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GROUNDWATER POTENTIAL AND FLOW PATTERN USING ELECTRICAL RESISTIVITY DATA IN UTURU, ABIA STATE, NIGERIA

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Abstract: This study is aimed at evaluating the groundwater potential and flow pattern in Uturu using the electrical resistivity data gotten from the Electrical resistivity method. The VES results showed that the first three VES locations have six layers, while VES-4 has five layers. VES-1 and VES-3 have the same QHA curve, while VES-2 and VES-4 have KHA and KQQ curve types respectively. The geoelectric unit curves and the adopted lithological borehole log show that the lithology of the shallow seated layers is characterized by thin loamy/lumus to laterietic topsoil, clay, sandy clay and medium grained sand, while the aquiferous zones are characterized by coarse grained sands. The aquifer layers of VES-1, VES-2 and VES-4 are sandy clay and are not good potable water zones. The VES-3 was found to have very good groundwater potential with a resistivity range of 41.8Ωm to 2525Ωm, aquifer thickness range of 0.605m to 37.2m and a better deep-seated layer of depth range, 0.607m to72.8m located in a coarse-grained sand. The flow pattern of the groundwater in VES-3 was found to lie in the Northeastern to Southwestern direction. This is because the geoelectric section of this VES point lies across the Northeast to Southeast. It is recommended that any borehole to be sited in this study area should be drilled beyond the 72.8m of the VES-3 to get to the white grained coarse sand (good and potable water aquiferous zone) located within the depth of about 93 to 111m.

Keywords: Groundwater; Resistivity; Flow Pattern; Aquiferous Zone.

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1. Introduction

Human societies have always sought out and depended on water as a resource for domestic, agricultural, and industrial uses. According to Ritter et al. (2002), there are three primary sources of fresh water: the atmosphere (rainwater), surface water (rivers and lakes), and groundwater (reservoirs beneath the earth). Scientific study has shown that groundwater makes up 97% of the fresh water available to humans and environment, with lakes, streams, ponds, and rivers providing less than 3% of the total at any given time (Mills, 1982). According to recent surveys, 33.82 percent of Nigerians rely on surface water sources to meet their home and industrial needs, while about 40.1% of the population depends on groundwater sources (FOS, 2001).

For groundwater studies (Devi et al., 2002; Lenkey et al., 2005; Ekine and Iheonunekwu, 2007; Igboekwe and Nwankwo, 2011; Gupta et al., 2012; Achilike, 2020 and others) and groundwater contamination investigations (Park et al., 2007; Frohlick et al., 2008; Nwosu et al., 2013; Nwosu and Nwankwo, 2016 and others), a number of researchers in the geoscience field have employed the vertical electrical sounding (VES) geophysical method. Geophysical solutions are necessary for portal water problems, which have been particularly prevalent in this study region. For every 50 people that migrate into a hamlet in Abia State, wells experience a one cubic meter (1 m^3) depletion due to groundwater abstraction (Ahianba et al., 2008).

In order to address this problem, it is now essential to map out productive aquiferous zones, demarcate groundwater potentials, and develop flow patterns. Using GPS, water well, and geological data, Ezekwe et al. (2013) looked at the regional groundwater occurrence and flow pattern in a local area. Nwosu et al. (2013) used a 120 Schlumberger vertical electrical soundings (VES) array to evaluate the groundwater potential from pumping test analysis. The results revealed a multi-layered earth, indicating a prolific groundwater potential and exploitation in the southern zone of the area. The results of Nwosu and Nwankwo's (2016) investigation revealed resistivity variations in multi-geoelectric layers throughout the study region The aquifer horizon was delineated using twenty (20) VES stations to locate possible locations for conventional water well development. The horizon is thick enough to permit the drilling and installation of standard water boreholes, according to the aquifer features. In order to evaluate the susceptibility of aquifers to surface-induced contaminations, Adindu et al. (2021) investigated the groundwater potential and aquifer protection employing forty-four (44) VES locations using geoelectric data in the northern parts of Abia State. The aquifer's depth varies with elevation, being deep in highlands and shallow in lowlands and valleys, according to the study's findings. This showed that the thickness of the aquifer at the studied region decreased with depth, and that this was associated with an increase in fines.

In other to mitigate the problem of the groundwater in Uturu, this study uses the VES resistivity data gotten from the Schlumberger electrode spacing and Wenner array to delineate the groundwater potential and flow pattern in the study area.

2. Geology of the Study Area

The Anambra Basin is home to the research area. The primary Geologic Units that outcrop in the area are the Mamu, Ajali, Nsukka, and Imo Shale Formations. The incidence, location, and characteristics of these formations have been well studied by researchers like Kogbe (1975) and Whiteman (1982). The bulk of the rock units in these formations, according to Whiteman (1982), are made of sandy shale with lenses of sandstone and sandy

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limestone. This shale is typically thinly bedded. When drilling for water in the area, it is common to have a successful borehole in one area and an unsuccessful one in a nearby part of the same community due to the weakly bedded character of the sediments. This results in large financial losses.

The study area is located within latitudes 5°46.742'N and 5°49.542'N and longitudes 7°23.159'E and 7°25.319'E within Isuikwuato LGA area of Abia State, Nigeria (Figure 1). It is bordered by the Abia State University (ABSU) to the east, Okigwe LGA of Imo State to the west, Ihube and Leru to the north, Umuahia and Bende to the south. As the studied region moves from a rural to an urban state, it is undergoing a lot of development activities (Chigbu, 2013).

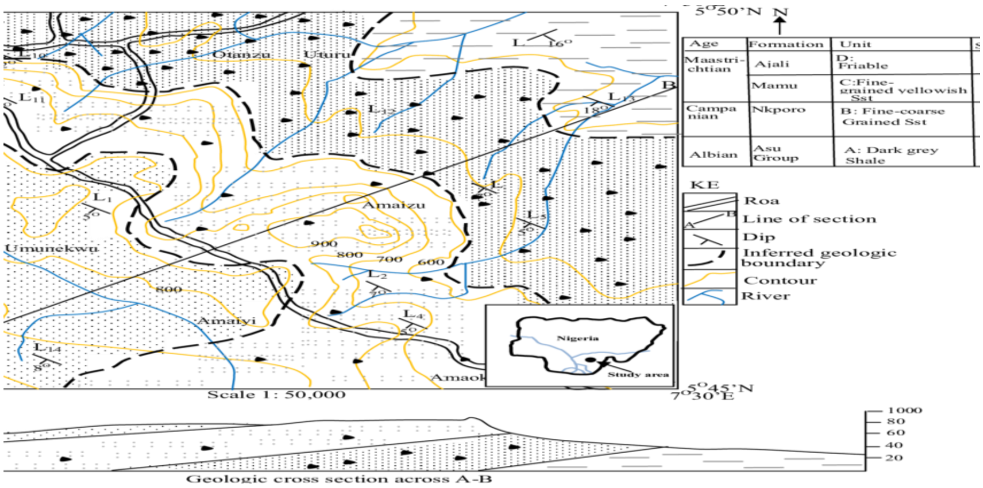


Fig. 1. Location of the Study Area (Obasi et al., 2013)

3. Materials and Method

The Abem LS 2 Terramter, four non-polarizable electrodes (two current and two potential used to inject current to the subsurface and measure the potential difference between the two potential electrodes respectively), four reels of insulated conductor cables (for the transmission of the earth's response/signal to the Terrameter), two measuring taps (for measuring the distances between the electrodes), two hammers (for hammering the electrodes into the subsurface), a 12V DC power source (the battery used to power the Abem Terrameter), four (4) reels of insulated conductor cables (for the transmission of the earth's response/signal to the Terrameter) and IPwin12 software package were used in this present study.

The field procedures and necessary connections for the Schlumberger array were properly carried out and the observed field data (which is the ratio of the resulting voltage to the imposed current and only a measure of resistance of the subsurface) were read off directly from the terrameter. This was used to compute the corresponding apparent resistivity (in Ohmmeters) by multiplying with the geometric factor values as functions of electrode spacing, which then gives the required apparent resistivity results as functions of depths of individual layers using relevant equations in literature. The sounding curves for each point was obtained by plotting the calculated apparent resistivity over various penetration depths against the half current electrode spacing (AB/2) on a log-log graph. The sounding curves were used for the conventional partial curve matching technique. The auxiliary point diagrams were used to estimates the initial resistivities and thicknesses of the various geo-electric layers and used for computer iteration using the IPwin12 software package. The software was able to transform and model the values to obtain a best fit relation to the field data

4. Results Presentation and Discussion

The results of the VES points gotten using the Schlumberger electrode configuration and Wenner array are presented in Figures 2 to 6. The interpretation was done using the areas of low and/or high resistivity values and thickness of the geo-electric unit curve types generated. The results were further validated using thelithologic logs of some borehole with similar geology within the study area (Igbokwe and Nwankwo, 2011) and other related studies. The results of the interpreted VES data and geoelectric layers (containing the resistivity, depth, and thickness) are shown in Figures 2, 3, 4 and 5 respectively. From the qualitative interpretation of the curve type, the VES-1, VES-2 and VSE-3 are six (6) layered points, while VES4 is a five (5)layered point, with a combination of A, Q, H and K type curves. The VES-1 and VES3-have the same QHA curve (with $\rho_1>\rho_2>\rho_3>\rho_4<\rho_5<\rho_6$), VES-2 has KHA curve (with $\rho_1<\rho_2>\rho_3>\rho_4<\rho_5<\rho_6$) and VES4 has KQQ curve (with $\rho_1<\rho_2>\rho_3>\rho_4>\rho_5$).

The quantitative interpretation of the model results in terms of true resistivity of the formation using the lithologic log of a borehole drilled within the study area (Figure 6) show that the lithology of the shallow seated layers is characterized by thin loamy/lumus to laterietic topsoil, clay, sandy clay and medium grained sand. The groundwater potential aquifer zones are characterized by coarse grained sands (comprising of grey medium, purple coarse, white grey, white coarse and white fine-grained sands). The layers of VES-1, VES-2 and VES-4 and the 1st, 2nd and 3rd layers of VES-3 are sandy clay and are not potential groundwater aquifer zones. The 4th and 5th layers of VES-3 are potential groundwater aquifer zones (Figure 3).The 4th layeris seated at a depth of 35.6m, aquifer thickness of 25.1m and resistivity of 10.8 Ωm. The deepest-seated 5th layer is at a depth of 72.8m, aquifer thickness of 37.2m and resistivity of 41.8 Ωm and are located in a coarse-grained sand. Low resistivity value at a deep-seated depth and high aquifer thickness indicates good groundwater aquifer zone. Thus, the VES-3 was adopted for the groundwater potential and flow pattern evaluation in this study based on its lower resistivity, good thickness and better seated-depth at 4th and 5th layers.

N	ρ	h	d	Alt
1	3871	1.05	1.05	-1.054
2	768	1.31	2.37	-2.366
3	461	2.01	4.38	-4.377
4	313	5.98	10.4	-10.36
5	2366	22.1	32.5	-32.47
6	5501			

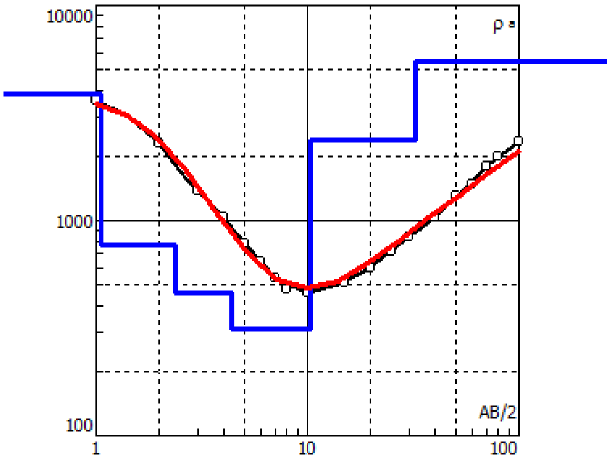
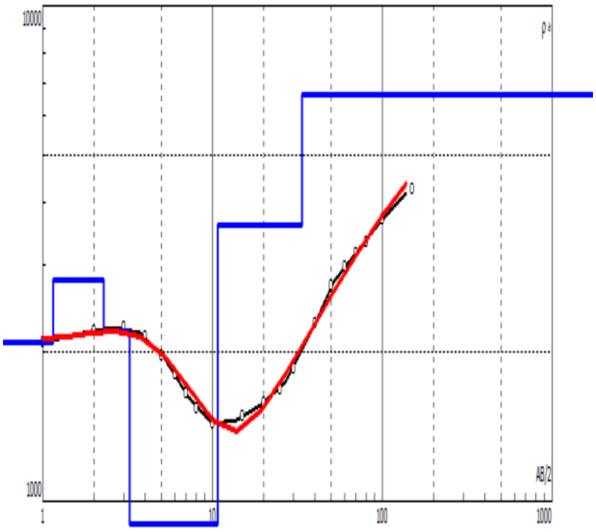
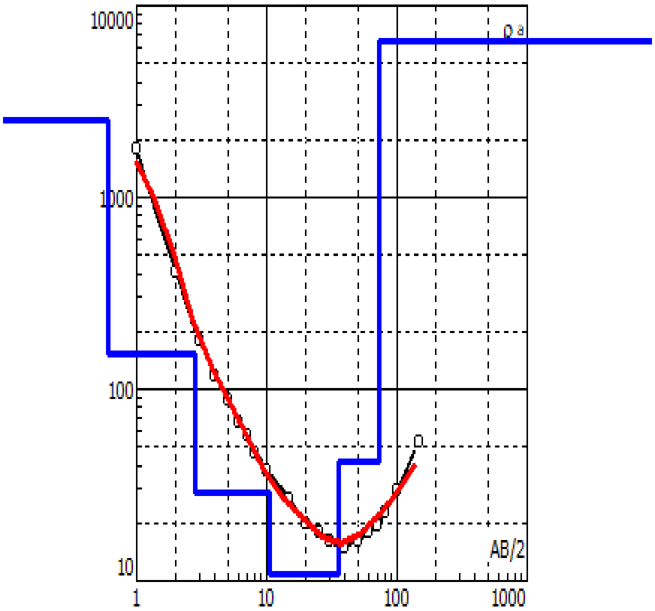


Fig. 2. Interpretation Curve for VES-1



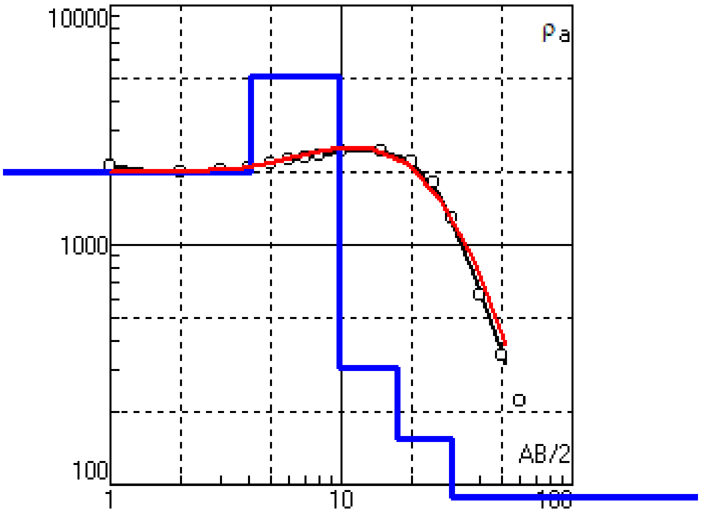
N	ρ	h	d	Alt
1	2092	1.15	1.15	-1.151
2	2796	1.13	2.28	-2.284
3	2206	0.962	3.25	-3.247
4	900	7.48	10.7	-10.73
5	3608	22.9	33.6	-33.63
6	6616			

Fig. 3. Interpretation Curve for VES-2



N	ρ	h	d	Alt
1	2525	0.605	0.605	-0.6048
2	153	2.2	2.81	-2.807
3	28.8	7.74	10.5	-10.54
4	10.8	25.1	35.6	-35.62
5	41.8	37.2	72.8	-72.79
6	6616			

Fig. 4. Interpretation Curve for VES-3



N	ρ	h	d	Alt
1	2002	4.02	4.02	-4.02
2	5062	5.78	9.8	-9.80
3	307	7.72	17.5	-17.5
4	155	12.6	30.1	-30.0
5	88.7			

Fig. 5. Interpretation Curve for VES-4

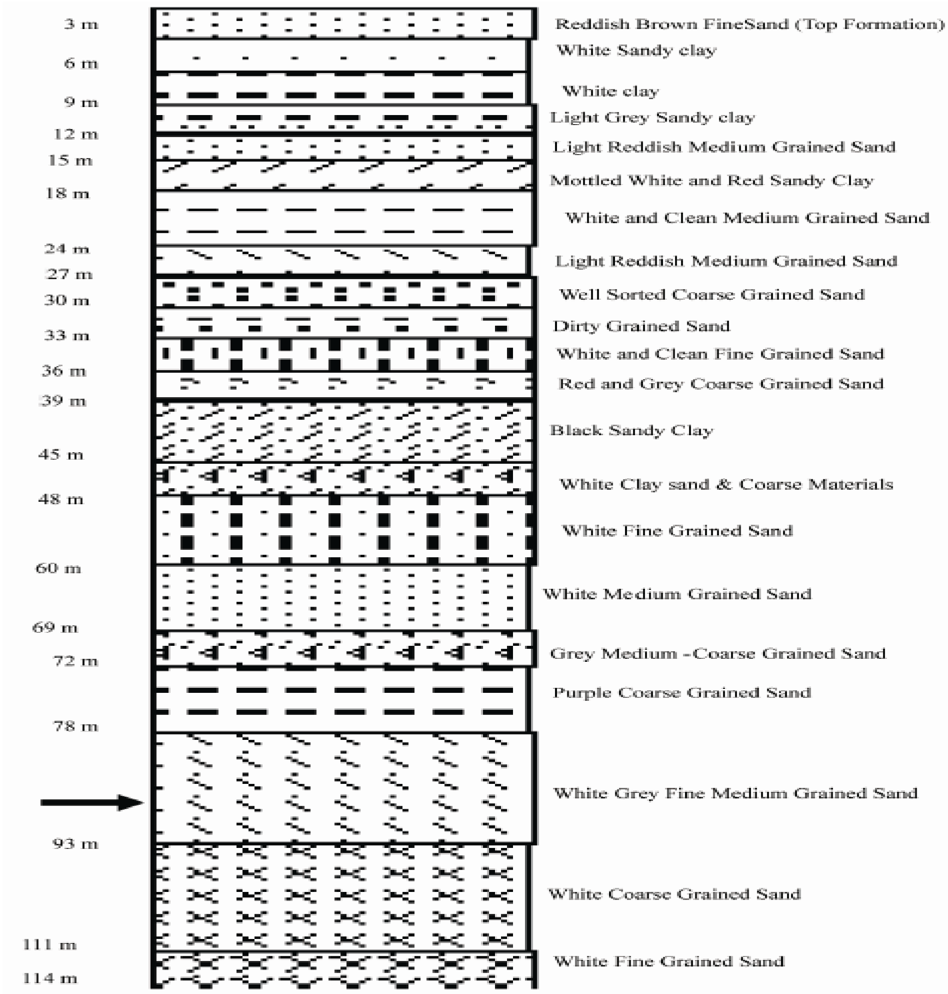


Fig. 6. Lithologic logs ofsome Boreholes within the study area (Igboekwe and Nwankwo, 2011)

In other to determine the flow pattern (which is associated with the recharge and discharge units) of the adopted VES point (VES-3), the Iso resistivity trend map (contour) of the main potential aquiferious zoneswas established as shown in Figure 7. This zone, composed of fine-medium-coarse grain sand is interbedded with clay. This occurs between the 4th and 5th geoelectric layers with resistivity range of 10.8-41.8Ωm, depth that varies from 35.6-72.8m and layer thickness of 25.1-37.2m. The zones of high resistivity (red) at a shallow depth and very low layer thickness represent the recharge region, while zones of low resistivity (blue) at high depth and high layer thickness represent the discharge region. Thus, the interpreted layered resistivity model (Figure 7) for the two main aquiferious zones show that the groundwater flow pattern tends from the Northeast to Southwest direction (which corresponds from the recharge to the discharge regions) of the study area.

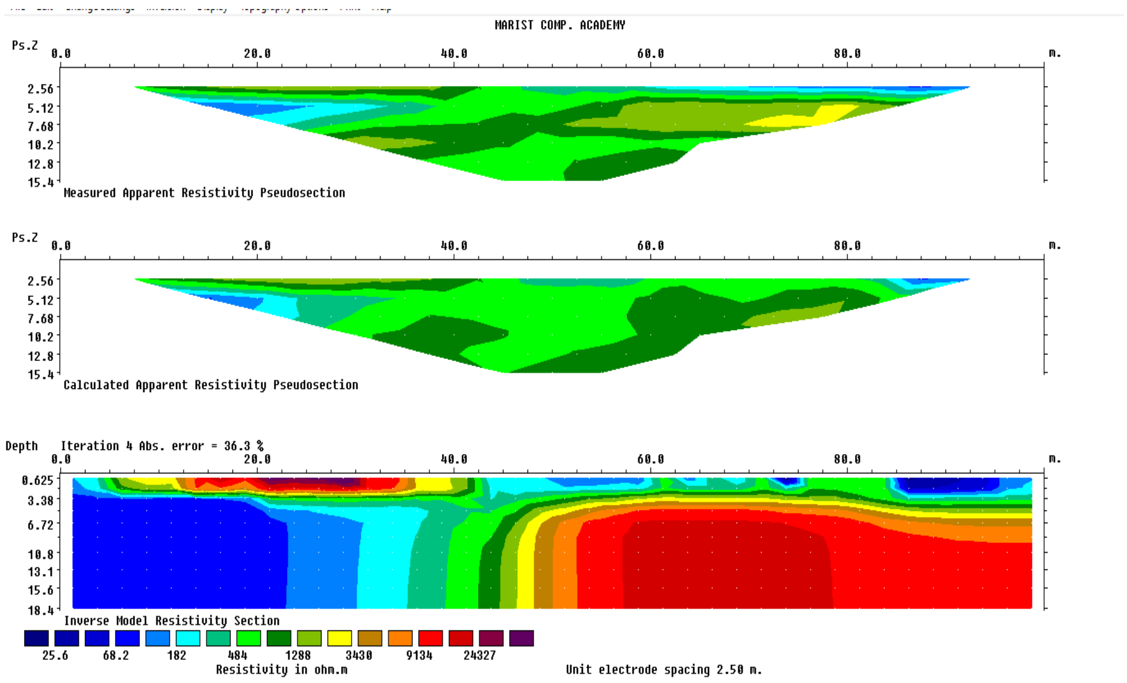


Fig. 7. Resistivity Distribution Map for Measured, Calculated and Inverse Model

5. Discussion of Findings

The interpretation of data in this study was achieved by the analyses of the subsurface layers based on the variation of the geoelectric layers from the vertical electrical sounding data. The software program was used to create the field curves by plotting the generated apparent resistivity (AR) values against the half-current spacings on a log-log graph (Figures 2, 3, 4 and 5). The analysis of the resistivity data was based on the assumption that the earth is made up of homogenous layers separated by horizontal interfaces. The parameters derived from the modeling included the total number of layers, the thickness of each layer and the apparent resistivity values for each layer. The shallow layers are made of top soil with brown-reddish laterite underneath, according to the geoelectric section and lithology of the borehole utilized for the quantitative interpretation for the adopted VES-3. The fine-medium-coarse-grained sands, or aquiferous zone, are the deeper seated strata that lie just behind the laterite (Igboekwe and Akpan, 2011).

The intricate interactions between the region's geology, physiography, groundwater flow pattern, recharge, and discharge processes determine the groundwater potential of the region (Nwosu & Nwankwo, 2016). The study's findings demonstrated that the study area is divided into high zones for groundwater exploration (VES-3, which has the greatest potential due to its high depth, high aquifer thickness, and lower resistivity) and very low groundwater potential zones (VES-1, VES-2, and VES-4) (Figures 2–5).

As depth increases, the resistivity values found in this study do increase steadily (Figure 7). The layer parameters that were derived from the soundings at several places are evident of this fact (Igoekwe and Akpan, 2011; Igboekwe and Nwankwo, 2011). This indicates that the formation under study contributes to the aquifer's retention. The strata of sandstones, shale, and clay are depicted in the geology. This indicates that the area belongs to the Lower and Upper Coal Measures and the Tertiary to Early Cretaceous Ajali formation: which is in agreement with the result of the study carried out by Nwosu et al. (2013). The lithologic and geophysical settings of the sedimentary rocks that make up these formations control the timing of groundwater movement. As it was in the study carried out by Ekine and Iheonunekwu (2007), they are characterized by gray sandstone clay lenses and contain groundwater. It is important to emphasize that the area's highly permeable formation, lateritic overburden, worn top soil, and underlying clay-shale membrane all contribute to the hydrologic conditions that support aquifer development.

The results of this study have shown that the VES-3 point has a very good groundwater potential with a resistivity range of 41.8Ωm to 2525Ωm, aquifer thickness range of 0.605m to 37.2m and a better seated depth of 0.607m to72.8m. The geologic formations' structure and orientation are responsible for the decrease in resistivity with depth, which is consistent with the findings of Ibeneme et al. (2020). The geologic formations dip from Northeast to Southwest, and the trend of iso resistivity values is along the strike direction (NW-SW) (Figure 7). Consequently, the flow pattern of the groundwater potential VES-3 point is assumed to be in the Northeastern to Southwestern (NE to SW) direction because the geoelectric section of this VES point lies (or dips) across the Northeast to Southeast (from the recharge to the discharge zones).

This result is in agreement with the results of other studies carried out in the study area (Igboekwe and Akpan, 2011 and Ibeneme et al., 2020). This study confirms that the area has two-aquifer system as reported by Awalla and Ezeigbo (2002) in their study of ground water in Uburu-Okposo near the study area. This study, together with one by Ezekwe et al. (2013), shows a thin and extensive confined and unconfined aquifer system with two types of groundwater flow, even if the previously stated studies suggest a thin but extensive water table aquifer. The water table aquifer normally shows localized flow, while the regional constrained aquifer system usually has a dominant flow pattern (Ekwe et al., 2006). Nevertheless, this regional aquifer system has been partially severed by igneous intrusions. As a result, groundwater flows from recharge areas northwest toward the Ivo River at Lekwesi (which serves as the main point of recharge for the regional ground water flow, including the study area's rapid surface run-off); southwest toward Lokpaukwu; southeast and eastward through the mining district toward the Ishiagu Triangle and southward from the mining district; which corresponds to the recharge areas.

Conclusion of Findings

This study has delineated the potential groundwater and its flow pattern in the study area.

The results of the four (4) VES points show that the VES-1, VES-2 and VES-4 are of low groundwater potential, while the VES-3 is an aquiferous groundwater zone, with a resistivity range of 41.8Ωm to 2525Ωm, aquifer thickness range of 0.605m to 37.2m and a better seated depth of 0.607m to72.8m. The flow pattern of the groundwater potential VES-3 point flow from the recharge zone in the Northeastern to Southwestern (NE to SW) direction. This is because the geoelectric section of this VES point dip(lies) across the Northeast to Southeast which is in agreement with similar studies carried out in the area. It is recommended that for a good and portal groundwater aquifer delineation, any borehole to be drilled in this study should be drilled beyond the 72.8m of the VES-3 to get to the white fine-grained sand located at a depth of about 93 to 111m.Again, the results of this study can be a veritable too for both the government and academia in the formulation of developmental policies and programs for proper good groundwater in the study area if adopted and implemented.

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