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DELINEATION OF SHALLOW AQUIFERS USING ELECTRIC RESISTIVITY METHOD (ERM) AT PATLA, UDUPI DISTRICT, KARNATAKA.

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Abstract

Electrical resistivity methods are aimed at understanding underground hydrogeological conditions effectively and accurately. We conducted 20 Vertical Electric Sounding (VES) were conducted using Schlumberger with AB/2=50m at the US Nayak High School, Patla, Udupi District, in the school playground. The field data were plotted and interpreted quantitatively using the ZOND IP software. The sounding curves are K, Q and HK, giving a sequence of 3 to 4 layers. The prominent curves of types K and Q show the presence of three layers, and a combination of HK curves indicates the four underground layers. Among the total twenty VES locations, eighteen (VES-1 to VES-18) have three-layer cases, which include topsoil underlain by laterite, and the lowermost layer is lithomargic clay. VES 19 & 20 also includes the fourth layer is found below the lithomarge. The results show low resistivity values at the lower end, implying that the groundwater potential zone is the lithomargic clay layer detected at all VES stations. In addition, this study helped to delineate this layer as an area of shallow groundwater potential or a likely aquifer in the school playing field. More coherent studies are needed to understand aquifer formation to detect potential groundwater areas in the humid tropical region surrounded primarily by laterite deposition.

Key words: Electrical Resistivity Method (ERM), Vertical Electrical Sounding (VES), Schlumberger array, Groundwater potential zone, Lithomargic clay

Introduction

Groundwater is the world's largest source of fresh water, stored below the surface in primary and secondary rock openings (Price, 1996; Taylor et al. 2013). Approximately 50% of potable water is sourced from urban groundwater and 85% from rural areas (Malyan et al. 2019). Today, more than 50% of the population lives close to the world's coastline (Small and Nicholls. 2003). Coastal residents are typically affected by groundwater contamination that interacts with salinity or various chemicals (Bahar and Reza. 2010). Exploring groundwater in hard rock terrain proves to be a formidable and demanding task, especially when promising groundwater zones are interconnected with fractured and fissured geological media. In such conditions, the viability of groundwater largely hinges on the thickness of the weathered or fractured layer above the basement. (Al Garni. 2009). Today, advances in science and technology have played an important role in advancing several non-destructive and cost-effective methods used in groundwater exploration surveys. Understanding geological features with physics provides the best results in delineating and assessing groundwater. Due to the improvement of new geophysical methods, there are imminent

investigations for exploring the groundwater potential in coastal and inland areas (Akinbinu. 2015; Dhakate et al. 2016; Abuzied and Alrefaee. 2017; Ekwok et al. 2020).
Geophysical methods consist of uncomplicated procedures conducted at the Earth's surface to investigate subsurface features. This involves measuring distinct physical properties and interpreting the collected data, primarily to gain insights into the geological characteristics beneath the surface. Geophysical methods offer a swift and cost-effective solution for guiding drilling activities to identify the locations and orientations of fractured zones in hard rock regions, as outlined by Powers et al. (1999). The utilization of geophysical methods, particularly the electrical resistivity method, is instrumental in the mapping of groundwater resources.
An important geophysical technique for groundwater exploration applied primarily is Electrical Resistivity Methods (Putro et al. 2017; Priya and Jhariya. 2020; Mokoena et al. 2021; Arshad et al. 2007; Kumar and Swathi. 2014; Gaikwad et al. 2021) to identifying subsurface formations and determining the thickness of shallow aquifers. The initial stage of geophysical survey ERM has been used to demarcate and map the geological and geohydrological setting of prevailing shallow aquifers (Riyawat et al. 2018). The method is easy and non-destructive to execute in generating maps and recognising subsurface groundwater situations.
As the SW part of India, mainly the Western Ghats terrain, due to thick vegetation cover and lateritic cap, a resistivity survey is crucial to understand the subsurface condition and groundwater potential zones (Nair et al. 2017; Das et al. 2022). In various parts of Karnataka, electrical resistivity surveys helped find subsurface layer thickness, which led to documenting groundwater potential zones (Venugopal et al. 2011).
The present study attempts to identify subsurface formations in lateritic terrain and delineate shallow groundwater potential zones using Vertical Electrical Soundings (VES) with Schlumberger electrical configuration using ERM. The utilization of the Vertical Electrical Sounding (VES) technique allows for the estimation of depth, thickness, and water-yielding capacity of various subsurface layers. Hence, in this study, the VES method is implemented to delineate and assess zones with potential for groundwater.

Study Area

The study area is the playground at the U.S. Nayak High School in Patla, Udupi district, Karnataka state, India. Patla village is situated 20 kilometers inland from India's west coast at latitude 74.832050 and longitude 13.306622. The region has an arid climate, with an annual average temperature of 29 °C and 4136 mm of annual rainfall. One open well, one successful, and one unsuccessful bore well are present in the current study area.

MATERIAL AND METHODS

20 Vertical Electrical Soundings (VES) with a maximum depth of AB/2=100 mts were carried out in the current study using the Schlumberger electrode arrangement. In this study, D.C. resistivity metres made specifically for this procedure by National Geophysical Research Institute (NGRI), were employed. When used with 96 W dry cell battery packages, the resistivity metres have a

digital display for potential difference (v) and current (I). Copper rods are inserted into a porous pot containing C_uSO_4 to aid conduct current, while iron rods are utilised as current electrodes. The method used for calculation of apparent resistivity is given in the following equation-

$$\rho_a = \pi \left[\frac{\left(\frac{AB}{2}\right)^2 - \left(\frac{MN}{2}\right)^2}{MN} \right] \frac{\Delta V}{I} \text{ --Eq. 1}$$

where AB and MN are the current and potential electrode spacing, respectively (Kearey et al. 2002). The VES curves were interpreted by using ZOND IP software. The resistivities and thickness of different layers were estimated (table 1) by keeping in view of cross section of existing open well.

RESULTS AND DISCUSSION

Table 1 provides the interpretation findings from 20 vertical electrical soundings. According to findings on VES curves, 3–4 layers are produced by hearing curves of the K, Q, and HK types. Whereas in 3-layer sequences, curves are mostly of Q type (1> 2> 3) and least frequently of K type (1 2> 3), and HK type is a combination curve of 4-layer sequence.

Table 1. Resistivity data interpretation and corresponding thickness.

VES No.	No. of Layers	Apparent Resistivity ρ (Ωm)				Thickness h(m)			Total Thickness	Curve Type
		ρ1	ρ2	ρ3	ρ4	h1	h2	h3		
1	3	1218.72	2743.24	271.66	NA	2.45	7.55	NA	10	K
2	3	1721.69	1234.5	180.64	NA	3.48	20.38	NA	23.86	Q
3	3	1072.75	741.28	130.49	NA	8.49	14.09	NA	22.58	Q
4	3	1027.35	749.89	230.82	NA	3.25	8.48	NA	11.73	Q
5	3	1791.07	2575.07	236.29	NA	3.58	12.31	NA	15.89	K
6	3	1923.58	816.05	292.07	N	4.32	18.04	N	22.36	Q

					A			A		
7	3	1308.18	900.24	180.83	NA	3.68	17.58	NA	21.91	Q
8	3	1389	589.48	224.65	NA	2.02	14.21	NA	16.22	Q
9	3	1029.08	2675.38	170.75	NA	3.29	15.39	NA	18.68	K
10	3	2154.43	1625.96	141.25	NA	6.46	21.22	NA	27.69	Q
11	3	2055.9	1211.53	210	NA	7.31	21.42	NA	28.73	Q
12	3	1646.9	814.91	215.44	NA	3.51	28.32	NA	31.83	Q
13	3	1969.9	591.86	121.15	NA	2.08	20.58	NA	22.66	Q
14	3	1242.92	576.91	171.13	NA	4.41	17.78	NA	22.19	Q
15	3	2238.72	1883.65	70	NA	2.94	26.49	NA	29.43	Q
16	3	1486.7	717.06	210	NA	4.55	29.34	NA	33.89	Q
17	3	3640.08	902.73	207.33	Null	2.08	28.61	NA	30.69	Q
18	3	1376.86	690.06	199.53	Null	3.49	21.8	NA	25.29	Q
19	4	1176.36	883.2	1397.1	602.67	1.58	4.01	19.41	25	HK
20	4	1089.79	692.76	1561.38	403.47	1.58	2.29	10.43	14.31	HK

From the above table, the first layer's resistivity value (ρ1) varies from 1027.5(VES-4) - 3640.08 (VES-17) ohm-m, and thickness ranges from 1.58m(VES-19/20) - 8.48m(VES-3). Based on the topography and soil type, the thickness may vary in different VES stations. This study area mainly has Topsoil as the first layer.

Table 1. Resistivity and thickness of different layers

Rock Type	Resistivity (Ωm)	Thickness (m)
Top Soil	1027.35-3640.08	1.58-8.49
Laterite	576.91-2743.24	2.29-29.34
Lithomargic Clay	110.03-1561	10.43-19.41
Hard Rock	403.47-602.67	-

In the second layer, the resistivity values range from 576.91(VES-14) – 2743.24 (VES-1) ohm-m and thickness range from 2.29 (VES-20) – 29.34 (VES-16)m, which indicates the presence of Laterite (>1500 m). Here the Lithomargic clay is overlaid by Laterite. Except for VES-1, VES-5, and VES-9, the third layer resistivity values range from 70.79(VES-15) – 1561 (VES-20) ohm-m and thickness range from 10.43 – 19.41 m which reveals the presence of a weathered clay zone and clayey laterite. In our study area, the third layer indicates low resistivity values from which we can easily recognize the third layer of lithomargic clay has a high potential for bearing groundwater.

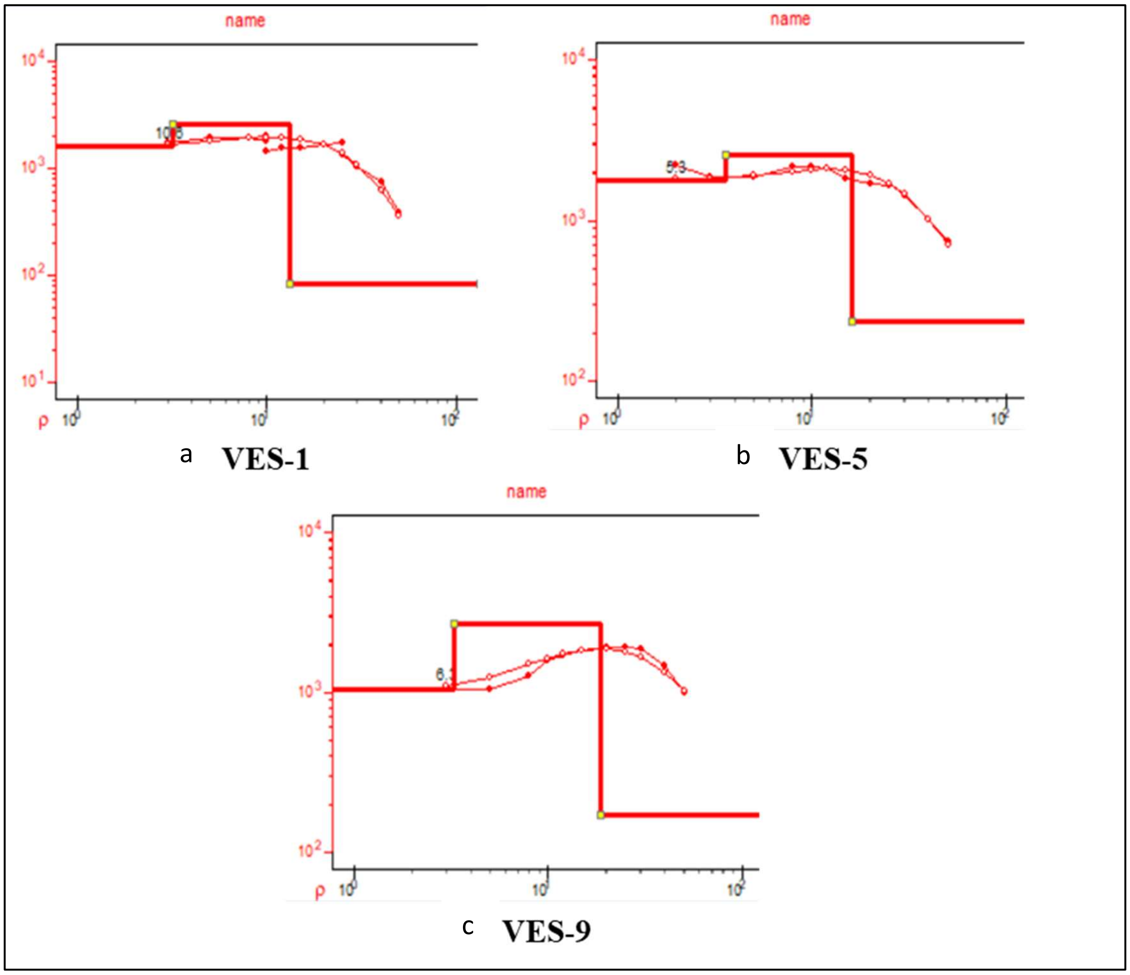

Fig. 1 Resistivity sounding curves (K type)

In VES-1, VES-5, and VES-9 (Fig. 1), a K-type curve is produced (ρ1< ρ2> ρ3). The topsoil resistivity value shown here ranges from 1029.08 – 1791.07 ohm-m with a thickness of 2.45 – 3.58 m. In the second layer resistivity values range from 2575.07 – 2743.24 ohm-m with thickness ranging from 7.55 – 15.39 m showing the lateritic rock. The third layer shows low resistivity values ranging from 170.45 – 271.66 ohm-m. Due to the presence of water in lithomargic clay, these locations are suitable for digging open well. Except for VES-1, VES-5, VES-9, VES-19, and VES-20 (Fig. 2), all other soundings give a Q-type curve (ρ1> ρ2> ρ3). In which the first layer resistivity values range from 1027.35 – 3640.08 ohm-m with a thickness of 2.02 – 8.49 m. In the second layer resistivity values range from 576.91 – 1883.65 ohm-m with a thickness of 8.48 – 29.34 m. In the third layer, the resistivity values show a variation from 70.79 – 292.07 ohm-m, which is suitable for digging bore wells.

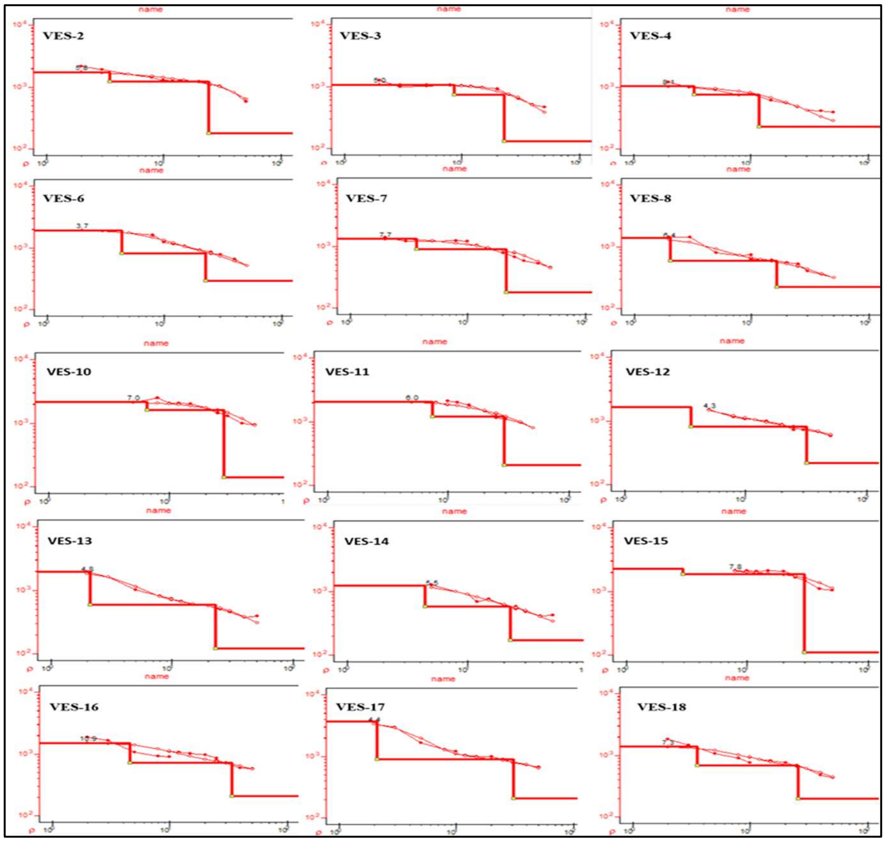

Figure 2. Resistivity sounding curves (Q type)

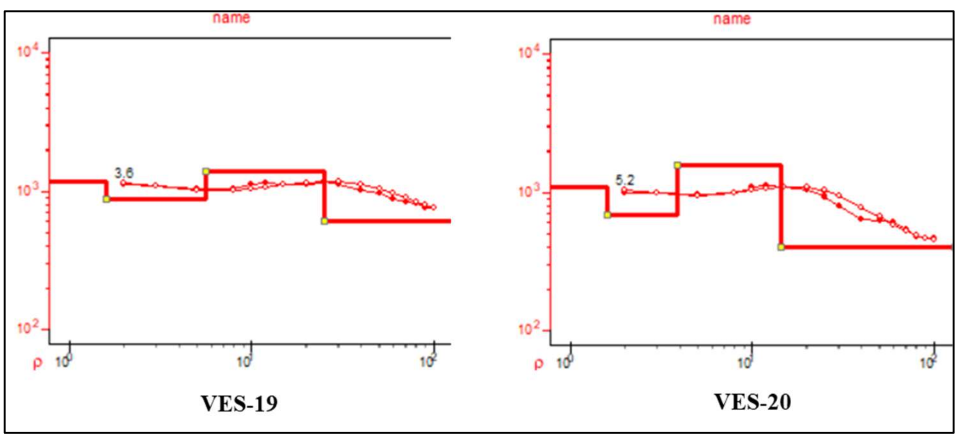

Figure 3. Resistivity sounding curves (HK type)

VES-19 & VES-20 (Fig. 3.) indicate an HK-type curve (ρ1> ρ2< ρ3> ρ4) having a 4-layer situation of topsoil, laterite, clay, and hard rock. The depth to hard rock is 25 m and 14.31 m in VES-19 & VES-20 respectively.

From the 18 shallow soundings and 18 VES curves, came to observe that except all the 18 locations shows a three layer situation. In which, except VES 1, VES 5, VES 9 remaining 15 sounding shows Q type curve, in Q type curves there are three Earth layers are present in which top layer has higher apparent resistivity compared to two other deeper layers($\rho1 > \rho2 > \rho3$). Other three sounding has K type curves in which second layer of earth has higher apparent resistivity among the three ($\rho1 > \rho2 > \rho3$). In case of 3 deep sounding it shows a HK type curve.

For investigating the lithology of the area, we have used the lithological cross section of the open well located in the ground. The vertical cross section of the open well noted as top soil forms the first layer, which is followed by a layer of red laterite and then followed by lithomargic clay layer. The resistivity data from the survey shown in the table above also supports this lithology. From the table, observes that top layer of the earth has a resistivity value range from 1027 Ωm (least value, VES 4) to 3640 Ωm (highest value, VES 17). This resistivity value range is similar to that of top soil. The second layer has a resistivity range between 576 Ωm (least value VES 14) and 2743 Ωm (highest value, VES 1). These values of resistivity falls under laterite's resistivity range. The third layer has a least resistivity value of 70 Ωm (VES 15) and has a highest value of 1561 Ωm (VES 20). This value range supports the presence of clay layer. Thus, from the resistivity values and the vertical cross section of the open well identifies the presence of three Earth layers – top soil, laterite, clay layers. Deep sounding finds that there is also a fourth layer earth present below, near the failed bore well there is presence of powdered granitic gneiss which is bought from the depth while digging the well which shows the presence of hard granitic gneiss as the fourth layer. But the resistivity values of this layer is low as compared to that of hard rocks. Which is due to the presence of water in this layer.

Layer 1 – Top soil: It has resistivity values between 1027 Ωm and 3640 Ωm, this resistivity values shows an increasing order as we moves the VES locations from north to south. For example, VES 1-1218 < VES 5-1791 < VES 9-1029 or VES 2-1721 < VES 6-1923 < VES 10-2154, same trend follows by VES 3, VES 7, VES 11 and VES 4, VES 8, VES 12. Except VES 1, VES 5, VES 9 all other VES locations of 18 sounding shows Q type cure that is in all that points top soil has high apparent resistivity than other 2 layers. Top soil in this area has a thickness range between 1.58 m (least value VES 19 and VES 20) to 8.49 m (highest value VES 3).

Layer 2 – Laterite: resistivity values between 576 Ωm and 2743 Ωm. In case of laterite, locations at the western portion of the study area has high resistivity (VES 1, VES 5, VES 9). So this points develops a K type curve as it is the high resistivity layer. As we moves the VES locations from west towards east the resistivity values shows decreasing. Thickness of the second layer laterite ranges from 2.29 (VES 20) to 29.34 (VES 16).

Layer 3 – Clay: In clay layer here the resistivity values are higher for locations in the eastern and western portion comparing to central portion of the study area. The third layer clay has thickness variation from 10.43 (lowest VES 20) to 19.41 (highest VES 19).

Layer 4 – Granitic gneiss: it is observed to be the fourth layer or layer of hard rock below the clay. Generally hard rocks has high resistivity reaches up to 2000 or 3000 but here it is only 602 and 403. It is due to the presence of fractures in this layer and also this fracture contains water content in it.

These data were shown in the table below:

Table 3. Layer thickness and corresponding resistivity values

Rock Type	Resistivity (Ωm)	Thickness (m)
Top Soil	1027.35-3640.08	1.58-8.49
Laterite	576.91-2743.24	2.29-29.34
Lithomargic Clay	110.03-1561	10.43-19.41
Hard Rock	403.47-602.67	

CONCLUSIONS

The objective of the groundwater inquiry was to locate the zone of saturation utilising the Electrical Resistivity survey. Since this method has always been helpful for studying shallow and deep ground water, it was utilised to pinpoint the potential aquifers. In this work, an attempt has been made to designate a prospective aquifer that can most likely be a groundwater potential zone using 20 VES reading locations chosen from the school playground. In all of the VES stations, topsoil, laterite, and lithomargic clay (weathered zone) are found. However, VES-19 and VES-20 have a four-layer curve made up of hard rock (bottom rock), laterite, lithomargic clay, and topsoil. This method has always proven effective, affordable, and competent for the detection of subsurface material and comprehension of the groundwater condition. The shallow aquifer is formed by the lithomargic clay (weathered zone).

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