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Evaluation of groundwater resources protection within mega school, Ayeka, Southwestern Nigeria

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Abstract

Electrical Resistivity method involving Vertical Electrical Sounding (VES) was carried out within the Maga school, Ayeka, southwestern Nigeria. This was carried out with aim of evaluating the protective capacity of the layers overlying the aquifers in preventing pollution from getting to the groundwater resources within the area. A total of twelve Vertical Electrical Soundings (VES) were acquired using the Schlumberger configuration. The half-current electrode spacing (AB/2) of the Schlumberger configuration was varied from 1 to 225 m. The sounding curves derived from the VES data were quantitatively interpreted using partial curve matching and further refined using computer assisted program. From the interpreted geoelectric result, four lithological layers were delineated; the topsoil, the sandy clay, the lateritic sand and the clayey sand/sand. The topsoil resistivity ranges from 89 to 162 Ωm and its thickness varies from 0.9 to 2.0 m, the sandy clay resistivity varies from 215 to 512 Ωm and its thickness ranges from 3.1 to 7.6 m, the lateritic sand resistivity varies from 1025 to 2611 Ωm and thickness ranges from 13.3 to 23.9 m and the clayey sand/sand resistivity ranges from 183 to 522 Ωm with a depth range from 19.7 to 30.4 m. The protective capacity map revealed that all the parts of the study area fall within a weak protective capacity zone. This is informed by the low longitudinal conductance which suggests a weak protective capacity rating. As a result of this, the study area is therefore vulnerable to pollution if it is exposed to contaminant sources which could come from septic tanks, underground petroleum storage tanks, industrial waste and landfills.

Keywords: Groundwater; Pollution; Electrical resistivity; Aquifer; Protective capacity; Geoelectric sounding

1. Introduction

Groundwater is very important to human life and is one of the most valuable natural resources. Groundwater finds usage not only for domestic purposes (such as cooking, drinking, bathing and other household purpose) but also for agricultural purposes majorly for irrigation, livestock and other usages [1, 2, 3]. Apart from exploration for groundwater, contamination of groundwater is another major concern to geoscientist and other related fields of science worldwide. As the need for groundwater resources development continues to increase due to the increase in the population's demand for more of it, so also there is the need to understand the relevance of the subsurface geology in the protection of this resource. Many developed and developing countries depend heavily on the supply of groundwater for several purposes [4]. Exploration for groundwater in many parts of the world is majorly carried out using geophysical methods, especially through the use of the Electrical resistivity method [5, 6, 7]. The electrical resistivity survey finds application in hydrogeological, engineering, and environmental investigations. In the hydrogeological investigation, the electrical resistivity survey helps in the delineation of aquifer, geological structure and lithologic boundaries among others. This method has been widely and commonly used both in the basement complex terrains and

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the sedimentary environment for groundwater investigation [8, 9, 10, 11, 12, 13]. The electrical resistivity method involving the Vertical Electrical Sounding (VES) technique has been widely used by various geophysicists to investigate subsurface lithology and pollution occurrence at different sites [14, 15]. This study presents the use of vertical electrical sounding in evaluating the groundwater resources protection within the premises of Mega school, Ayeka.

2. Location description and geology of the study area

The study area is the MEGA school which is located along Okitipupa/Igbokoda road. This place is situated in Ayeka, Ondo State, Nigeria. Its geographical coordinates lie between latitude 6° 29' 18.15" N and 6° 29' 26.08"N and longitude 4° 47' 21.47" E and 4° 47' 26.33" E (Figure 1). The study area lies within the easternmost part of the Dahomey basin, southwestern Nigeria which is bordered to the north by the crystalline rocks of the Southwestern Nigeria Basement Complex and to the South by the Atlantic Ocean. The study area also lies within the tropical rainforest region, as a result of this, two seasons (wet and dry seasons) are experienced throughout the year. The wet season starts around March and can last till October and is usually dominated by heavy rainfall. On the other hand, the dry season is always experienced from November to March. The annual rainfall is estimated to be from 1000 to 1500 mm. During this period, the annual temperature varies from 18 to 34°C. Relatively high humidity is experienced during the wet season while low humidity occurs during the dry season [16].

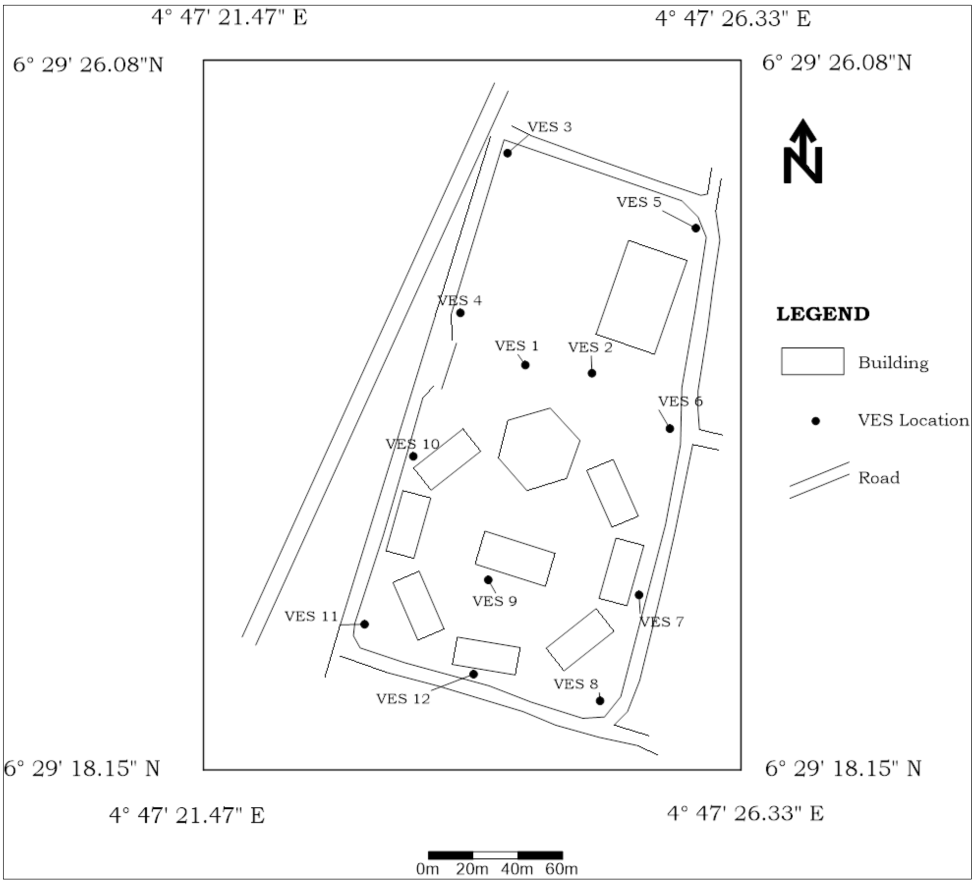

Figure 1 Map of the study area

3. Material and methods

The vertical electrical sounding (VES) was carried out using the Schlumberger array. A total of twelve stations were occupied across the study area. The half electrode spacing (AB/2) was varied from 1 to 225 m. The Ohmega resistivity meter was used for the data acquisition. The field data were used to generate sounding curves by plotting the apparent resistivity values against the half electrode spacing (AB/2). The partial curve matching technique was used in the manual interpretation of the sounding curves by making use of the master curves [17] and the auxiliary point charts [18, 19]. The obtained geoelectric parameters from the manual interpretation were further refined using the software algorithm WINRESIST version [20]. The iterated geoelectric parameters from the software algorithm were used to generate the second-order geoelectric parameters called Dar Zarrouk parameters [21]. The second-order parameter used for this study is the longitudinal conductance (S_i) and this is expressed using the equation developed by Zohdy et al. [22] which states that for n layers, the total longitudinal unit conductance is given by:

$$S = \sum_{i=1}^{n} \frac{h_i}{\rho_i} = \frac{h_1}{\rho_1} + \frac{h_2}{\rho_2} + \frac{h_3}{\rho_3} + \ldots\ldots\ldots\ldots \frac{h_n}{\rho_n} \qquad (1)$$

Where h_i is the layer thickness, ρ_i is the layer resistivity and the number of layers from the surface to the top of aquifer varies from i = 1 to n.

4. Results and discussion

The results are presented as sounding curves, tables, geoelectric sections and maps. Typical sounding curves obtained from the study area are shown in Figures 2a and b. The same curve type (AK curve) was obtained from all the sounding curves. The interpreted result is shown in Table 1.

Two geoelectric sections were generated along NE-SW and NW-SE directions (Figures 3a and b). The geoelectric sections represent 2D-section that connects geoelectric parameters from different VES and it shows the variations of resistivity and thickness values of different layers within the delineated depth. From the geoelectric sections, four geologic/geoelectric layers were delineated; the topsoil, the sandy clay, the lateritic sand, and the clayey sand/sand. The topsoil thickness ranges from 0.9 to 2.0 m while its resistivity values range from 89 to 162 Ωm. This topsoil thickness is relatively thin and its resistivity values show that it is clay/sandy clay. The second layer which indicates clayey-sand has resistivity values ranging from 215 to 512 Ωm and thickness between 3.1 to 7.6 m. Directly underlying the clayey sand is the lateritic sand. The lateritic sand layer has resistivities between 1025 to 2611 Ωm and a thickness range of 13.3 to 23.9 m. The clayey sand/sand layer resistivity values range from 183 to 522 Ωm with a depth ranging from 19.7 to 30.4 m. This layer serves as the major aquifer in the study area from which groundwater is tapped from the existing drilled boreholes.

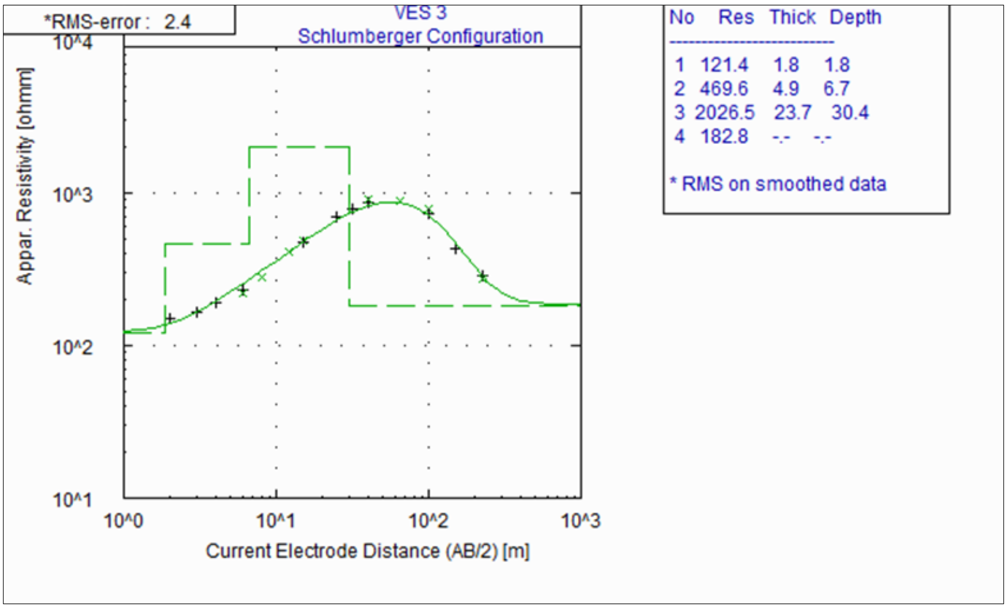

Figure 2a Typical sounding curve from the study area

The aquifer protective capacity of the study area was evaluated to understand the nature of the materials that overlain the delineated aquifers in preventing pollution from getting to the aquifer. In order to evaluate the nature of the overlain materials, these parameters which involve the layer resistivity and its thickness coupled with the longitudinal unit conductance (S) were analyzed. These parameters help to determine the ability of the overlain material in preventing polluted or contaminated fluids in getting into aquifers. The protective capacity of the lithologic layers has been established to be directly proportional to the longitudinal conductance [23]. The subsurface materials of the earth have different capacities to filter infiltrating fluid and therefore their ability to retard or filter percolating polluted fluid is very important. The longitudinal unit conductance (S) values from this study area range from 0.032 to 0.054 mhos (Figure 4). Using the classification table of Oladapo and Akintorinwa [23] in Table 2, the longitudinal unit conductance values derived from the study area all fall within the weak protective capacity zones. Consequently, this indicates that the area is vulnerable to pollution if exposed to contaminant sources located within or close to the investigated environment. The contaminant sources could be septic tanks, underground petroleum storage tanks, industrial waste and landfills.

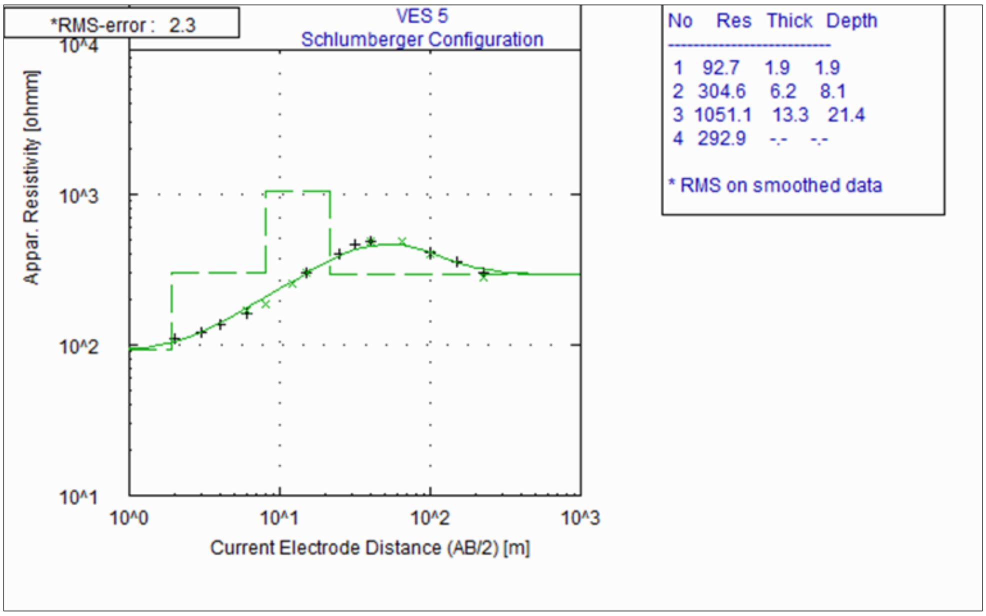

Figure 2b Typical sounding curve from the study area

Table 1 Summary of Layer Model Interpretation of the Sounding Data

VES No.	Resistivity (Wm)				Thickness (m)			Curve type
	ρ_1	ρ_2	ρ_3	ρ_4	h_1	h_2	h_3	
1	92	216	2611	361	1.6	3.1	17.1	AK
2	110	215	2274	341	1.4	3.2	15.8	AK
3	121	470	2027	183	1.8	4.9	23.7	AK
4	118	512	2521	289	1.6	4.6	23.9	AK
5	93	305	1051	293	1.9	6.2	13.3	AK
6	162	371	1025	522	1.6	6	15.7	AK
7	123	505	2283	274	1.8	4.3	21.8	AK
8	107	218	2287	350	1.5	3.1	15.1	AK
9	89	326	1294	268	1.2	6.4	16	AK
10	101	318	1157	294	2	6.3	14.9	AK
11	108	315	1125	305	1.9	5.9	14.7	AK
12	109	250	1307	279	0.9	7.6	15.5	AK

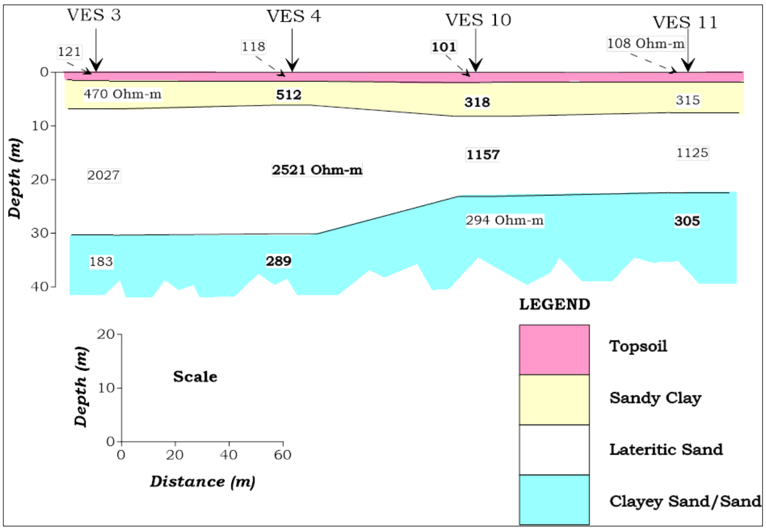

Figure 3a Geoelectric Section along Southwest – Northeast direction in the area

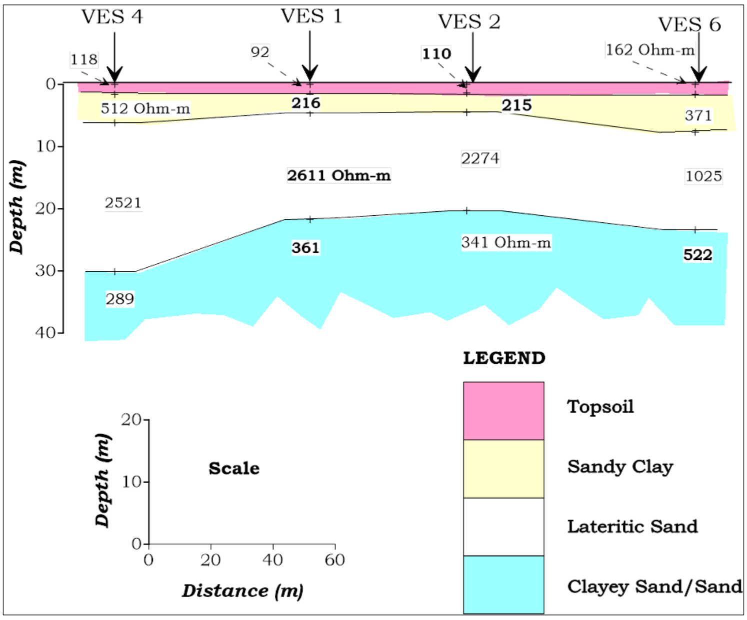

Figure 3b Geoelectric Section along Southwest – Northeast direction in the area.

Table 2 Modified Longitudinal Conductance/Protective Capacity Rating [23]

Longitudinal conductance(mhos)	Protective capacity rating
>10	Excellent
5 – 10	Very Good
0.7 – 4.9	Good
0.2 – 0.69	Moderate
0.1– 0.19	Weak
< 0.1	Poor

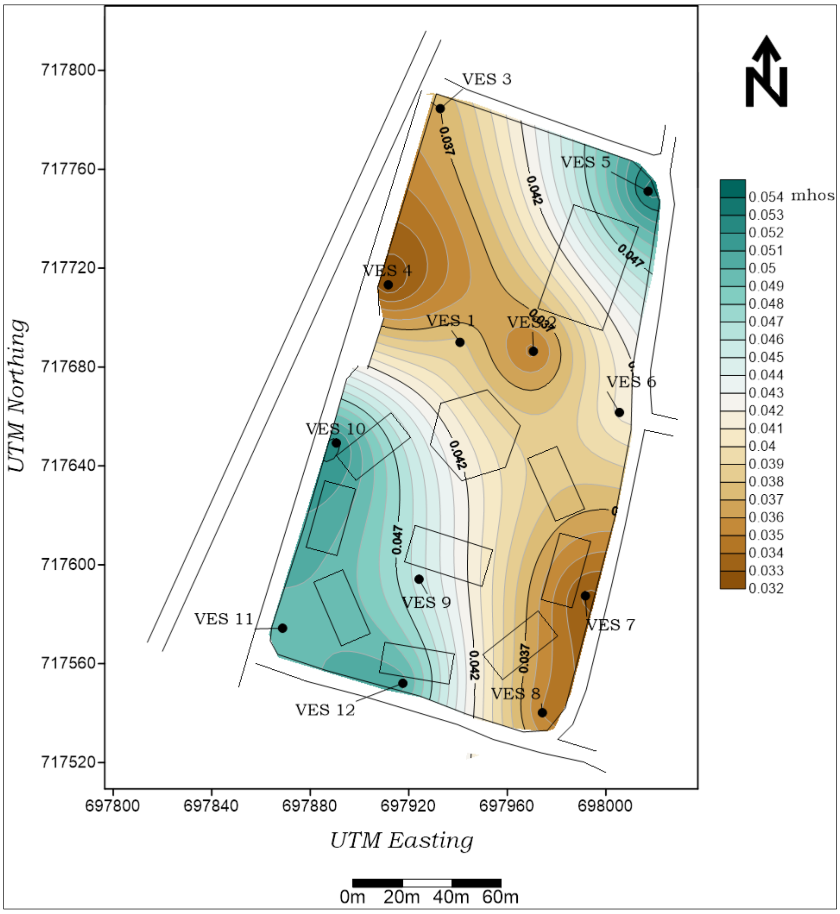

Figure 4 Longitudinal conductance map of the study area

5. Conclusion

The geophysical method involving electrical resistivity survey has proven to be very helpful in the evaluation of groundwater resources protection within MEGA school premises. A total of twelve (12) Schlumberger vertical electrical sounding (VES) locations were occupied. The VES data were quantitatively interpreted using partial curve matching. These were further refined using WinResist software. The refined and iterated geoelectric parameters from the WinResist software were used to generate the second-order geoelectric parameter (Dar Zarrouk parameter) to produce longitudinal unit conductance map. The longitudinal unit conductance map helps in zoning the study area to a weak protective capacity zone which implies that the area is vulnerable to pollution if exposed to any contaminant source which could be from septic tanks, underground petroleum storage tanks, industrial waste and landfills.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declared that there is no conflict of interest regarding this publication.

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