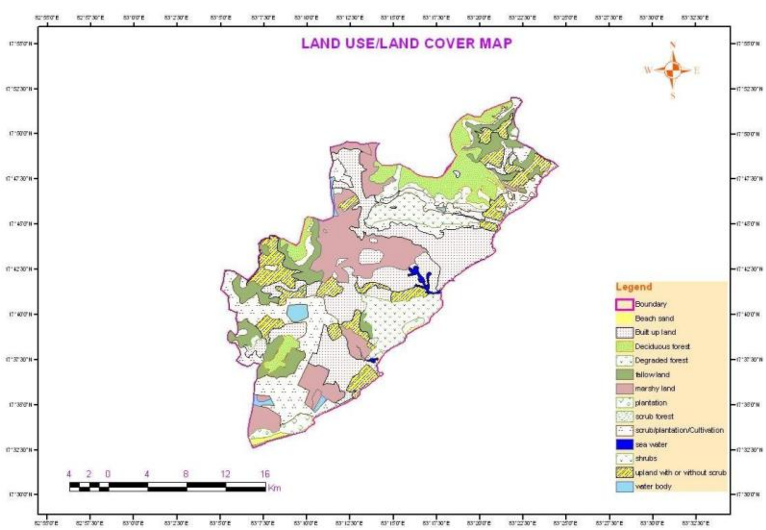

Fig.7: Land use/Land cover map of the study area

Table 1: LU/LC patterns of the study area

LU/LC classes	Area	
	Sq. Km	Percentage
Built-up land	264.87	48.6
Vegetation & Hilly terrain	124.81	22.9
Agriculture land	62.68	11.5
Waste land	67.04	12.3
Marshy land	10.36	1.9
water bodies	15.26	2.8

4. Index Overlay Method with Multi-Class Map

The final step of GIS application in this study is to analyze all data layers through the process called "Overlay". Index overlay is a spatial operation in which a thematic layer is superimposed onto another to form a new layer. In fact, this operation can be performed both in vector and raster data; however, raster overlay is often more efficient than vector overlay. This is because attribute values in raster data are not listed in tables as in vector data, but are represented by grid cells in thematic layers. Therefore, arithmetic operations and some other statistical operations can be performed directly during the overlay process. In this case the map classes occurring on each input map are assigned different scores, as well as the maps themselves receiving different weights as before. It is convenient to define the scores in an attribute table for each input map.

Geographic information system (GIS) has emerged as a powerful tool for storing, analyzing, and displaying spatial data and using these data for decision making in several areas including engineering and environmental fields (Stafford, 1991; Burrough and McDonnell, 1998). The use of GIS technology has greatly simplified the assessment of natural resources and environmental concerns, including groundwater. In groundwater studies, GIS is commonly used for site suitability analyses, managing site inventory data, estimation of groundwater vulnerability to contamination, groundwater flow modeling, modeling solute transport and leaching, and integrating groundwater quality assessment models with spatial data to create spatial decision support systems (Engel and Navulur, 1999). In a similar vein, hydrochemical processes show to have an influence on the prevalence of anthropogenic and natural contaminant in coastal environment (Park et. al., 2005 and Mondal et. al., 2010). It is evident from the literature that infiltration of effluents has led to the contamination of aquifers in different parts of India (Shivkumar et. al., 1997; Pujari and Deshpande 2005 and Naik et. al., 2007).

The input layers which are considered for the analysis of potential groundwater zones are geology, geomorphology, lineaments, soils, slope, land use/land cover and drainage. The score values for all individual classes for each map will be assigned along with the map weightages will be entered as an attribute data for the purposes of index overlay analysis purpose to obtain a new spatial vulnerability map.

Map Weights

M1 = Weightage*[class (Geology)]

M2 = Weightage *[class (Geomorphology)]

M3 = Weightage *[class (Lineaments)]

M4 = Weightage * [class (Slope)]

M5 =Weightage * [class (Soils)]

M6 =Weightage* [class (LU/LC)]

M7 = Weightage *[class (Drainage)]

Depending upon the overlay of these thematic layers in the study area these were assigned with a particular weightage number and multiplied to obtain a map which is used for further analysis. In the same way depending upon their levels of concentrations of the groundwater zones were also assigned with a particular weightage and multiplied to obtain maps which as used for overlay analysis of all these parameters along with drainage of the study area to obtain groundwater zones. Thus each grid cell data is calculated and represented in the form of map showing the potential groundwater zones in Fig.8. We have classified entire study area under four categories. There are three linear patches extending from Sagarnagar to Thotlakonda, Maddilapalem to NAD and between Madhuravada to Hanumantavaka.

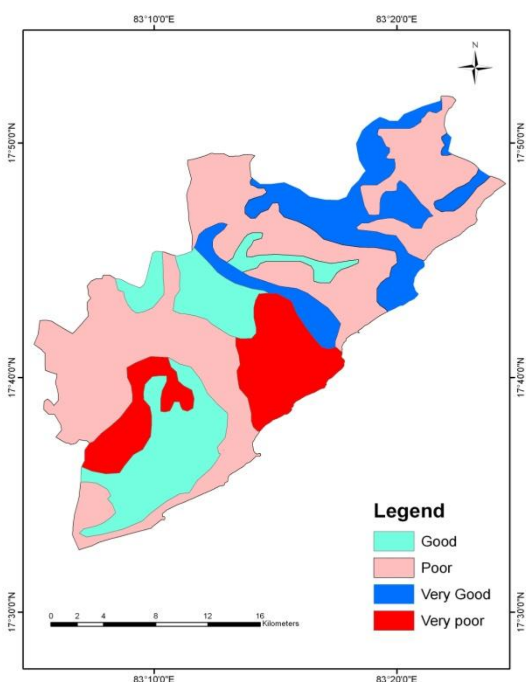

Fig.8: Groundwater potential zones map of the study area

Conclusions:

Ground water in study area occurs under confined and semi confined conditions. Groundwater is the major source for domestic purpose in the area. The water table occurs in between 5 to 25 m below ground level in the city. This is due to the topographical and subsurface conditions at different places in the study area. Out of the four types of rocks exists in the study area; it has been observed that Khondalite rock formation areas are more promising for ground water exploratoin. The reason may be highly weathering and fracturing nature of the rock than the other types of rocks. The next promising type of rock that has good water bearing zone is Quartzite and is also prone to high fracturing due to its brittleness. Charnohkite and Leptynite rock formations are poor water bearing zones may be due to their low weathering and fracture nature. In the study area Khondalite rock is dominant and at most of the places ground water is available.

The shallow water table occurs in the central marshy area, where the quality of water is slightly brackish and the areas that come under this zone are Poorna market, Convent junction and some industrial zones. The deep water table occurs at Seethammadhara, Seethammapeta, Kancharapalem, Gopalapatnam, etc. Most of these areas are located over the foot hills and therefore, wells may get dry during summer season. Fortunately most population density areas like MVP colony, PM palem, Madhrawada, Seetammadhara, Madhavadhara, NAD junction, Gajuwaka, Gopalapatnam, Simhachalam, Vaagunta, Dabagardens and Sagar nagar having very good to good groundwater conditions. Whereas Old town area, Siripuram, LB colony, Sivaji palem, Industry estate, Kanchra palem and Steel plant area having very poor to poor groundwater conditions.To meet the domestic requirements dug and bore wells were constructed to exploit ground water. Due to excess draft, particularly in urban areas, most of the wells are getting dry, which leads to seawater intrusion into certain areas along the seacoast. Industrial liquid effluents and municipal sewage further deteriorated the quality of ground water in the area water table fluctuation in the year 2006 is in between 3.28 m bgl (below ground level) to 8.22 m bgl in the area. The water table fluctuation varies from year to year.

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