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GEOELECTRICAL INVESTIGATION FOR GROUNDWATER EXPLORATION: A CASE STUDY FROM RAMANAGARA TALUK, KARNATAKA, INDIA

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ABSTRACT

The role of Electrical Resistivity Method for groundwater exploration is vital, which provides lot of information on hidden subsurface hydro-geological conditions accurately. This non-invasive method designed for estimation of dynamic and static ground water reserves as well as to infer depth and thickness of various subsurface layers. Vertical Electrical Sounding (VES) were conducted in selected zones of Ramanagar taluk, Karnataka using the Schlumberger array configuration for identifying subsurface lithology favourable for occurrence of groundwater. VES data were collected and interpreted using conventional curve matching and computer iteration method. The geoelectric sections revealed top soil, weathered rock, fractured bedrock and fresh bedrock. The value for topsoil ranges from 20Ωm to 250Ωm with thickness varies from 0.3m to 2.0m. The second layer is weathered rock and resistivity ranges from 50Ωm to 100Ωm and thickness of 1.0 m to 10.0m. The third favourable layer is fractured basement which ranges in value from 100Ωm to 150Ωm with thickness ranges from 3m to 23m. The fresh or bedrock basement has a resistivity of 1000Ωm to infinity. The saturated zone of the weathered and fractured basement at depth will favour groundwater exploration and development in this area, while the thin layer of soil profile with gentle slope would serve as the protective layer and recharge area in the study area.

KEYWORDS: Groundwater, Vertical Electrical Sounding, Electrical resistivity method, fractures.

INTRODUCTION

Groundwater is gaining its impetus as the available surface water resources are inadequate to meet all the water requirements particularly in rural, semi-urban and urban areas. The consumption of groundwater is increasing day by day because of burgeoning population and is being exploited non-scientifically through indiscriminate drilling of borewells without knowing the status of water bearing aquifers. The occurrence and movement of groundwater especially in fractured crystalline bedrock aquifers in a given area depends immensely on many factors viz., topography, lithology, geological structures, secondary porosity, fracture and its connectivity (Carruthers, 1984).

Geophysical method is helpful to find out the hidden subsurface hydrogeological setting. It is a non-invasive technique which provide indirect information of the subsurface information. This non-destructive and sensitive tool has been applied in groundwater exploration (thickness and boundary of an aquifer), determination of soil horizon thickness and bedrock depth, salt water intrusion, mineral investigation, detection of contamination of groundwater, etc.

Among the various geophysical methods (Electrical methods. Seismic methods. Magnetic methods. Gravity methods and Radiometric methods) of groundwater investigation, the Electrical Resistivity Method is a powerful technique which has been widely applied for groundwater exploration (Roy and Apparao, 1971; Todd, 1980; Olorunfemi et al., 1999; Zhdanov and Keller, 1994; Singh et al., 2002; Murali, and Patangay, 2006; Ariyo, 2007; Selvam et al., 2010; Yousef Ali et al., 2015; Jeyavel Raja Kumar et. al., 2016). Fractures are important in engineering, geotechnical, hydrogeological and environmental practice because they provide pathways for fluid flow and are the path ways dispersion of contaminants. The rocks are heterogeneities in nature and can produce significant pseudo-anisotropy effect. Hence, azimuthal resistivity survey is a modified resistivity ER along four different azimuths about a common center provides variation in resistivity along particular direction. These apparentresistivities are plotted as function of azimuth in radial coordinates to produce polygons of anisotropy for each depth of investigation. Different authors have shown the usefulness of Azimuthal Resistivity Survey (ARS) in determining the principal direction of electrical Anisotropy (Malliket al.1983; Busby, 2000; Odoh, 2010; Roy et al., 2011; Ajibade, 2012;Ravindran, 2012; Kumar et al., 2014; Asare et al., 2015). In India, especially NGRI (National Geophysical Research Institute, which is a research institution in geosciences under the aegis of the Council of Scientific and Industrial Research, Ministry of Science and Technology, Govt. of India) team have been working for the past 55 years in various geophysical studies and the review article published by Sarma (2014) brings about their contribution.

In Ramanagara taluk of Karnataka, groundwater extracted through deep bore wells is the main source of water supply in most of the rural areas especially in hard rock terrains. This taluk was taken as study area because the inhabitants suffer shortage of water for their daily and agricultural activities due to low yield of the wells. Many borewells are failed or giving very low yield even at deeper depths and reasons for the failure of boreholes is lack of pre drilling scientific investigation (Ganesha et al., 1997). Hence, a systematic and scientific approach to the problem was essential for the study area in order to overcome these problems. This paper reports the vertical electrical sounding resistivity method to decipher potential groundwater zones in the study area.

Study area

Ramanagaram district of Karnataka state lies between the north latitude 12°24' and 13°09' and East longitude 77°06' and 77°34' and the total geographic area is 3576 Sq. Km. The study area belongs to Ramanagara taluk of Ramanagara district bounded by longitude 77°08’23”-77°29’03”E and latitude 12°35’08”-12°52’44” and has 25 Zilla Panchayath and 133 villages. Fig.1 shows the location map of study area. Ramanagara taluk forms a part of semi-arid dry zone of Karnataka and mean annual rainfall is 847 mm mostly from June to September during SW monsoon. Topographically, the area is characterized by a relatively rugged and undulating topography. The soil in the study area comprises red and brown sandy soils with little clay content and profile thickness is about 2-4mts having low permeability.

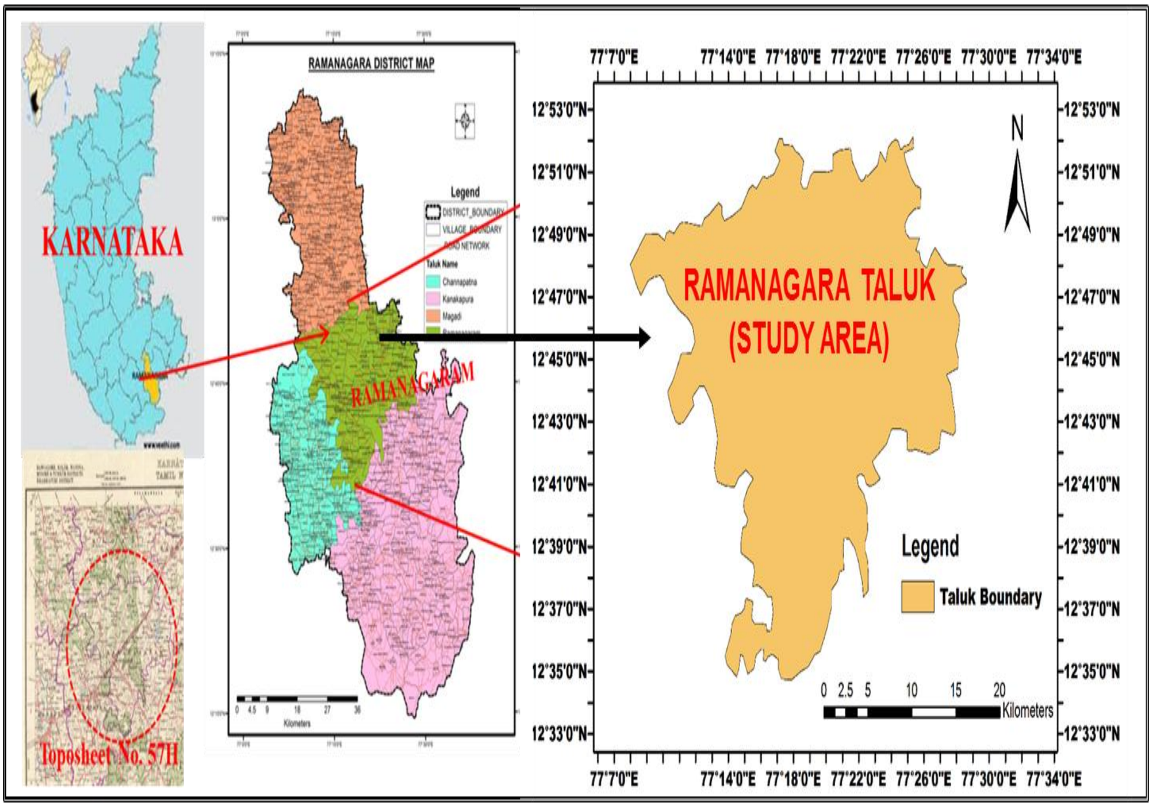

Fig. 1: Location map of the study area.

Geology of the area

The area under investigation comprises basically three types of rock and they are peninsular gneisses, granites and dyke rocks with varied colour and textures. The main rock types in the study area are Peninsular gneisses as country rock and granites. There are three types of intrusives occur in the study area and they are dolerite dykes, closepet granites and quarto-feldspar veins. Among them medium to coarse grained greyish and pinkish closepet granites are the oldest formations trending nearly N-S followed by fine grained black dolerite dykes and with quartzite veins. Other rocks found in this area are enclaves of charnockites as small patches and amphibolite dykes. Structurally, the rocks have undergone fracturing, jointing and shearing and the deep borewells suggests that water bearing aquifers exists in highly fractured zone beyond 200 m bgl. Gneiss and Granitic rocks are more suitable for of groundwater accumulation as they have joints, which measures few cm to meters at ground surface and diminishes in width with depth. Fig.2 shows the geological map of the study area.

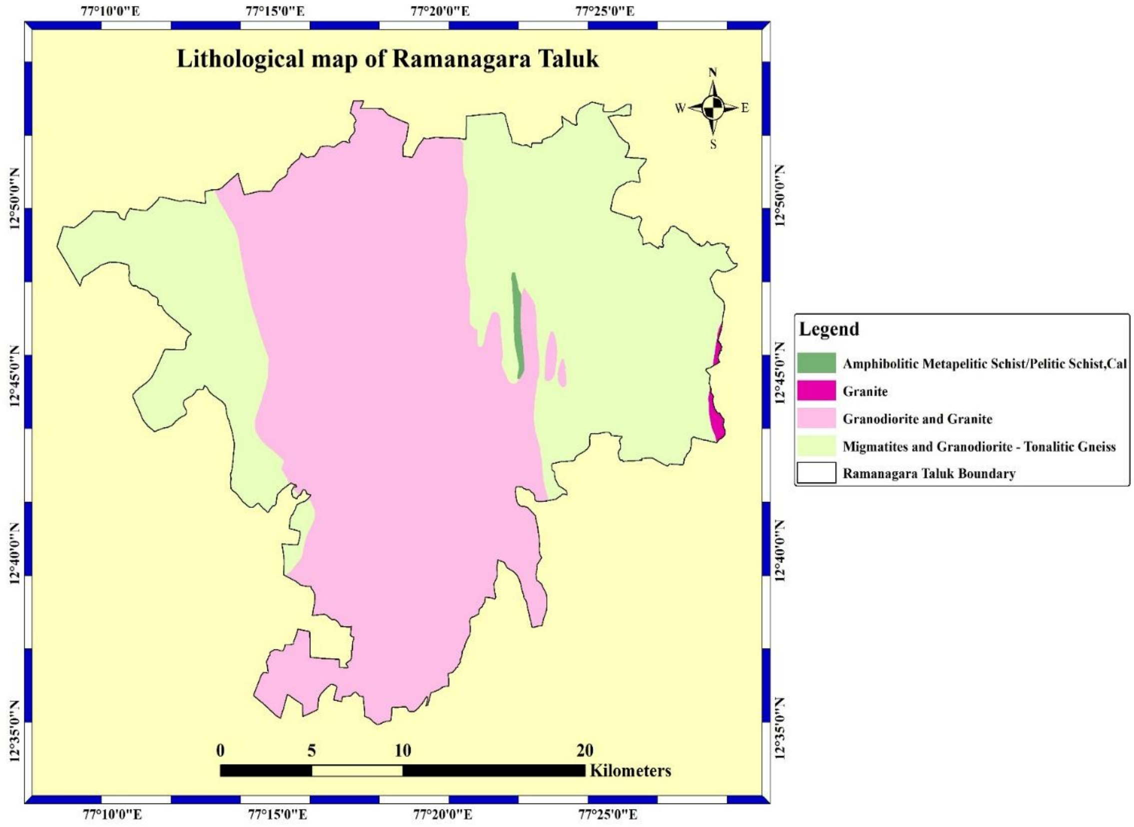

Fig. 2: Geology map of the study area.

MATERIALS AND METHODS

The DC electrical resistivity method is the most suitable method among all the geophysical methods for delineation of aquifer hard-rocks terrains. In electrical resistivity (ER) surveying techniques, a known electrical current is passed through the ground and potential difference (voltage) is measured. Since the current is known, and the potential can be measured, an apparent resistivity can be calculated. The separation between the current electrodes depends on the type of surveying being performed and the required investigation depth.

The Schlumberger method was adopted in the entire field survey as it has a greater penetration than the Wenner method. The array consists of four electrodes arranged along a straight line with outer two being current electrodes and the inner two are potential electrodes. Spacing between the current electrodes is greater than five times the spacing between the potential electrodes.

The data acquisition were done manually using CRM-20 (Computerized Resistivity Meter) in the investigated area. The maximum current electrode spacing (AB/2) used in the area was 150 m. The values of the resistance obtained in the field were multiplied with their respective

Geometric factor (K) which gave the required apparent resistivity results. The required data was plotted on a log-log graph sheet and the resultant curve was quantitatively interpreted using IPI2WIN software. In case of Azimuthal Resistivity Survey (ARS) the current electrode spacing (AB/2) having a maximum spread of 160 m and potential electrode spacing (MN/2) were rotated about a center point at each location and measurement were made along N-S, E-W, NE-SW, and SE-NW directions. VES were performed at selected locations to understand anisotropic behavior of the rocks.

RESULTS AND DISCUSSIONS

Vertical electrical soundings were carried out on selected zones considering geomorphological and hydrogeological inference in the study area. The surveyed locations along with results of VES sounding are given in Table-1. The quantitative and qualitative interpretation of the VES conducted at different locations revealed that the investigated area comprises three to five geoelectric layers. Fig.3 show typical resistivity curves quantitatively interpreted using IPI2WIN software. The field data mainly delineates only 3 layers as top soil / weathered mantle, fractured bed rock and hard and compact bed rocks. However, quantitative representation of data using the software delineates three to five layers as topsoil, highly weathered, weathered bedrock, fractured bedrock and fresh bedrock. The first layer comprise of topsoil made up of sandy clay, clayey sand and gravel. The second layer consists of highly weathered layers which acts as conduit for percolation of water to lower depths. The third layer is weathered layer varied from one place to another and at shallow depths it constitute favourable aquiferous layer. The fourth layer consists of fractured zone and quite favourable zone for groundwater particularly if recharge zone is nearby. Finally, the fifth layer which is bedrock at deeper levels and in most of the cases it is dry zone. It is evident from the quantitative interpretation that A, K, HA, HK, and QH curves are dominant followed by HKH and QHK curves.

Table-1: Results of electrical resistivity soundings.

VES NO	LOCATION / VILLAGE	NO OF LAYERS	1st LAYER		2nd LAYER		3rd LAYER		4th LAYER		5th LAYER		CURVE TYPE
			RESISTIVITY (OHMS –M)	THICKNESS (MTS)	RESISTIVITY (OHMS –M)	THICKNESS (MTS)	RESISTIVITY (OHMS –M)	THICKNESS (MTS)	RESISTIVITY (OHMS –M)	THICKNESS (MTS)	RESISTIVITY (OHMS –M)	THICKNESS (MTS)	
VES-1	RAMNAGAR	4	51.4	0.9	13	1	70	16.2	1829				HA
VES-2	RAMNAGAR	4	249	1.07	116	3.88	695	11.1	3134				HA
VES-3	BACHAHALLI	4	83.9	1.42	11.6	2.03	51.2	21	28993				HA
VES-4	BACHAHALLI	4	107	0.78	10	0.92	86.9	20.7	1390				HA
VES-5	GOLLAHALLI	4	58.49	1.36	11.07	1.95	16988	3.48	19.7				HK
VES-6	GOLLAHALLI	4	273	0.74	50.7	3.89	27.6	6.87	2196				QH
VES-7	GOLLAHALLI	5	5195	0.25	176	2.24	38.1	3	299	11.5	963	-	QHK
VES-9	MADAPUR	4	554	0.427	124	4	19.7	4.44	17283				QH
VES-10	KOONAMUDDANA HALLI	4	678	0.415	144	4.02	20.7	4.22	19855				QH
VES-11	KOONAMUDDANA HALLI	4	660	0.43	140	4.47	19	4.71	20346				QH
VES-12	JEEGENAHALLI	3	45.9	0.89	20.1	7.15	2373						H
VES-13	VADERAHALLI	4	19.8	0.58	54.5	6.97	140	16.1	4746				A
VES-14	ABBANAKUPPE	4	272	1.27	103	5.98	10	5.55	324				QH
VES-15	BENNAHALLI	5	339	1.02	107	4.91	30.9	8.98	6908	7.66	25.8	-	QHK
VES-17	CHUNCHUDA	5	235	0.77	15	0.98	687	1.92	75.7	14	1415	-	HKH
VES-18	PUTTERAMMANA DODDI	4	191	1.25	19.5	1.17	85.5	22.2	1310				HA
VES-19	ANJANAPURA	5	286	1.24	25.7	0.86	109	14.6	323	90.3	32583	-	HAA
VES-20	HOSURUDODDI	5	170	1.53	42.1	0.99	380	3.21	24.1	8.31	58497	-	HKH
VES-21	LAKKOJINAHALLI	5	120	1.47	28.4	0.96	325	2.64	19.5	7.31	40746	-	HKH
VES-22	NANJAPURA	4	22.8	0.78	1416	0.16	95	23.5	65688				HK
VES-23	KURABALLI	3	28.9	1.27	65	13.4	1544						A
VES-24	KURABALLI	3	27.4	1.46	64.4	24.4	1821						A
VES-25	KUTAKAL	3	98.9	2.07	20.4	10.5	476						H
VES-26	KUTAKAL	4	17365	0.20	119	2.36	22.8	8.68	295				H
VES-27	GURGALLI	3	106	1.29	208	7.2	2611						H
VES-28	GURGALLI	3	109	1.38	211	7.1	2501						H

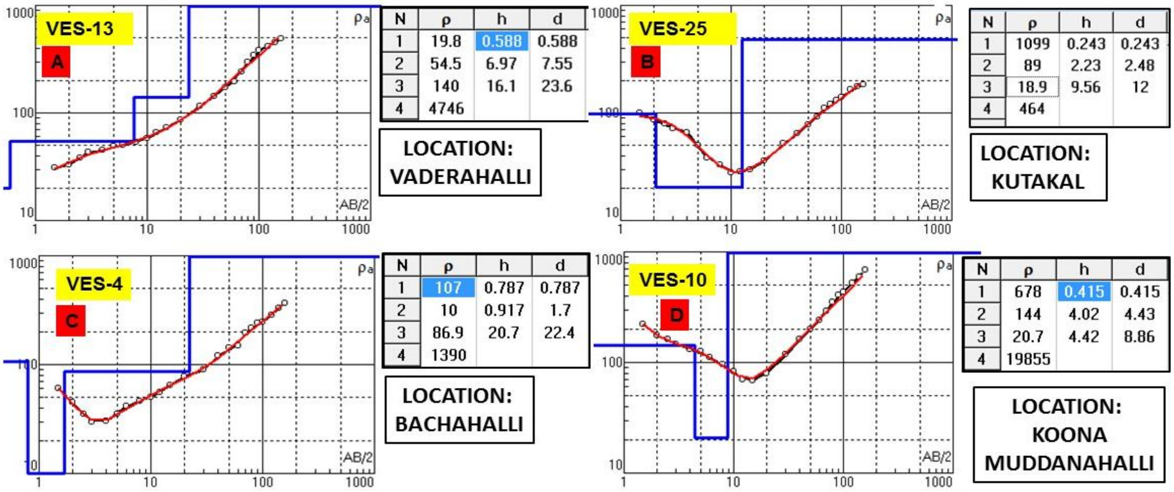

Fig. 3: Typical VES curve interpretation using IPI2WIN software.

The A-type curve (ρ1<ρ2<ρ3) is a three layer geoelectrical characterized by a top layer underlain by higher resistive formation. The highest apparent resistivity is more than 1000 Ωm in all the areas. These zones are characterized by continuous increase in resistivity values and hence these locations are not feasible for drilling borewells.

The H-type curve is a three layer geoelectrical sequence with curve morphology ρ1 > ρ2 < ρ3. The first layer is the top soil with higher resistivity (in the order of 250 Ωm) and the second layer is a fracture zone with medium resistivity (100-150 Ωm). The resistivity values of layers which show continuous decrease in resistivity with respect to depth indicates probable site for groundwater in shallow aquifer zone. The third and infinite layer is the bedrock that can either be fresh, hard and massive, weathered or fractured depending on the resistivity (up to 1600 Ωm).

The HA and HK type curves are the most predominant curve and the geoelectric sequence is ρ1 > ρ2 < ρ3 < ρ4 and ρ1>ρ2<ρ3<ρ4 respectively. The resistivity of the first layer consist of top soil consists of sand and gravel with relatively higher resistances (200-250 Ωm). This topsoil is directly underlain in most sounding point by clayey sand or highly weathered formation with low resistivity (50-100 Ωm). The Third layer has medium resistivity and this layer acts as the shallow aquifer which is a fracture or weathered zone which constitutes an favourably good aquifer (100-150 Ωm). This fracture zone is succeeded by the fresh basement hard rock layer without any fractures indicated by high resistivity (>600 Ωm).

In case of HKH and QHK, which are 5 layers with the geoelectric sequences $\rho1>\rho2<\rho3>\rho4<\rho5$ and $\rho1>\rho2>\rho3<\rho4>\rho5$ respectively have been identified in few places. The top soil layer with high resistivity is underlain by saturated sandy clay or highly weathered zone which may be considered as shallow aquifer under unconfined condition. The second confined aquifer is found in fourth layer with fractured nature and the fifth layer is basement hard rock. Further, another 5 layer sequence HAA ($\rho1>\rho2<\rho3<\rho4<\rho5$) which is characterized by continuous increase in resistivity indicating dry zone also found in few places.

It was observed from the field evidences that the interpretation of VES data sometimes cannot be correlated with geological section. This may be different rocks may show almost same resistivity and it is due to its compactness and porosity / fractured nature. In this connection an attempt was made to study heterogeneous nature of rocks by Azimuthal Resistivity Surveys (ARS) at few places. This survey was carried out using Schlumberger electrode configuration and the current electrode spacing (AB/2) having a maximum spread of 160m.The electrodes were rotated about a centre point and measurements were made in the directions of N- S, E-W, SE-NW and NE-SW. The apparent resistivity measured along different directions for a given AB/2 separations at each location were plotted along their corresponding azimuths. The result of this survey showed that there is no much variation in resistivity in any azimuths. In fact, the difference in resistivity obtained at any point for the given AB/2 separation in any direction is between 5-25 Ωm and not consistent also.

CONCLUSIONS

The Groundwater exploration is gaining more and more importance as it is one of the major component of life system. Electrical resistivity surveys involving VES was used to evaluate the groundwater potential in a crystalline basement terrain and to pinpoint target locations for drilling boreholes in the study area.

In general, three major zones were delineated as thin soil zone or weathered mantle, fractured zone, and massive. In certain regions, 4 to 5 layer curves were also observed which may be the gradation between weathered and fractured layers as a semi-weathered zone. The studies reveal that the groundwater potential of shallow aquifers is due to weathered zone with very low resistivity and moderate thickness and the deeper aquifers is determined by fracture zone with very low resistivity and very high thickness.

Present work has shown that in a hard rock environment, Vertical Electrical Sounding (VES) has proved to be very reliable for underground water studies and therefore this method can be used for shallow and deep groundwater zones.

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