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Groundwater Potential Zonation of Delampady Grama Panchayath, Kasaragod, Northern Kerala: A Geophysical and GIS Approach

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Abstract: Existence of life on the Earth depends on the water, the elixir of life. To ensure the right quantity of water in right quality, exploration of available resources and mapping of the same is very essential. Delampady Grama Panchayath of Kasaragod District, Northern Kerala, located between longitudes 75° 09' 55" to 75° 19' 45" E and latitudes 12° 30' 13" to 12° 37' 02" N is a region where summer monsoon is highest in Kasaragod district but, the Panchayath is measured as one of the area in the district where groundwater obtainability is less. In the Panchayath, a number of places where scarcity for drinking water has been stated. Here, an effort has been made to identify and demarcate the ground water potential zones using electrical resistivity method and geospatial tools which are proven methods by many hydro-geologists. Pre and post monsoon water table fluctuation from 15 open wells, vertical electrical sounding at nearby 12 locations, surface flow accumulation and land form analysis has been done to achieve the goal. The assessment resulted in identification and categorization of groundwater potential zones as high, moderate and low limited. This demarcation of groundwater potential zones will help in planning sustainable water resource development and management strategies for the region.
Keywords: Ground water potential zonation, VES, Geospatial tools, Delampady Grama Panchayath

I. INTRODUCTION

Water is a prime natural resource, a basic human need and a precious national asset. It is one of the valuable natural resources that determine the health of a human being in an area (K. Ibrahim Bathis and S.A Ahmed, 2016).The planning and management of water resource and its optimal, economical and equitable use are important and urgent. The available quantity is limited, but the demand on water keeps on increasing with increase in population and to produce more food, and other needed products. The rate of depletion of aquifer storage due to over exploitation and deterioration of water quality due to uncontrolled anthropogenic activities is of immediate concern in major cities and towns of the country (Khurshid et al., 1997; Sohani et al., 2001; Meenakumari and Hosmani, 2003; Dhindsa et al., 2004; Ramasubrahmanian et al., 2004; Subrahmanian, 2000; Singh et al., 2011). This has resulted in the improvement of techniques for investigating the occurrence and movement of ground water. Over past few decades, access to drinking water in India has increased (Singh et al., 2013). Occurrence and distribution of groundwater is closely related with the climate, regional setting, lithology, geomorphology, fractures in hard rocks, structural features and land use type (Edet et al., 1998; Greenbaun, 1992; Jaturon et al., 2014; Kumar et al., 2007; Saud, 2010; Senthil Kumar and Shankar, 2014). Better understanding of the groundwater occurrence and its movement can be achieved only by integrating different existing remote sensing and field studies of geological and geophysical explorations.

Remote Sensing and Geographic Information System provides a better platform to analyze the spatial variations in the above mentioned parameters which are dependent of groundwater occurrence. With the ease of availability of data and its processing in GIS environment for meeting the target of groundwater potential zonation with considerable accuracy led many of hydro-geologists to turn and depend on geospatial technology (Gumma and Pavelic, 2013; Murthy, 2000; Rashid et al., 2011; Senthil Kumar and Shankar, 2014). Advantages of spatial, spectral and temporal availability and manipulation of Earth surface and subsurface data covering vast and inaccessible areas within a short time have a great potentiality in groundwater hydrology for accessing, monitoring and groundwater resources (Dar et al., 2010). Integration of different layers were tried by many researchers such as drainage pattern, geomorphology, soil, lineament (Preeja et al., 2011; Rassam et al., 2008; Saraf and Choudhary, 1998, K. Ibrahim Bathis and S.A Ahmed, 2016), soil texture and rainfall intensity (Magesh et al., 2012), resistivity, aquifer thickness, or fault maps (Senthil Kumar and Shankar, 2014) for better understanding of hydrological and hydrogeological conditions of the area.

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The use of geophysics for groundwater exploration and water quality evaluations has increased over the last few years due to the rapid advances in computer software and associated numerical modeling solutions (S I Fadele et al., 2013). Of all non-intrusive surface geophysical methods, the electrical resistivity profiling and vertical electrical sounding (VES) methods has been applied most widely to detect the occurrence of groundwater (S I Fadele et al., 2013; C V Gopalan., 2011; Mohammed aslam et al., 2010) with proven efficiency. These authors suggested that resistivity of rock formation gives an indication of ground water occurrence with an established inverse relationship.

Use of geospatial technologies with geospatial data and or with geophysical a data was attempted by many researchers in different combinations to unravel the mystery behind the occurrence of groundwater. Here in the current study, an attempt is made to detect, evaluate and demarcate the groundwater potential zones in the Delampady Grama Panchayath by integrating Vertical Electrical Sounding carried out in 12 selected locations of the Panchayath with remote sensing and GIS techniques. In addition to this water level fluctuations during pre-monsoon and post-monsoon were also taken into account as they are representatives of real field picture.

II. GEOLOGY AND HYDROLOGY OF THE AREA

The study area is Delampady Grama Panchayath of Kasaragod District, Northern Kerala and located between longitudes 75° 09' 55" to 75° 19' 45" E and latitudes 12° 30' 13" to 12° 37' 02" N. The Panchayath is bounded North West by Karadka and south by Kuttikole and Bedaduka Panchayaths and North East side is bordered with Karnataka State (Fig.1). Topographically the Panchayath is exhibiting highly undulating terrain with a maximum elevation of 361 m located at Eastern border of the Panchayath and minimum elevation is 19.36 m located at south western margin of the study area. The general relief of the area is 341.98 m whereas the general slope of the study area is towards South West (Fig.2). Total area of the study under consideration is 79.56 square kilometers in which 29.73 Sq. Km. of the Panchayath is covered under reserved forest and plantation.

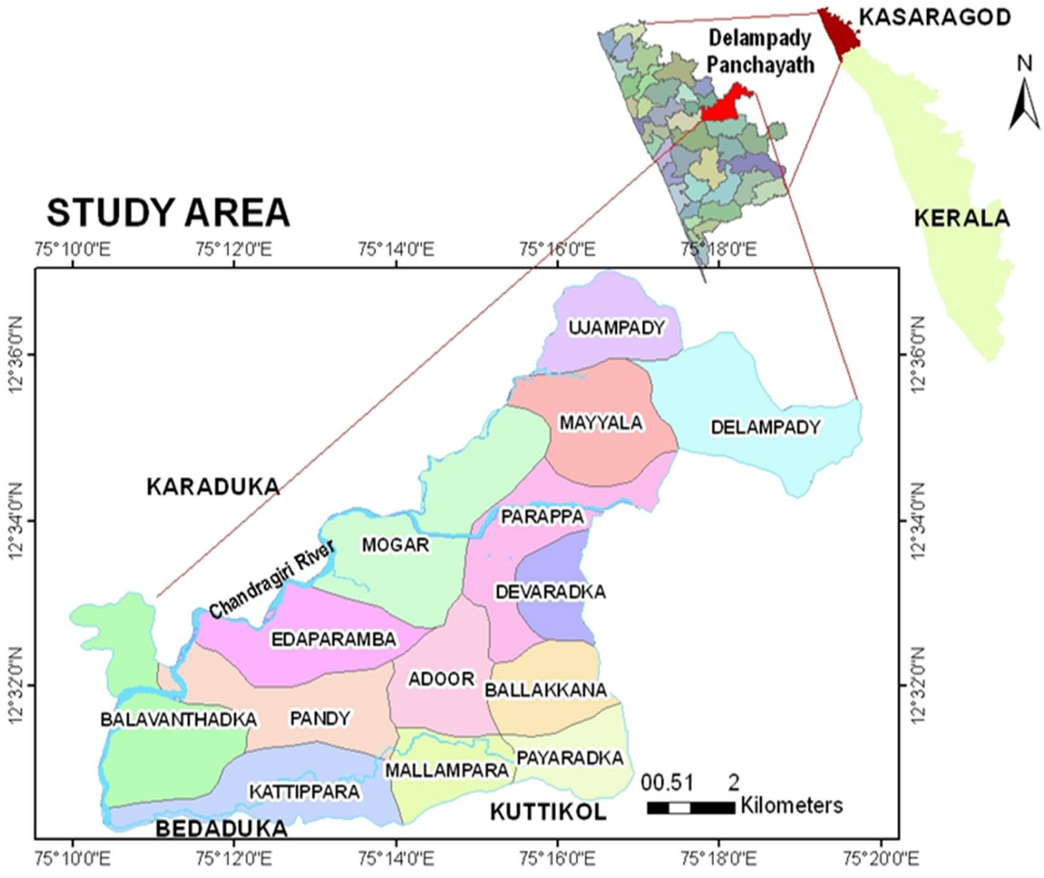

Fig.1 Showing study area under consideration.

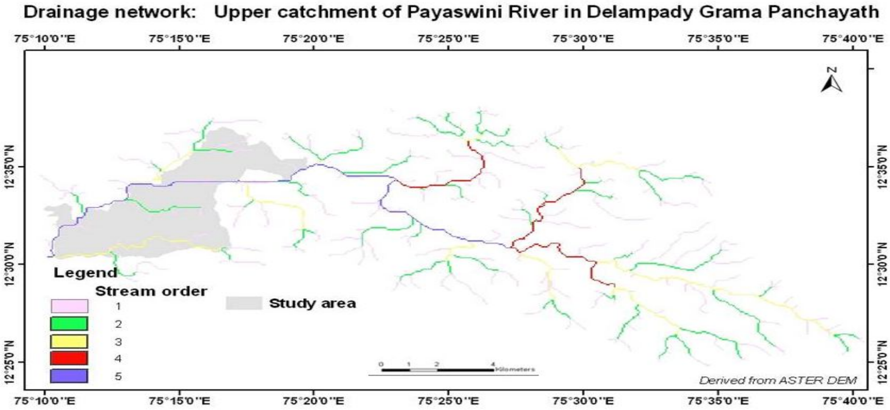

Fig. 2 showing drainage network from upper regime up to western end of the study area

The river Payaswini which originates from Koorgh hills passes through Delampady Panchayath and number of streams from various regions adjoins this river. This is the region where summer monsoon is highest in Kasaragod district but considered as one of the area in the district where ground water availability is less. In the Panchayath, number of places where scarcity for drinking water has been reported.

Physiographically, Delampady Panchayath can be classified into hills, slope and plains. The region Katikaje to west of Pandi of Adoor village slopes towards North whereas Delampadi, Chamakochi and Nerody area slopes towards southern side. The entire area is falls under midlands of Kerala and can be sub-divided into four regions as Hilly regions, Valley regions, River sides and Plains.

Ballakana, Mallampara, Puliparamba, Nachipaduppu, Pandy, Mayyala and Parappa are hilly regions. Major part of this region is covered by reserved forest. Katukaje, Mandebettu, Balangaya, Ballakana, and Mayyala are the valley portions. These regions are suitable for agriculture. Cashew, rubber etc., are the main crops. Arecanut and coconut are also cultivated based on the availability of water. Within the limits of the Panchayath, the two sides of the Payaswini River, 15 km, make the river side. This area is very fertile and extends from Mudoor in the eastern side to Kadumane in the western side. Paddy and arecanut are the main crops in this region. Plain regions include Adoor, Kurnoor, Thalpacheri, Periyadka, Katippara and Mudoor which are suitable for paddy cultivation. A major part of the region in Panchayath is covered with a lateritic top layer. Lateritization can be seen up to a depth of 4 to 5 meters, sometimes up to 15 meters along the slope of hilly regions.

Among the Precambrian crystalline rocks in the area, Charnockite covers major part of the area followed by Granite Gneiss, Biotite-Hornblende Gneiss, Hornblende- Biotite Gneiss, Quartzite and Garnetiferous Biotite. All litho units show a general E-W trend in their alignment (Fig.3). The similar alignment can be observed in the geomorphic units i.e. denudational hill, structural hill etc., (Fig.4).

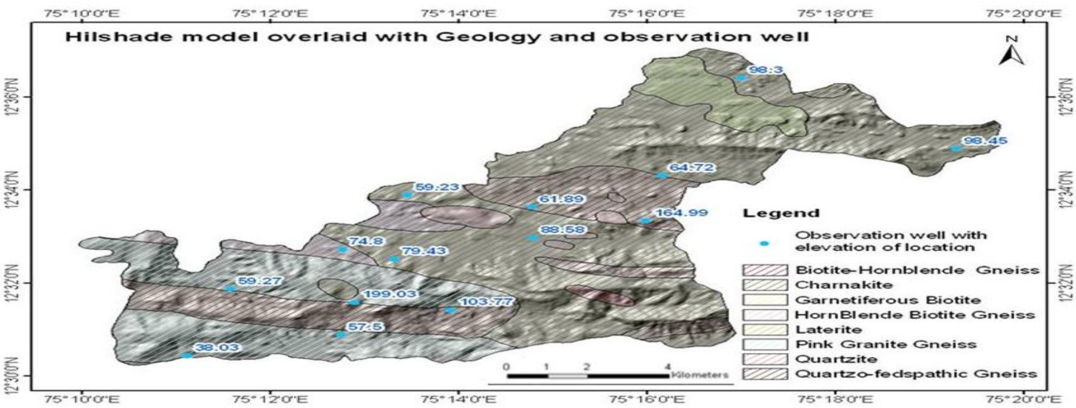

Fig. 3 General trend of litho-units of the area overlaid with hill shade. Sky-blue coloured points represent the locations of observation wells with elevation of the location.

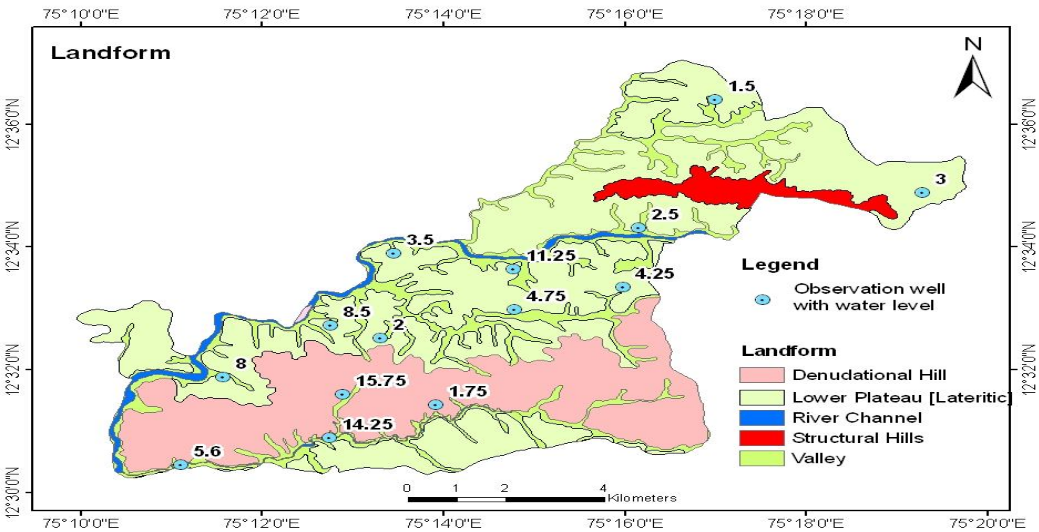

Fig. 4: Figure showing different major geomorphic units with locations of observation wells and depth to water level (in meters) during post monsoon.

III. MATERIALS AND METHODS

Extensive field study has been carried out to evaluate the groundwater conditions of the study area. Fourteen observation wells almost uniformly located over the study area have been selected to monitor the groundwater levels. Observation well location and location for Vertical electrical Sounding (VES) were selected by considering geology and landforms of the study area. Observation well locations represent various lithological units as well as geomorphic units. Detailed well log information was also recorded from observation open wells. Water levels of pre-monsoon and post-monsoon were measured and fluctuations of the water level are found to prepare the water table maps with ASTER DEM by interpolating the same in GIS environment for analysis.

Locations for the Vertical Electrical Sounding have been selected nearer to the locations of observation wells in order to correlate well litho-log data and electrical resistivity as well as thickness of various layers. The principal instrument used for the survey is Aquameter CRM 500, a geo-electrical resistivity apparatus made by Anvic systems, Pune, India. The electrode configuration used for the geo-electrical sounding is Schlumberger array. In the Schlumberger electrode configuration the potential electrodes are kept close to each other and away from the current electrodes, with the distance between the potential electrodes (a) being generally kept less than 0.2 L (L- Distance between current electrodes.) The expression for apparent resistivity for this configuration can be written as

$$\rho a = \pi/4 \frac{(L^2 - a^2)}{a} \frac{V}{I}$$

Where, ρa= apparent resistivity; L= Distance between current electrodes; a= Distance between potential electrodes; V= Potential difference measured; I= Current applied. The apparent resistivity, ρ_a, values were plotted against the electrode spacing (1/2L) on a log-log scale to obtain the VES sounding curves using an appropriate computer software, IPI2win in the present study.

To perform groundwater potential zonation, resistivity value of each layer is processed using IPI2. Point spatial data layer was created with resistivity and thickness of different layers as attribute data. Interpolation of the data was carried out using Toporaster tool for spatial analysis in ArcMap. Interpolated raster data were then reclassified as Resistivity <200 - 1, 200 - 400 2 and >400 as 3. Similarly, geomorphology layer was also reclassified as Valley - 1, River channel and islands -1, lower plateau - 2 and structural hill and denudational hills -3 and converted to a raster layer. Reclassified rasters are added using math tool for spatial analysis. Resultant layer pixel values are classified as <6 - High potential, 6 - 8 Moderate potential and >8 Low potentials. Well, location with pre-monsoon groundwater levels (Lower water level of a year) overlaid on the map. Since there are no significant lineaments in the study area, lineaments were not given weightage. The entire area is covered with thick laterite cap. Even though basement lithology are different, laterite act as a major aquifer in the study area and so Geology has given equal weightage.

IV. RESULTS AND DISCUSSION

A. Water Table Maps

Water table layer data is generated by subtracting water level data from topographic elevation of the observation well. Pre-monsoon and post-monsoon water table layers have been generated by interpolating water table data from observation wells. Pre-monsoon and post-monsoon water table layers are shown in Figure 5 & 6

Water table data indicates that Pandi bayal area records the highest water table and water table is 183.18 mamsl. Bellerikaje records the lowest water table value that is 40.3 m. On comparison of water table data with the topography of the area it is clear that the regions of higher altitude show a deeper water table. In case of lower altitude areas Water table is shallow.

B. Water table: Post Monsoon

Water table of post monsoonal period shows a very slight increase in the water table at Pandi Bayal, the area with higher depth to water table. But in the case of Bellerikaje, the area of shallow depth to water table shows an increase of about 3 m. It is clear that, there is no much difference in the other characteristics in this map from the sequence shown by the water table map for the pre-monsoonal period. These slight and marked increases at different locations are representative of the water potential in the region. Higher fluctuations stand for good hydrogeological conditions prevailing in the region (seasonal recharge and discharge).

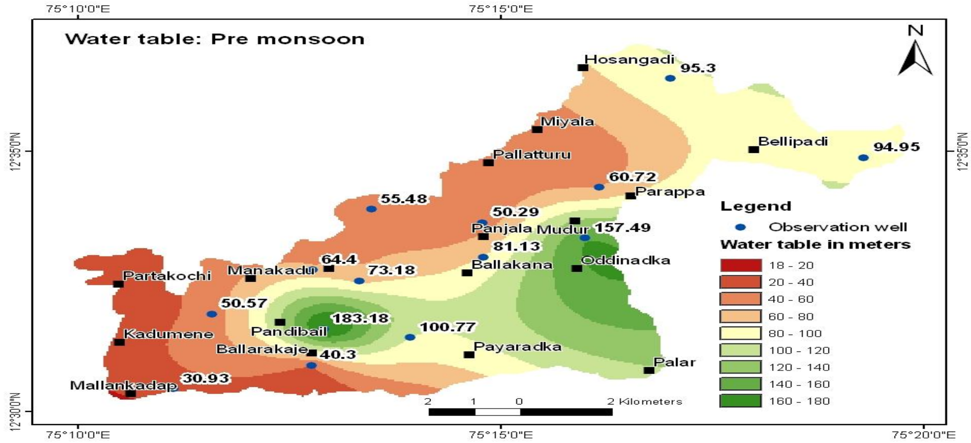

Fig. 5 Pre-monsoon water table interpolated. Blue dot represents the spots of observation wells with water table in meters.

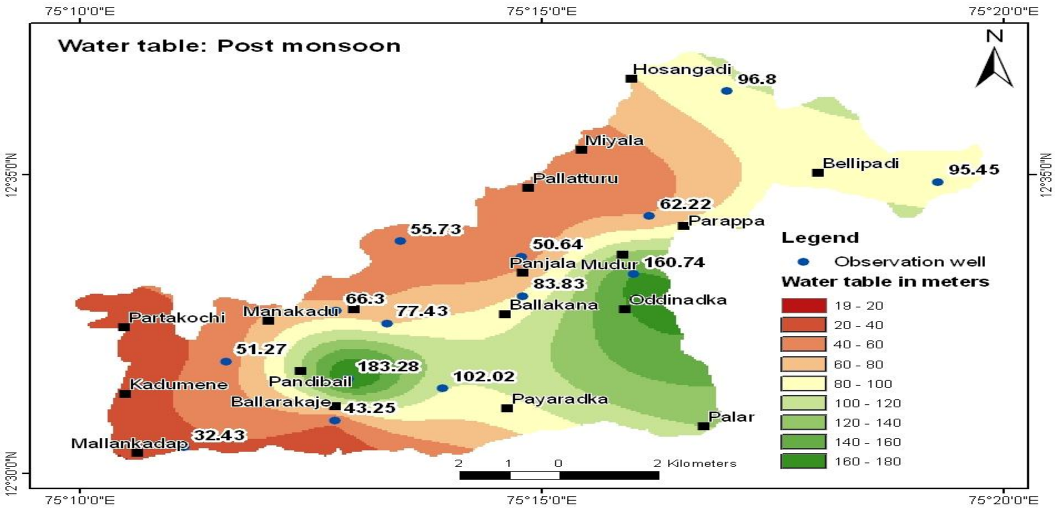

Figure 6 Post-monsoon water table interpolated.

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C. Interpretation of VES data

The expression subsurface formations were interpreted using IPI2win software to understand the subsurface geology and their role in groundwater occurrence. Processing of the VES data resulted in different number of layers at each location. Three layer types include H-type ($\rho_1>\rho_2<\rho_3$) and K-type ($\rho_1<\rho_2>\rho_3$). AK-type ($\rho_1<\rho_2<\rho_3>\rho_4$), KH-type ($\rho_1<\rho_2>\rho_3<\rho_4$) and QH-type ($\rho_1>\rho_2>\rho_3<\rho_4$) are the results found in four layer types. One two layer case is also identified. The results of the interpreted VES curves are given in the table 1.

Table 1 Results of the interpreted VES curves.

RESULTS OF THE INTERPRETED VES CURVES					
VES Station	Thickness (m)	Layer resistivity (Ωm)	Remarks	Curve type	No of Layers
Theerthakkara	1.78	722	TP	QH	4
	25.4	221	WB		
	47.8	73.4	PWB		
		24102	FB		
Bellerikaja	5.34	985	TP	H	3
	40.8	275	WB		
		767	FB		
Kottumba	0.75	1369	TP	AK	4
	7.17	890	WB		
	22.1	221	PWB		
		775	FB		
Maniyoor	0.75	1592	TP	KH	4
	7.16	423	WB		
	68		PWB		
		39583	FB		
Balavanthadka	0.75	816	TP	KH	4
	7.21	1699	WB		
	22.1	697	PWB		
		1195	FB		
Jediyar	2.1	281	TP	K	3
	38.9	1460	WB		
		3.25	CZ		
Mayyala	19.9	329	TP		2
		2781	FB		
Parappa	1.11	873	TP	KH	4
	3.67	2818	CZ		
	7.56	255	WB		
		1301	FB		
Bellippadi	0.799	533	TP	KH	4
	6.68	904	DZ		
	26	446	WB		
		8527	FB		
Mundekkadu	3.25	425	TP	KH	4
	7.22	1988	DZ		
	19.7	274	WB		
		15110	FB		
Adoor	3.45	575	TP	H	3
	23.3	108	WB		
		828	FB		
Pandi bayal	0.75	2552	DS	KH	4
	7.86	3549	HL		
	75.2	312	CZ		
		24465	FB		

The modeling of the VES measurements carried out at twelve (12) stations has been used to derive the geo-electric sections for the various profiles. Sections show that there are mostly three and four geologic layers beneath each VES station and one VES station gives two layers geologic information also. The top layer is unconsolidated lateritic soil and in some regions hard laterite. This top layer is followed by lithomargic clay with varying thickness in different places. The third layer is partly weathered basement and the fourth, the fresh basement.

First layer resistivity values ranges from 2552 Ω m to 281 Ω m and thickness from 19.9 m to 0.75m (refer fig. 7A and B). It is however observed that locations 6 and 7 shows lower resistivity values varying between 281 Ω m to 329 Ω m suggesting the moisture content in the top soils. The very high resistivity value observed at location 12 followed by 3 with thickness of only 0.75 m suggests chances for the presence of a hard boulder.

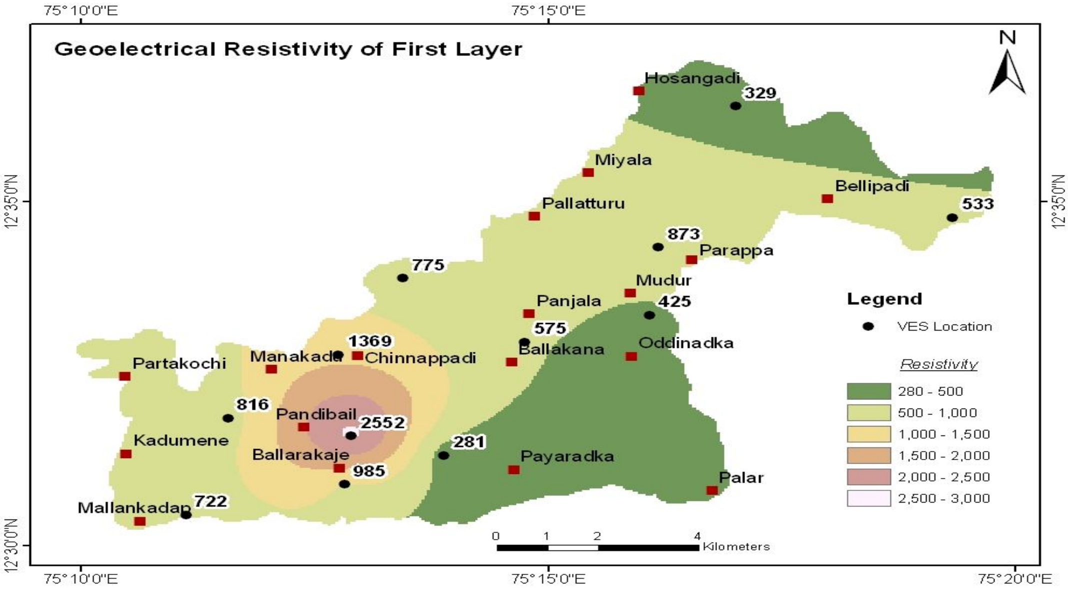

Figure 7A. First layer resistivity distribution in the study area

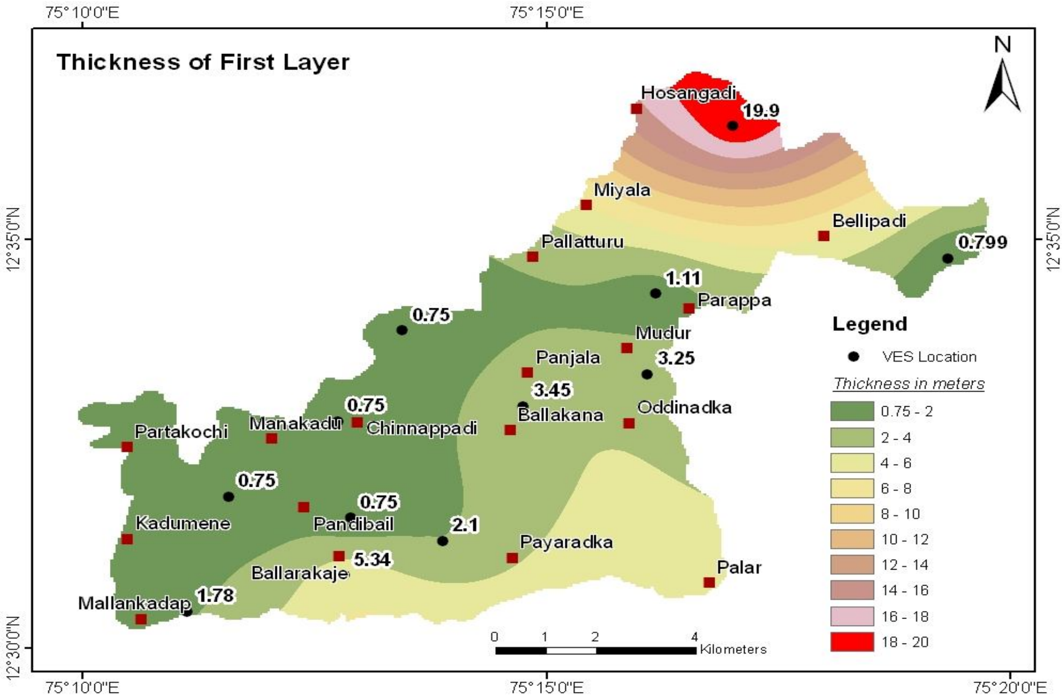

Figure 7B. First layer thickness distribution in the study area

The second layer is lithomargic clay in some regions and in others, it is weathered basement with resistivity and thickness values varying between 3549 Ω m to 108 Ω m and 36.8 m to 2.55 m respectively (Refer Fig. 8A and B). In the second layers, higher resistivity values ranges from 3549 Ω m to 890 Ω m in locations 3, 4, 5, 6, 8, 9, 10 and 12. This is due to unconsolidated soil without moisture (zone of aeration) at locations 3, 4, 5, 8, 9, 10 and at location 6, it is due to the partly weathered basement and at 12 it is by hard laterite. Locations 1, 2 and 11 shows lower resistivity values with considerable thicknesses of 23.6 m, 35.5 m and 19.8 m respectively.

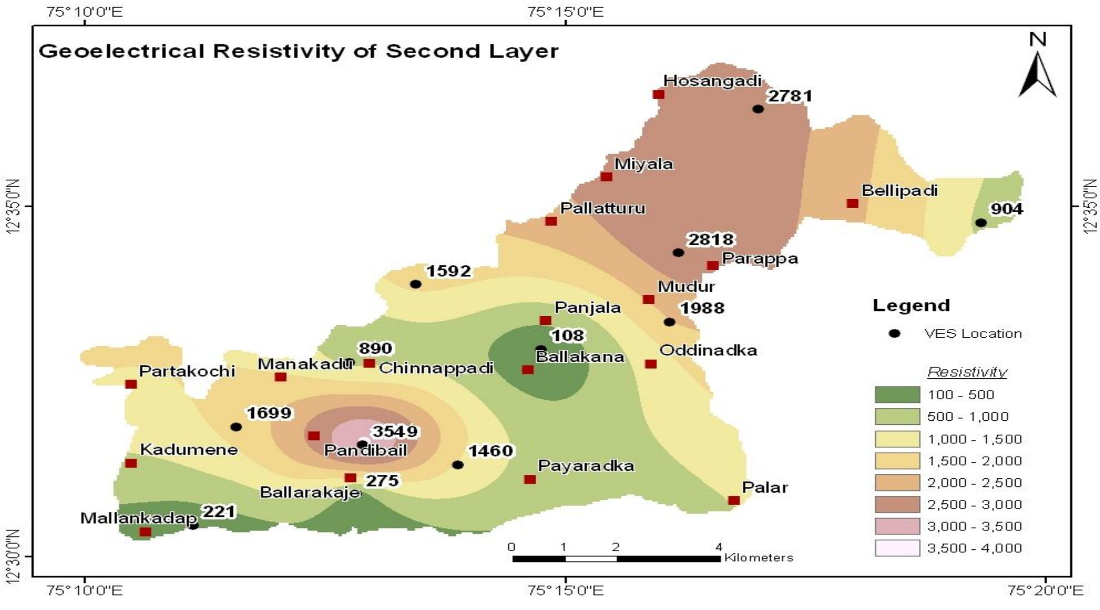

Figure 8A. Second layer resistivity distribution in the study area

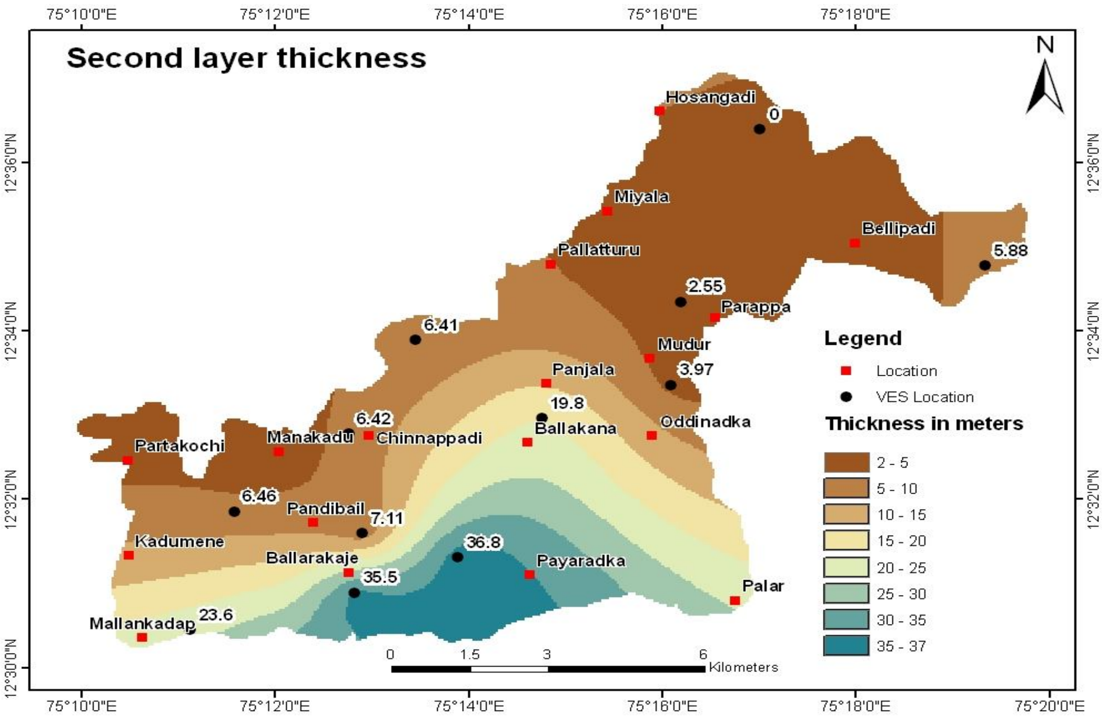

Figure 8B. Second layer thickness distribution in the study area.

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The third layer includes partly weathered/fracture basement with resistivity and thickness values varying between 697 Ω m to 73.5 Ω m and 3.9 m to 67.4 m respectively (Fig. 9A and B). The layer is extensive and thickest at VES station 12 and thinnest at location 8. Locations 1, 3, 4, 9, 10 and 12 shows lower resistivity values with considerable thickness suggesting the presence of fractured hard rock. The fourth layer is presumably fresh basement with range of resistivity values from 39583 Ω m to 1301 Ω m and with infinite depth.

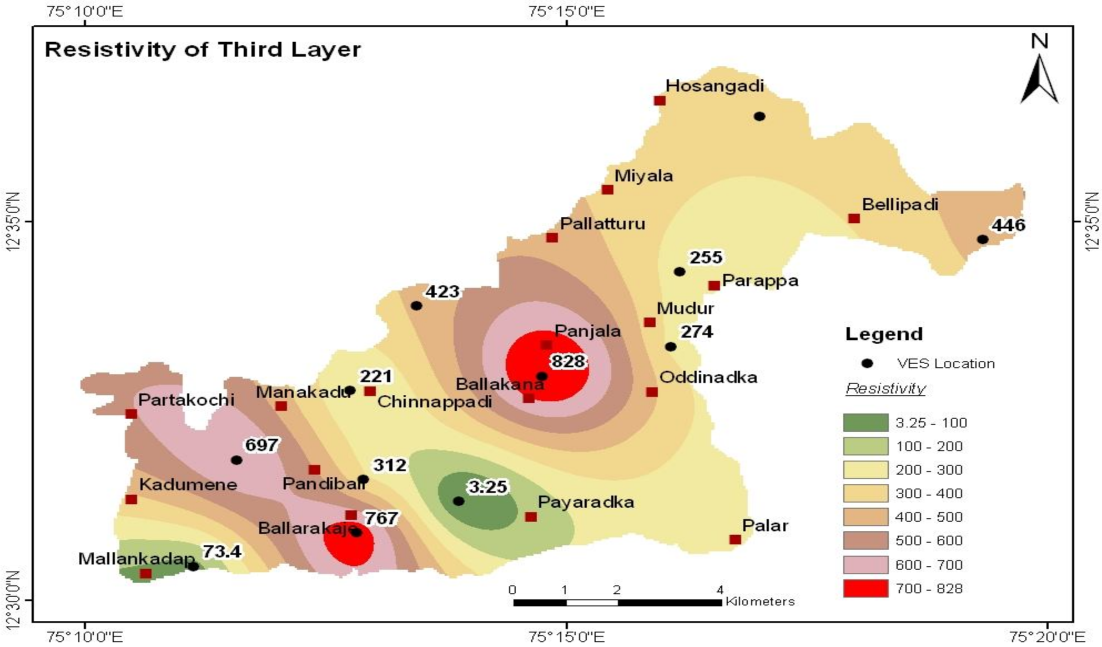

Figure 9A. Third layer resistivity distribution in the study area

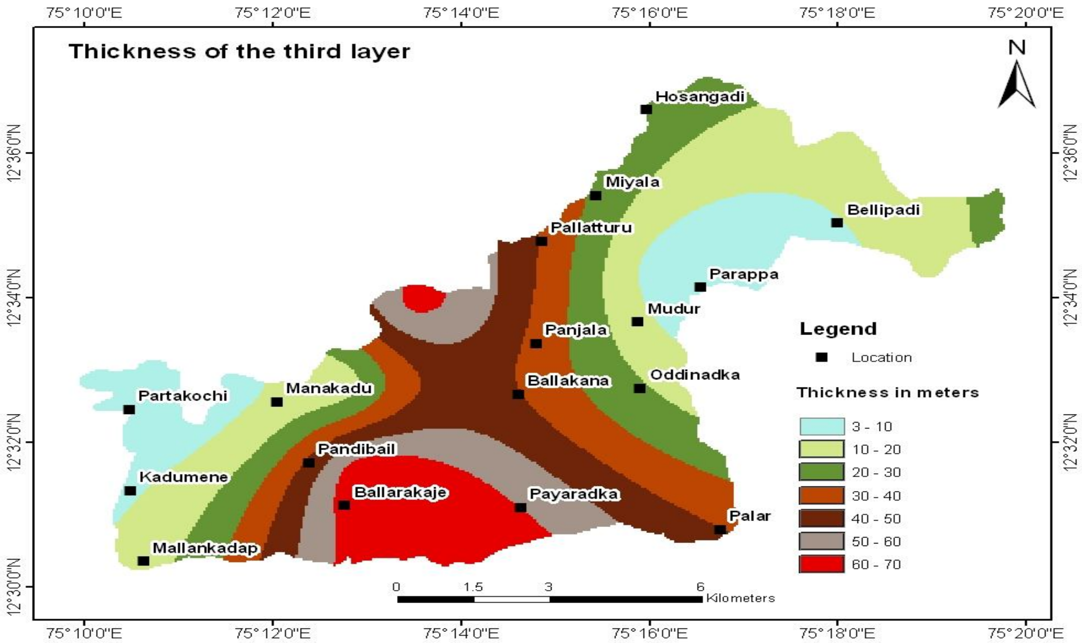

Figure 9B. Third layer thickness distribution in the study area.

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D. Ground Water Potential Zonation

Ground water potential zonation has been carried out by considering geomorphology, water table and second or third layer low resistivity with considerable thickness. Groundwater potential zonation has been made based on landforms, lithology, resistivity of geological formations and water level fluctuations. Three zones have been identified and demarcated as high, moderate and low limited. High potential zones are confined to River channel, valley fills and portions of lower plateau area and Moderate zones confined to lower plateau and parts of denudational hill region. Limited potential zones have been delineated along denudational hill area and structural hills are considered as barren zone. Water level of pre-monsoon overlaid on the same potential map clears that, at good and moderate potential zones, depth to water level is considerably low when compared with the low limited portions (Figure 9). In order to meet the present and future needs of water, groundwater potential zonation plays key role using which systematic water development strategies can be planned. This digital database will help the planners in the local government body to effectively plan the water development and management strategies by meeting the needs of different people such of irrigation facilities, domestic usages etc. As the area is more dependent on groundwater and even local self-government run projects are also tapping the deeper aquifers through bore wells to meet the domestic needs of the people, over exploitation of the groundwater is at its peak.

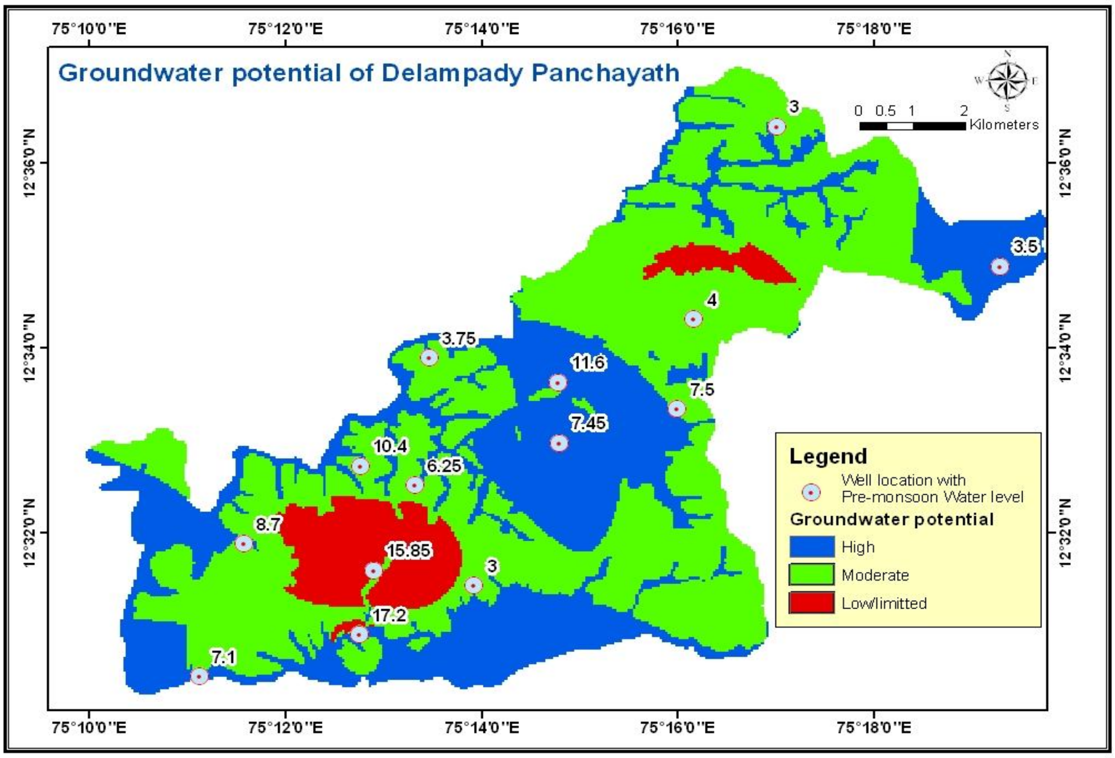

Figure 10. Groundwater potential zones in the study area.

V. CONCLUSIONS

Groundwater potential zones which is essential to have any watershed development and management plan is prepared by integrating geophysical data with remote sensing data in GIS environment. This attempt has resulted in good result which matches with the depth to water level of the data and other field observations made. High moderate and low limited zones are identified and demarcated where moderate class dominates in the area. Even though author depended on primary water level data as study area is small, there are secondary water level data available which can be used for regional scale studies provided VES data is made available either from secondary or primary sources. This attempt will help for the better understanding of the hydrogeological conditions of the terrain for focusing on fine resolution studies to come up with water management strategies for watershed development.

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