International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 4 Issue 11, November-2015

Delineation of Groundwater Potential Zones using Remote Sensing and GIS Techniques: A Case Study of Sarada Gedda Sub Watershed

Ch Kannam Naidu [1]
Civil Engineering Department
AITAM- Tekkali
Srikakulam District,A.P,India.

Dr. B. Visweswara Reddy[2]
Civil Engineering Department
AITAM- Tekkali
Srikakulam District,A.P,India.

Ch Chandra Mouli [3]
Civil Engineering Department
AITAM- Tekkali
Srikakulam District,A.P,India.

***Abstract*— In present days many researchers have delineated groundwater potential zones using Remote Sensing and GIS techniques by the Weighted Index Overlay Analysis (WIOA) for various geographic regions of the world. Many of the researchers have not been given weightage calcualtions for the thematic layers they considered in their research. But in this research, a detailed approach have been given for weightage calcultions for various thematic layers considered. In this research the following thematic layers have been taken which include Land use/Land cover, Geomorphology, Geology, Soil, Drainage density, Lineament density, Lineament frequency and Lineament Intersection. All the thematic layers have been extracted from the existing data, KOMPSAT and LANDSAT ETM+ satellite data. For the extraction of thematic layers and analysis ,the ArcGIS 9.3,1 and ERDAS Imagine 9.1 softwares have been used for delineating the groundwater potential zones. The delineated groundwater potential zones have been validated with the open wells in the study area.**

Keywords— Groundwater, Remote Sensing and GIS, Weighted Index Overlay, KOMPSAT, LANDSAT ETM+, ArcGIS, ERDAS Imagine

I. INTRODUCTION

Competition over freshwater resources has been increasing during a few decades due to the over growth of population, economic development, increased demand for agricultural products for both food and non-food use. So, we can't imagine a world without water!! [1]. Globally its availability is only 3% in the form of Icecaps and glaciers (68.7%), Groundwater (30.1%) and other forms (0.9%) like water vapor in the atmosphere [2]. In that ground water is most significant natural resource which supports both human needs and economic development. In the recent years enormous increased the demand for good quality water in the agricultural, industrial and domestic sectors to meet the growing needs. Groundwater is mostly preferred to meet this growing demand because of its lower level of contamination and wider distribution [3]. Due to the increasing of population, urbanization, deforestation and industrialization pressure on this resource is alarmingly increasing. The available surface water resources are inadequate to meet all the water requirements for various purposes. It may be noted that not only its demand has increased over the years but it seems that the demand will not be ceased. Hence, the delineation of groundwater potential zones has acquired great importance.

Remote Sensing is an excellent tool for researchers in understanding the "bewildering" problems of groundwater exploration. In recent years, satellite remote sensing data has been widely used in locating groundwater potential zones[1] [4], [5]. Its advantages of spatial, spectral and temporal availability of data have proved to be useful for quick and useful baseline information about the factors controlling the occurrence and movement of groundwater like geology, geomorphology, land use/ land cover, drainage patterns, lineaments etc [6], [7]. Excellent reviews of remote sensing applications in groundwater hydrology are presented in Farnsworth et [8], Waters et [9] and Engman and Gurney[10], which concluded that remote sensing has been widely used as a tool. In the recent years, modern technologies like Geographic Information System (GIS) is being used for various purposes such as groundwater investigations and many authors [11] have attempted to delineate groundwater potential zones. GIS techniques facilitate integration and analysis of large volumes of data, whereas, field studies help to further validate results. The integration of remote sensing and GIS has proven to be an efficient tool in groundwater studies [12], [13], [14], where remote sensing serves as the preliminary inventory method to understand the groundwater conditions and GIS enables integration and management of multi-thematic data. In addition, the advantage of using remote sensing techniques together with GPS in a single platform and integration of GIS techniques facilitated better data analysis and their interpretations [15].

In this study, Weighted Index Overlay Analysis (WIOA) approach for easy assessment of groundwater potential is adopted for GIS integration of thematic layers developed from the Remote Sensing data [16]. Remote sensing technique integrated with GIS platform through Weighted Index Overlay Analysis (WIOA) is found to be very effective tool for identification of potential zones for groundwater exploration [14].

II. STUDY AREA

The present study area Sarada Gedda sub watershed is located in Srikakulam district of North Coastal Andhra

Pradesh, India. It lies between latitudes from 18°23'33.167"N to 18°25'47.866"N and longitudes from 83°32'22.842"E to 83°36'31.766"E. It covers an area about 16.03 sq km. The area occurs within the Survey of India toposheet of 65N/11 (Figure 1.0). Open wells are there in the study area. Many Parts of study area is mainly utilized for growing the crops like sugarcane, rice and millets. The surface water bodies are also present in the study area along with scrub land.

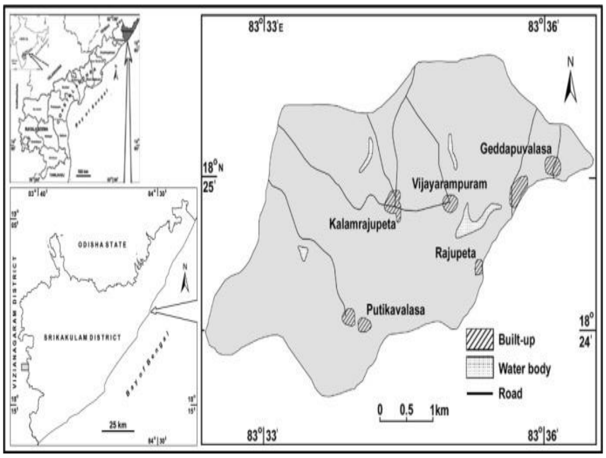

Figure 1. Location map of the Sarada Gedda sub watershed

III. DATA USED AND METHODOLOGY

The Survey of India (SOI) toposheet (No. 65N/11 of 1:50000) along with existing data (NRSC Bhuvan data), Landsat data (ETM$^+$ 28m spatial resolution Path 141, Row 047, 08th December, 2000) and KOMPSAT data (1m spatial resolution) were used for generation of various thematic layers such as Land use/Land cover, Geomorphology, Geology, Soil, Drainage density, Lineament density, Lineament frequency and Lineament intersection.

The study area was delineated into three groundwater potential zones which include Good, Moderate and poor by weighted index overlay analysis (WIOA). The Groundwater Potential Index (GWPI) was used for this classification. GWPI was calculated by multiplying the rank and weightage of each thematic layer as expressed in the following equation.

GWPI = Σ (Land use/Land cover feature rank x 24 + Geomorphology feature rank x 26 + Geology feature rank x 11 + Soil feature rank x 16, Drainage density feature rank x 18 + Lineament density feature rank x 3 + Lineament frequency feature rank x 2 + Lineament Intersection feature rank x 0)

Weightage calculations are shown in below Table 1.0

Table 1.0

A (1)	B (2)	C (3)	D (4)	E (5)	F (6)	G (7)	H (8)
1	LU/LC	14.56	37	00.00	0	37	24
2	Geomorpho--logy	15.44	39	00.00	0	39	26
3	Geology	00.00	0	06.73	16	16	11
4	Soil	00.00	0	10.03	24	24	16
5	Drainage Density	09.31	23	01.20	3	26	18
6	Lineament Density	00.41	1	01.26	3	4	3
7	Lineament Frequency	00.00	0	01.51	4	4	2
8	Lineament Intersection	00.00	0	00.00	0	0	0
	Total	**39.72**	**100**	**20.73**	**50**	**150**	**100**

A- S.No., B- Thematic Layer

B- C- Good area of feature in each thematic layer

D- Weightage I calculations $\frac{Column\ C}{Sum\ of\ Column\ C}\ x\ 100$,

E- Moderate area of feature in each thematic layer,

F- Weightage II calculations $\frac{Column\ E}{Sum\ of\ Column\ E}\ x\ 50$

G- Weightage I + Weightage II (i.e. D + F)

H- Weightage calculations $\frac{Column\ G}{Sum\ of\ Column\ G}\ x\ 150$

The below Table 2.0 shows Thematic Layers, Featues, Feature ranks and Layer weightages

Table 2.0

A	**B**	C	D	E
1	LU / LC	Crop land	3	24
		Water body	3	
		Scrub land	1	
		Built-up Land	1	
2	Geomorphology	Pediplain	3	26
		Structural hills	1	
3	Geology	Khondalite	2	11
		Granite gneiess	1	
4	Soil	Loamy soils	2	16
		Clayey soils	1	
5	Drainage Density	< 1 Km/Sq Km	3	18
		1– 2 Km/Sq Km	2	
		> 2 Km/Sq Km	1	
6	Lineament Density	> 4 Km/Sq Km	3	3
		2 - 4 Km/Sq Km	2	
		< 2 Km/Sq Km	1	
7	Lineament Frequency	3 - 5 No/Sq Km	2	2
		< 3 No/Sq Km	1	
8	Lineament Intersection	< 2 No/Sq Km	1	0

The groundwater potential (GWP) zones were categorized based on the GWPI values. From the range of GWPI values mean and standard deviation values were calculated. Based on the mean and standard deviation values the GWP zones were delineated. The delineated zones are shown in Table 3.0

Table 3.0

S.No	Categories	GWPI range	GWP zone
1	>= Mean + SD	>= 246	Good
2	Mean to Mean + SD	213 - 246	Moderate
3	< Mean	< 213	Poor

IV RESULTS AND DISCUSSIONS

Groundwater potential zones were delineated from the following maps which include land use/land cover, geomorphology, geology, soil, drainage density, lineament density, lineament frequency and lineament intersection by weighted index overlay analysis (WIOA). Hence, all the thematic maps pertaining to the study area were prepared as per the methods explained earlier. The salient aspects of these thematic maps are described below.

1. Land use / Land cover

Land use refers to the way in which human beings exploit the land and its resources [17], whereas land cover describes the physical state of the land surface [18, 19]. From the existing data and KOMPSAT satellite data of 1 m resolution, the land use/ land cover map was delineated. In the present study area the following four categories were delineated which include crop land, built-up land, scrub land and water bodies (Figure 2.0). The groundwater potentiality is good in crop land and water bodies since infiltration is high where as groundwater potentiality is poor in scrub land and built-up area since infiltration is low.

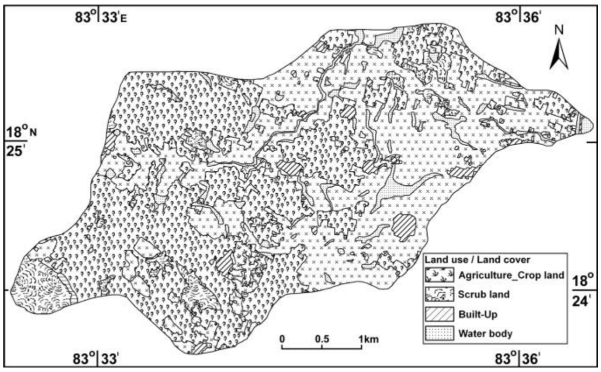

Figure 2.0 Land use / Land cover map

2. Geomorphology

Geomorphology is the scientific study of the nature and history of the landforms on the surface of the earth and other planets, and of the processes that create them. The major geomorphic units identified in this study area are structural hill and pediplain (Figure 3.0). Structural hills are characterized by composed of composite ridges and valleys traversed by structural features. These areas are having high runoff and low infiltration along secondary fractures; category-wise these are poor for groundwater potentiality [20], whereas pediplain is developed as a result of continuous processes of pediplaination so groundwater potentiality is good in pediplain area [21]**.**

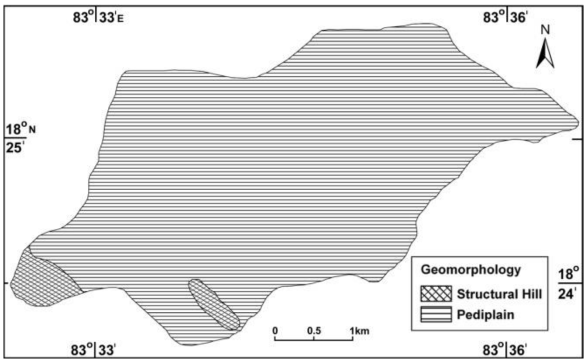

Figure 3.0 Geomorphology map

3. Geology

Geology plays an important role in the distribution and occurrence of groundwater. An understanding of the local geology was developed based on existing maps. The area is underlain by Archaean (Eastern Ghat Super Group) Granite gneiss and Khondalite (Figure 4.0). The groundwater prospects are poor in Granite gneiss since infiltration is low whereas Khondalite is moderate for groundwater potentiality since infiltration is moderate [22].

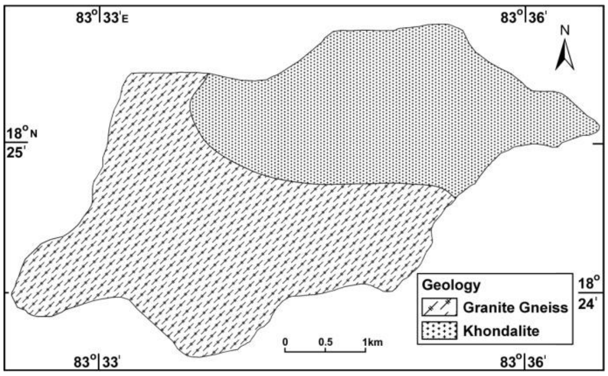

Figure 4.0 Geology map

4. Soil

The term soil has specific connotation to different groups involved with soil survey and mapping (Lille sand and Keifer 1987). The soil for the study area reveals two main soil categories namely clayey and loamy (Figure 5.0). The clayey soil has least infiltration rate hence assigned low priority [23]. The groundwater potentiality is poor in clayey soils. While loamy soils are moderately suitable for groundwater infiltration [24]. So groundwater potentiality is moderately suitable

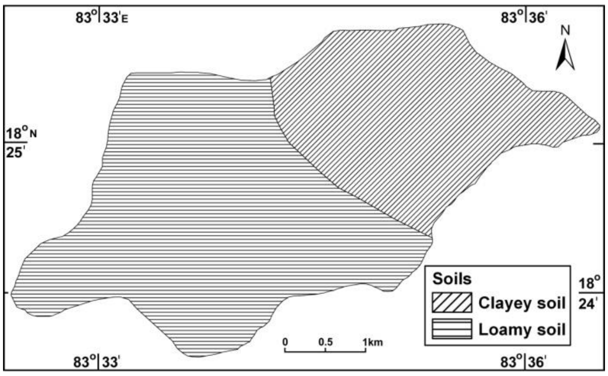

Figure 5.0 Soil map

5. Drainage density

Drainage density is a measure of quantitative length of linear feature expressed in Sq Km grid. It helps to assess and understand the characteristics of runoff and groundwater infiltration in this area [25]. Drainage network was extracted from Survey of India toposheet of 1:50000 scale using ArcGIS 9.3.1 software. The present study area is divided in to three zones which include Good (< 1 km/Sq km), Moderate (1- 2 Km/ Sq Km) and Poor (< 2 Km/ Sq Km) as shown in Figure 6.0. The area which is having poor drainage density indicates comparatively higher infiltration and low runoff, similarly the area which is having good drainage density indicates low infiltration and high runoff.

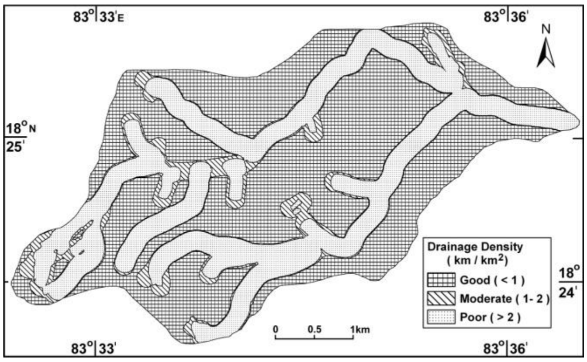

Figure 6.0 Drainage density map

6. Lineament Density

Lineaments are defined as mapable linear surface features, which differ distinctly from the patterns of adjacent features and most probably reflect subsurface phenomena [26]. We are extracted the lineaments from Landsat ETM^+ with the help of ERDAS Imagine 9.1 software by using the application of the Sobel directional filters 5x5 and 7x7 in the directions N-S, E-W, NE-SW and NW-SE [27]. Lineament density map is a measure of quantitative length of linear feature expressed in Sq Km grid. The study area has been classified in to three zones such as good (> 4 km/sq km), moderate (2 to 4 km/sq km), and poor (< 2 km/sq km). An area with high lineament density shows good groundwater potential (Figure 7.0).

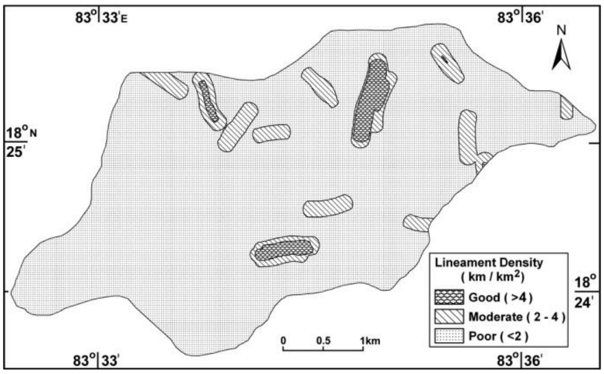

Figure 7.0 Lineament density map

7. Lineament Frequency

It means number of lineaments appeared in a Sq Km grid area. More the lineament in a Sq Km grid area represents good groundwater potentiality [28]. Weighted lineament frequency map was prepared by counting the number of lineaments per Sq.Km grid. The study area is categorized in to two zones such as moderate (3 to 5 km/ sq km) and poor (< 2 km/ sq km). In this study area moderate zone implies moderate groundwater potentiality as shown in Figure 8.0.

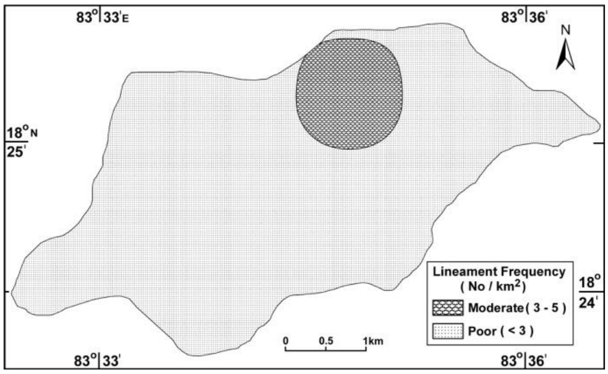

Figure 8.0 Lineament Frequency map

8. Lineament Intersection

It signifies number of lineament intersections in a Sq Km grid area. Weighted lineament intersection map was prepared by counting the number of intersections of lineaments per Sq.Km grid [28]. In this study area no lineament intersections are there so in this area groundwater potentiality is poor based on the lineament intersections (Figure 9.0).

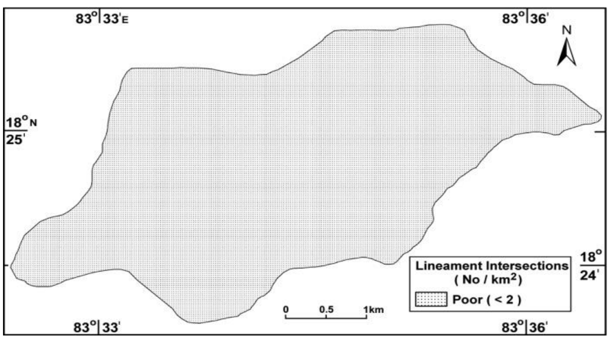

Figure 9.0 Lineament Intersection map

9. Groundwater potential zone mapping

The groundwater potential zones were delineated by Weighted Index Overlay Analysis (WIOA) by using the ArcGIS 9.3.1 [29]. In the Weighted Index Overlay Analysis, the ranks have been given for each individual feature of each thematic map and the weightages were assigned to the each thematic map which are shown in the **Table 2.0.** The GWPI calculations are given in the methodology. The groundwater potential zone of the study area has been delineated into three groundwater potential zones, namely good, moderate and poor (Figure 10.0). In this total (16.03 Sq.Km) study area, 8.11 Sq.Km area is belongs to good groundwater potential zone. Similarly, 6.10 Sq.Km area is belongs to moderate groundwater potential zone and 1.82 Sq.Km area is belongs to poor groundwater potential zone. The percentage of good groundwater potential zone area is 50.593%, moderate area is 38.053% and poor area is 11.354%.

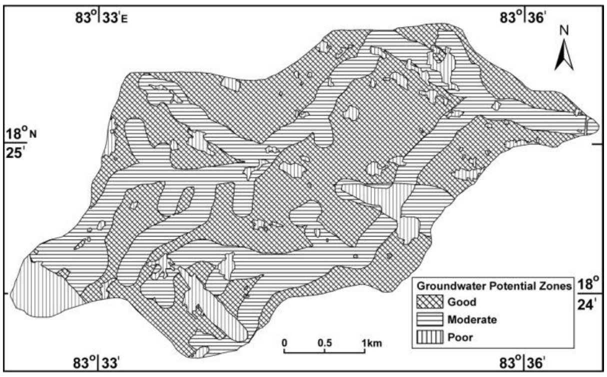

Figure 10.0 Groundwater potential map.

V. VALIDATION OF GROUNDWATER POTENTIAL ZONES MAP WITH GROUNDWATER LEVELS OF OPEN WELLS

The validation of the Groundwater potential zones was checked with the Groundwater level depth data of open wells. A comparison of this study between the water level depth data and groundwater potential zones map were done [20]. For this comparison, the groundwater levels of pre monsoon data were

collected from the field from thirty existing open wells during the years 2010 and 2015.

In the good groundwater potential zone area there are 17 wells are existed. Out of the 17 wells, 16 wells are having good groundwater levels (i.e., < 4 m groundwater levels). In the moderate groundwater potential zone area there are 4 wells are existed. All the 4 wells are having moderate groundwater levels (i.e., 4 – 8 m groundwater levels). Similarly, in the poor groundwater potential zone area there are 9 wells are existed. All the 9 wells are having poor groundwater levels (i.e., > 8 m groundwater levels).The details discussed above are shown in the below Figure 11.0.

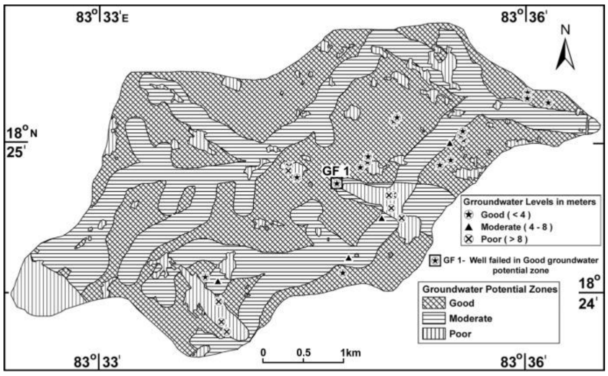

Figure 11.0 Validation of GWP map with Open wells

VI. CONCLUSIONS

The present study attempts to demarcate groundwater potential zones of the Sarada Gedda sub watershed of Srikakulam District, Andhra Pradesh using Remote Sensing and GIS techniques. The thematic layers such as Land use/ Land cover, Geomorphology, Geology, Soil, Drainage Density, Lineament Density, Lineament Frequency and Lineament Intersections were integrated with one another through weighted index overlay analysis and finally output map of groundwater potential zones was generated. The groundwater potential zones map generated is delineated into three different zones such as good, moderate and poor. The final output map of the present study is validated with groundwater levels data of the open wells.

REFERENCES

[1] Strzepek K., Boehlert B. 2010: Competition for water for the food system, Phil. Trans. R. Soc. B; 365 (1554), pp. 2927– 40.

[2] http://ga.water.usgs.gov/edu/waterdistribution.html USGS – "Earth's water distribution".

[3] Biswas Arkoprovo., Jana Adarsa and Sharma Shashi Prakash, 2012: Delineation of Groundwater Potential Zones using Satellite Remote Sensing and Geographic Information System Techniques: A Case study from Ganjam district, Orissa, India, Research Journal of Recent Science, Vol.1, No.9Vo, pp.59-66.

[4] Srivastav P. and Bhattacharya A.K. 2000: Delineation of groundwater potential zones in hard rock terrain of Bargarh District, Orissa using IRS, Journal of India. Society Remote Sensensing, Vol.28,(2-3), pp.129–140.

[5] Manimaran D. 2012: Groundwater geochemistry study using GIS in and around Vallanadu Hills, Tamilnadu, India, Research Journal of Recent Science, Vol.1, No.6, Pp.32–37.

[6] Bobba A.G., Bukata R.P., and Jerome J.H.1992: Digitally processed satellite data as a tool in detecting potential groundwater flow systems, Journal of Hydrology. 131(1-4), pp.25-62.

[7] Meijerink A.M.J. 2000: Groundwater in G.A. Schultz & E.T. Engman (Eds), Remote sensing in hydrology and water management, Berlin: Springer, pp. 305-325.

[8] Fransworth R.K., Barret E.C., & Dhanju M.S.1984: Application of Remote Sensing to Hydrology including Groundwater. Paris: UNESCO.

[9] Waters P., Greenbaum P., Smart L and Osmaston H.1990: Applications of Remote Sensing to groundwater hydrology, Remote Sensing Review, 4, pp. 223-264.

[10] Engman E.t., and Gurney R.J. 1991: Remote Sensing in Hydrology, London: Chapman and Hall.

[11] Shahid S. and Nath S.K. 1999: GIS integration of remote sensing and electrical sounding data for hydrogeological exploration, Journal of Spatial Hydrology, Vol.2, No.1, pp 1-12.

[12] Krishnamurthy J. and Srinivas G. 1996: Demarcation of geological and geomorphological features of parts of Dharwar Craron, Karnataka, using IRS LISS-II data, International Journal of Remote sensing, 17(16), pp.3271-3288.
[13] Krishnamurthy J., Kumar N.V., 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, Vol.17, pp1867-1885.
[14] Saraf K. and Choudhary P.R. 1998: Integrated Remote Sensing and GIS for Groundwater Exploration and Identification of Artificial Recharge Sites, International Journal of Remote Sensing, Vol 19, No. 10, pp 1825-1841.
[15] Vijit H. 2007: Groundwater potential in the hard rock terrain of Western Ghats – a case study from Kottayam district, Kerala using Resourcesat (IRS-P6) data and GIS techniques, Journal of the Indian Society of Remote Sensing, 35(2), pp.171-179.
[16] Binay Kumar and Uday Kumar. 2010: Integrated approach using RS and GIS techniques for mapping of ground water prospects in Lower Sanjai Watershed, Jharkhand, International Journal of Geomatics and Geosciences, Volume 1, No 3, pp 587-598.
[17] Jwan Al-doski, Shattri B. Mansor and Helmi Zulhaidi Mohd Shafri 2013: Change Detection Process and Techniques, Civil and Environmental Research, Vol.3, No.10, pp 37-45.
[18] Cheng Y., Nie J., Li G., Zhang C. & Wang W. 2008: Study on Land use and Land Cover Change with the Integration of RS, GIS and GPS Technologies-The Case of Baotou City in the Ecotone of Agriculture- Animal Husbandry, China, Geoscience and Remote Sensing Symposium, IGARSS, IEEE, International IEEE, pp. 4.
[19] Jaiswal R.K., Saxena R. & Mukherjee S. 1999: Application of remote sensing technology for land use/land cover change analysis, Journal of the Indian Society of Remote Sensing, Vol. 27, No. 2, pp. 123-128.
[20] Kavitha Mayilvaganan M, Mohana P and Naidu K.B. 2011: Delineating groundwater potential zones in Thurinjapuram watershed using geospatial techniques, Indian Journal of Science and Technology, Vol. 4 No. 11 pp.1470-76.
[21] Dr. Md .Babar. 2005: Hydrogeomorphology fundamentals applications and techniques, New India Publishing Agency.
[22] Krishnamurthy J., Venkatesa K N., Jayaraman V. and Manivel M. 1996: An approach to demarcate ground water potential zones through remote sensing and a geographical information system, International Journal of Remote Sensing, Vol.7, No.10, pp.1867-1884.
[23] Etishree Agarwal., Rajat Agarwal., Garg R. D and Garg P. K. Delineation of Groundwater Potential Zone: An AHP/ANP approach.
[24] http://shodhganga.inflibnet.ac.in/bitstream/10603/10098/12/12_chapter%207.pdf
[25] Suganthi S, Elango L and Subramanian S.K. 2013: Groundwater potential zonation by Remote Sensing and GIS techniques and its relation to the Groundwater level in the Coastal part of the Arani and Koratalai River Basin, Southern India, Earth Sciences Research Journal, Vol. 17, No. 2, pp.87 – 95.
[26] O'Leary D. W., Friedman J. D. and Pohn H. A.1976: Lineament, linear, lineation: Some proposed new standards for old terms, Geological Society America Bulletin, Vol.87, pp.1463-1469.
[27] Amina Kassou, Ali Essahlaoui and Mohamed Aissa. 2012: Extraction of Structural Lineaments from Satellite Images Landsat 7 ETM+ of Tighza Mining District (Central Morocco), Research Journal of Earth Sciences, Vol. 4, No.2, pp.44-48.
[28] [28]http://shodhganga.inflibnet.ac.in/bitstream/10603/9 493/12/ 12_chapter%204.pdf
[29] Sajikumar N., Gigo Pulikkottil. 2013: Integrated Remote Sensing and GIS Approach for Groundwater Exploration using Analytic Hierarchy Process (AHP) Technique, International Journal of Innovative Research in Science, Engineering and Technology, Volume 2, Special Issue 1, pp.66-74.