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IDENTIFICATION OF GROUNDWATER PROSPECTS FOR PALLERU SUB BASIN USING REMOTE SENSING AND GIS

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Abstract

Fresh water being one of the basic necessities for sustenance of life, the human race through the ages has striven to locate and develop it. Over ninety percent of liquid fresh water available at given moment on the earth lies beneath the land surface. Groundwater, unlike surface water, is available in some quantity almost everywhere that man can settle in. Even in areas where normally there are abundant surface water supplies through major, medium and minor irrigation projects, groundwater is playing an increasingly vital role in supplementing surface water. The increasing demand placed on it has stimulated investigations oriented towards quantification of the resource, which is basic to formulation of plans for its exploration, management and conservation. The primary objective of this paper is to identify groundwater prospects in Palleru sub basin using Remote Sensing and Geographical Information System techniques. The sub basin partly covers three districts namely Warangal, Nalgonda and Khammam of Andhra Pradesh. The study area covers 15 mandals from these districts. Warangal district covers seven mandals namely Ghanpur, Raghunathpalli, Palakurthy, Torrur, Kodakandla, Marripeda, Narasimhulapeta. Six mandals are covered under Nalgonda district. They are Tirumala, Tungaturthy, Jagireddigudem, Noothankal, Mothey and Atmakur. Kusumanchi and Tirumalayapalem are the two mandals that are covered under Khammam district.

The present work involves creating a database both spatial and non-spatial with the help of Survey of India toposheets and Remote Sensing imageries. Various thematic maps like drainage map, contour map, slope map, soil map, hydro-geomorphology map and lineament maps are prepared by using Survey of India topo sheets. After integrating all thematic maps using weighted overlay analysis tool, groundwater prospects map is generated for the study area.

Index terms: *Groundwater Prospects, Remote Sensing and Geographical Information System.*

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1. INTRODUCTION

Groundwater has emerged as an important source to meet the water requirements of various sectors including the major consumers of water like irrigation, domestic and industries. The sustainable development of groundwater resources requires precise quantitative assessment based on reasonably valid scientific principles. Quantification of the groundwater recharge is a basic pre-requisite for efficient groundwater resource development and this is particularly vital for India with widely prevalent semi arid and arid climate. The soil and water resources are limited often being in a delicate balance. For rapidly expanding urban areas, industrial and agricultural water requirement of the country is a fundamental importance.

The groundwater in most of the areas in the country is fresh. Brackish groundwater occurs in the arid zones of Rajasthan, coastal tracts in Saurashtra and Kutch, some zones in the East coast and certain parts in Punjab, Haryana, and Western Uttar Pradesh that are under extensive surface water irrigation. The fluoride levels in the groundwater are considerably higher than the permissible limit in vast areas of Andhra Pradesh, Haryana and Rajasthan and in some places in Punjab, Uttar Pradesh, Karnataka and Tamil Nadu. In the northeastern regions groundwater with iron content above the desirable limit occurs widely. Pollution due to human and animal wastes and fertilizer application has resulted in high levels of nitrate and potassium in groundwater in some parts of the country. Groundwater contamination in pockets of industrial zones is observed in localized areas. The over-exploitation of the coastal aquifers in the Saurashtra and Kutch regions of Gujarat has resulted in salinisation of coastal aquifers. The excessive groundwater withdrawal near the city of Chennai has led to seawater intrusion into coastal aquifers.

During the period 1951-92, the number of dug wells increased from 3.86 million to 10.12 million that of shallow tube wells from 3,000 to 5.38 million and public bore or tube wells from negligible to 68,000. There has been a steady increase in the area irrigated by groundwater from 6.5 Mha in 1951 to 35.38 Mha in 1993. During VIIIth plan, about 1.71 million dug wells, 1.67 million shallow tube wells and 11,400 deep tube wells were added. Such a magnitude of groundwater development requires realistic assessment of groundwater resources to avoid any deleterious effects on groundwater regime and to provide sustainability to the groundwater development process.

Quantification of groundwater resources is often critical and no single comprehensive technique has been identified to estimate accurately groundwater assessment. The complexities of the processes governing occurrence and movement of groundwater makes the problem of groundwater assessment somewhat difficult, mainly because not only enormous data is to be procured, but a multidisciplinary scientific approach is to be adopted for space and time location of groundwater, in quantity as well as in quality. Groundwater being a replenishable resource, its proper and economic development on a sustainable basis requires its realistic assessment. The conventional approach for groundwater investigations such as ground based surveys and exploratory drilling are time consuming and uneconomical. So, an integrated approach of Remote Sensing, Geo-physics and Geographical Information System has proved to be an efficient tool in groundwater studies

2. MATERIALS AND METHODS

The Palleru basin is the one of the sub-basins of river Krishna that lies between $17^{0}15^{'}$ to $18^{0}20^{'}$ North Latitudes and $79^{0}32^{'}$ to $80^{0}38^{'}$ East Longitude. The study area is covered in Survey of India toposheet nos. 5605, 5606, 5607, 56010, 56011, 56012, 56015, 56016. The Palleru sub basin has a Catchment area of 3,263 km^2, which constitutes 1.3% of the total basin area. The sub basin partly covers three districts namely Warangal, Nalgonda and Khammam of Andhra Pradesh. The study area covers 15 mandals from these districts. Warangal district occupies seven mandals namely Ghanpur, Raghunathpalli, Palakurthy, Torrur, Kodakandla, Marripeda and Narasimhulapeta. Six mandals are covered under Nalgonda district. They are Tirumala, Tungaturthy, Jagireddigudem, Noothankal, Mothey and Atmakur. Kusumanchi and Tirumalayapalem are the two mandals that are covered under Khammam district. In the present study, sub basin has been considered up to Palleru reservoir only covering a catchment area of 1941.81km^2. The location map of the study area is shown in Fig. (1.1).

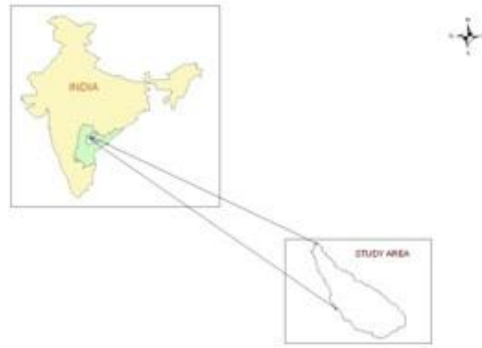

Fig. (1.1) Location Map of the Study Area

Various thematic maps like drainage map, contour map, slope map, hydro-geomorphology map, soil map and lineaments map are generated for the study area. All these maps are projected to a common co-ordinate system so that integration is possible and the accuracy of the output is maintained. Arc GIS 9.2 software is used for integration of the layers. Appropriate weightages are given for each layer by considering its importance with respect to the groundwater point of view. The layers were integrated using weighted overlay analysis in spatial analyst tool. Once the layers are integrated, a multi-criteria approach has been adopted to obtain information for groundwater prospects.

2.1 Preparation of the Drainage Map

Drainage pattern is prepared by using Survey of India toposheet on 1:50,000 scale. The drainage pattern observed in the study area is dendritic. The highest stream order is sixth order. Most of the streams are situated on the western side of the river in the study area. The streams situated on the right side of the river flow from Northeast to Southwest and the streams on left side of the river flow from Northwest to Southeast. Buffers are generated for each stream order and appropriate weightages are given according to their importance in view of groundwater occurrence. The number of streams in various stream orders, their buffer range and their respective weightages are presented in Table (1.1). The buffers generated for the drainage map are shown in Fig. (1.2).

S.No	Stream Order	Buffer Ranges (m)	Number of Streams	Appropriate Weightages
1	Sixth order	600	100	5
2	Fifth Order	500	107	5
3	Fourth order	400	225	3
4	Third Order	300	485	3
5	Second order	200	1025	1
6	First Order	100	2042	1

Table (1.1) Drainage Orders and Appropriate Weightages

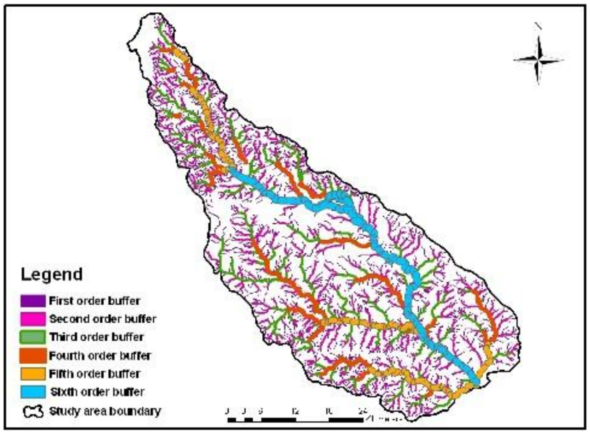

Fig. (1.2) Drainage Buffer Map of the Study Area

2.2 Preparation of the Contour Map

Contour map is prepared from Survey of India toposheet with 20m intervals. The corresponding contour intervals are recorded in the attribute table. The generated contours have a minimum contour elevation of 140 m and a maximum contour elevation of 500 m. The minimum contour is observed at Palleru reservoir and maximum contour is observed at Jagireddigudem mandal of Nalgonda District due to the presence of hills at that place. The contour map of the study area is represented in Fig. (1.3).

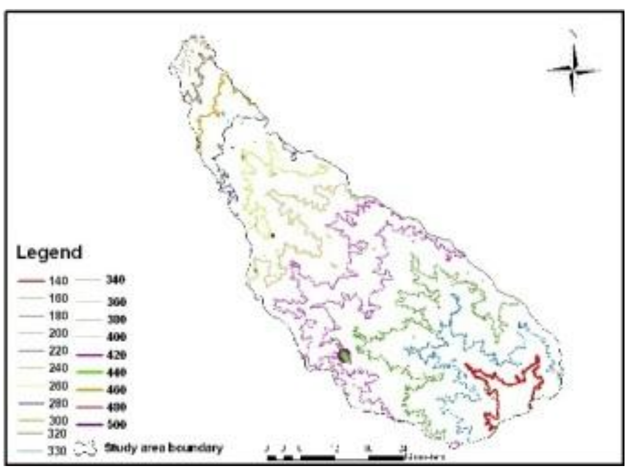

Fig. (1.3) Contour Map of the Study Area

2.3 Preparation of the Slope Map

Contour map is used for the generation of slope map. Closely spaced contours on the map reflect steepness when compared to widely spread contours. The slope observed in the study area is categorized into seven classes as per guidelines suggested by National Bureau of Soil Survey and Landuse Planning. The slope categories, area covered and their appropriate weightages are presented in the Table (1.2).

S.No	Slope Gradient	Category	Area in km^2	Appropriate Weightages
1	0-1	Nearly Level	1546.12	5
2	1-3	Very Gently Sloping	329.94	5
3	3-5	Gently Sloping	27.1	4
4	5-10	Moderately Sloping	5.34	3
5	10-15	Strongly Sloping	3.52	2
6	15-35	Moderately Steep to Steep Sloping	1.57	1
7	Greater than 35	Very Steep Sloping	0.26	1

Table (5.2) Slope Categories and their Weightages

From the slope map, it is observed that very steep slope is observed at Jagireddigudem and Atmakur mandals of Nalgonda District and almost the entire area is nearly level in the study area. Lands having lesser slope are useful for groundwater recharge, where as steep slopes are not fit for the groundwater recharge. Based on this criterion, the slope is classified as good, good to moderate, moderate, moderate to poor and poor. The slope map of the study area is shown in Fig. (1.4).

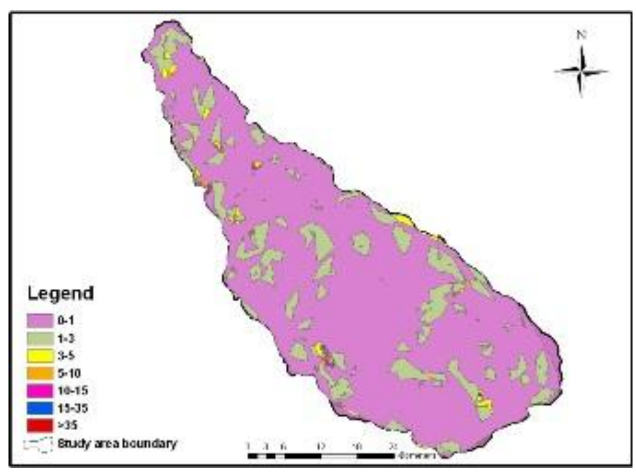

Fig. (1.4) Slope Map of the Study Area

2.4 Preparation of the Hydro-Geomorphology Map

The hydro-geomorphology deals with the geomorphic history of the area. The hydro-geomorphology map generated by Geological Survey of India to a scale of 1:2, 50,000 is used to prepare the hydro-geomorphology map for the entire study area and is categorized into five classes as Shallow Weathered

Pediplain, Moderately Weathered Pediplain, Shallow Weathered or Buried Pediplain, Pediment Inselbergs Complex and Inselbergs. A detailed description of each class is explained below:

Shallow Weathered Pediplain (SWP):
According to the Integrated Mission for Sustainable Development manual, the description for shallow weathered pediplain was given that it cannot form good aquifers except along fracture and fault zones and the groundwater prospects in these areas are expected to be good. In the study area fractures and faults are observed so the groundwater prospects are good. The areal extent of this unit is 1124.62 km^2 that covers 57.91% of the study area.

Moderately Weathered Pediplain (MWP):
The moderately weathered pediplain was described as, a fracture or fault concentrated areas which forms good prospects. In the study area fractures and faults are not observed. So, the groundwater prospects in these areas are expected to be good to moderate. The areal extent of this unit observed in the study area is 436.87 km^2 that covers 22.49% of the study area.

Shallow Weathered or Buried Pediplain (SWP or BPP-S):
Shallow weathered or buried pediplain areas are generally criss-crossed by lineaments or fractures with shallow overburden of weathered material of varying lithology. In the study area criss-cross lineaments and fractures are observed at Palakurthy, Ghanpur and Jagireddigudem mandals. So, the groundwater prospects in these areas are expected to be moderate to poor. The areal extent of this unit observed in the study area is 10.92 km^2 that covers 0.56% of the study area.

Pediment Inselbergs Complex:
Pediment Inselbergs Complex geomorphic units are generally observed in isolated low relief or hill surrounded by gently sloping, smooth erosion bedrock. Joints, fractures and faults are observed at Palakurthy, Ghanpur and Jagireddigudem mandals. So, the groundwater prospects in these areas are expected to be moderate to poor. The areal extent of this unit observed in the study area is 326.64 km^2 that covers 16.82% of the study area.

Inselbergs:
Inselbergs are having varying lithology. This geomorphic unit was observed at Raghunathpalli and at some parts of Palakurthy. The groundwater prospects in these areas are expected to be very poor. The areal extent of this unit is 15.16 km^2 covering 0.78% of the study area. Based on the above description the hydro-geomorphology of the study area is divided into five classes as good, good to moderate, moderate, moderate to poor, poor, depending on groundwater prospects. The hydro-geomorphology map of the study area is shown in Fig. (1.5).

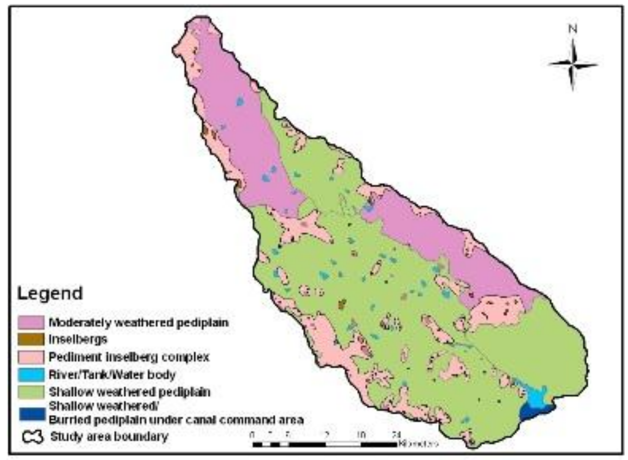

Fig. (1.5) Hydrogeomorphology Map of the Study Area

2.5 Preparation of the Soil Map

A good understanding of soils with reference to their nature and distribution is essential to formulate any land based production system. Soil is a diminishing resource whose loss or degradation is slow and not perceived readily. The soil map generated by National Bureau of Soil Survey and Landuse Planning on 1:2,50,000 scale is utilized for the preparation of the soil map for the study area. In the study area six types of soils are observed. They are gravelly clay soils, clay soils, loamy soils, gravelly loam or clay soils, clayey or calcareous soils, cracking clay or calcareous soils. It is observed that the major portion of the study area is covered by gravelly clay soils and clayey or calcareous soils. Based on the soil characteristics, they are grouped into good, good to moderate, moderate, moderate to poor and poor. The soil statistics and description of the soils are provided in Table (1.3) and the soil map of the study area is shown in Fig. (1.6).

S.No	Name of the soil	Area in km^2	Description of the Soil
1	Gravelly Clay Soil	852.68	Moderately deep, well-drained, gravelly loam soils with low available water capacity on undulating lands. Severely eroded.
2	Clay Soils	193.86	Moderately deep, well-drained, clayey soils with high available water capacity on gently sloping lands.
3	Loamy Soils	10.23	Moderately shallow, somewhat excessively drained, loamy soils with very low available water

			capacity on hills and ridges. Severely eroded.
4	Gravelly Loam or Clay Soils	12.64	Deep, well-drained, clayey soils with high available water capacity on gently sloping lands. Slightly eroded.
5	Clayey or Calcareous Soils	469.9	Deep, imperfectly drained, clayey, calcareous soils with very high available water capacity on very gently sloping valleys. Slightly eroded.
6	Cracking Clay or Calcareous Soils	387.4	Very deep, moderately well drained, cracking clay, calcareous soils with very high available water capacity on nearly level valleys. Salinity in patches.

Table (1.3) Soil Statistics and Description

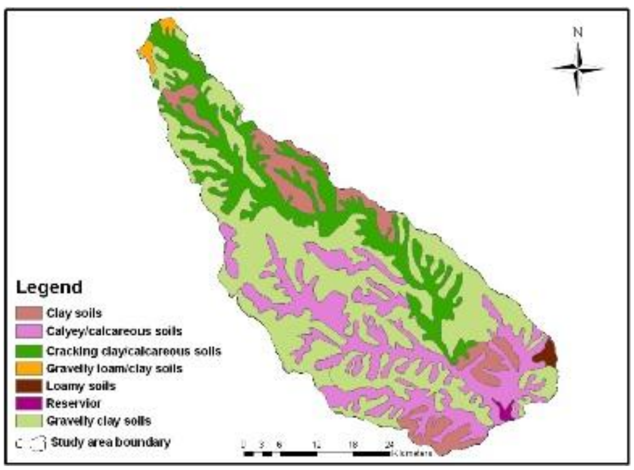

Fig. (1.6) Soil Map of the Study Area

2.6 Preparation of the Lineaments Map

A lineament is defined as a large-scale linear feature, which expresses itself in terms of topography, which is itself, an expression of the underlying structural features. From the groundwater point of view such features include, valleys controlled by faulting and jointing, hill ranges and ridges, displacement and abrupt truncation of rocks, straight streams and right angle setting of stream courses etc. The lineament map generated by Geological Survey of India to a scale of 1:2,50,000 scale is utilized in the preparation of the lineament map for the study area.

A total number of 153 lineaments are observed in the study area. If we observe the entire dendritic drainage pattern, the watercourses that are straight in alignment, are readily identified as fault lines because the straight alignment of watercourses will not occur unless it is following a fault zone. Some lineaments are perpendicular to river flow and some are along the river. The lineaments, which are perpendicular to river flow, are considered as fault zones. So, there is a possible recharge of groundwater at these areas. The generated buffer in the map shows the effect of lineaments. The buffers are generated for lineaments by considering 1000m as linear unit and are used for identifying groundwater prospects in the area. The generated buffer map of the lineaments is presented in Fig. (1.7).

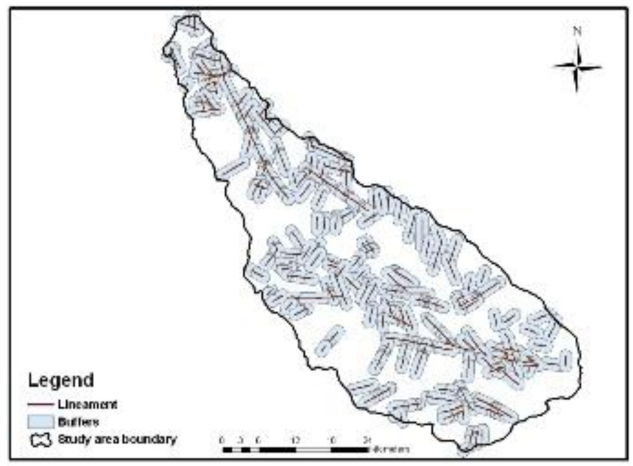

Fig. (1.7) Lineament Buffer Map of the Study Area

3. WEIGHTED OVERLAY ANALYSIS

A weighted overlay evaluates the relative influence of the input rasters. Weighted overlay overlays several rasters using a common measurement scale and weights are assigned according to its importance. The thematic maps, which are prepared, are converted into raster form, as the weighted overlay analysis uses only raster files. The conversion tools are used to convert vector layer to raster layer. The raster layers itself generates its own numbering to different fields. All the converted rasters are reclassified, which is used to reclassify the fields into different groups and assigns new values to rasters according to the classification. The weightages are given to each reclassified rasters according to their importance with respect to the groundwater occurrence. The generated raster values and reclassified values for each raster are represented in the Table (1.4).

S.No	Raster Layers	Classes	Raster Value	Reclassified Value
1	Hydro-geomorphology	Shallow weathered Pediplain	5	4
		Moderately weathered Pediplain	4	3
		Shallow weathered or buried Pediplain	3	2
		Pediment Inselbergs Complex	2	1
		Inselbergs	1	0
2	Soil	Clayey/Calcareous soils	2	1
		Clay soils	1	0
		Cracking clay/Calcareous soils	4	3
		Gravelly loam/Clay soils	5	4
		Loamy soils	1	0
		Gravelly clay soils	3	2
3	Slope (Percentage)	Nearly level	1	0
		Very gently sloping	1	0
		Gently sloping	2	1
		Moderately sloping	2	1
		Strongly sloping	3	2
		Moderately steep to steep sloping	4	3
		Very steep sloping	5	4
4	Lineament	Lineament	5	4
		Dyke	1	0
		River or stream	4	3
5	Drainage	Sixth order and Fifth order	5	4
		Fourth order and Third order	3	2
		Second order and First order	1	0

Table (1.**4**) Raster Values and Reclassified Values of Thematic Layers

3.1 Preparation of the Groundwater Prospects Map

The groundwater prospects map is obtained when the reclassified rasters are integrated by using weighted overlay analysis. All the raster layers are added and suitable weightages are given according to their importance towards groundwater accumulation and the total percentage of influence is given as 100%. The weightages given to each classification is presented in the Table (1.5). The percentage of influence given to hydro-geomorphology, soil, lineament, slope and drainage is 35%, 20%, 15%, 20% and 10% respectively. The output raster map generated shows the groundwater prospects of the study area. The groundwater prospects map is presented in Fig. (1.8). The output raster is converted into vector form to obtain the areas of each zone in the prospects map. In the study area, the areas obtained for good groundwater prospects is 503.91 km^2, good to moderate is 658.95 km^2, moderate is 459.86 km^2, moderate to poor is 289.86 km^2 and poor is 29.22 km^2.

S.No	Groundwater Prospects	Weightage Value for each layer	Area in Km^2	Percentage of area covered
1	Good	10	503.91	25.95
2	Good to Moderate	7	658.95	33.94
3	Moderate	5	459.86	23.68
4	Moderate to Poor	3	289.86	14.93
5	Poor	1	29.22	1.51

Table (5.5) Overlay Weightages

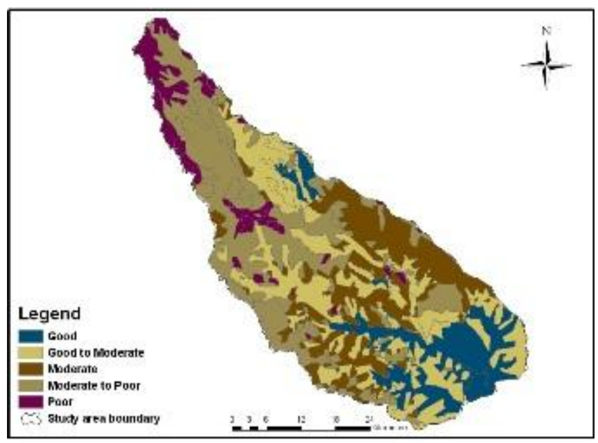

Fig. (1.8) Groundwater Prospects Map of the Study Area

CONCLUSION

Good groundwater prospects are observed at some parts of Kusumanchi, Tirumalayapalem, Mothey, Atmakur, Noothankal, Torrur and Kodakandla mandals due to the presence of the shallow weathered pediplain and dense drainage pattern. Good to Moderate prospects are observed majorly at Tungaturthy, Marripeda and Tirumala due to the presence of moderately weathered pediplain with faults and also due to clay soils and the availability of gravelly soils on gently sloping and moderately sloping lands. Moderate prospects are observed at Narasimhulapeta mandal due to the presence of the geomorphic units such as moderately weathered pediplain, shallow weathered pediplain with very less fractures. Moderate to Poor groundwater prospects are observed primarily at Palakurthy, Ghanpur and Jagireddigudem mandals due to the presence of shallow weathered pediplain and pediment inselberg complex. Poor groundwater prospects are observed at Raghunathpalli and at some parts of Tirumala and Palakurthy mandals due to the presence of Inselbergs.

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BIOGRAPHY

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