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RESEARCH ARTICLE

UTILIZING ELECTRICAL RESISTIVITY TECHNOLOGY AND BOREHOLE LOGGING FOR DETERMINATION OF GROUNDWATER POTENTIAL AND VULNERABILITY IN OGBA–NDONI–EGBEMA LOCAL GOVERNMENT AREA, RIVERS STATE, SOUTHERN NIGERIA

N.B. Osuamkpe*, I. Tamunobereton-ari, A.R.C. Amakiri, J. Amoniah

Department of Physics, Rivers State University, Nkpolu-Oroworukwo, Rivers State, Nigeria.
****Corresponding Author E-mail: fredbrantly@gmail.com***

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ABSTRACT

Geoelectrical resistivity technology (GRT) was utilized to determine the potential and the protective capacity of the groundwater system in Ogba–Ndoni–Egbema Local Government Area (ONELGA) of Rivers State, Southern Nigeria. The deliverable of the research work was to determine groundwater potential zones and vulnerability by using vertical electrical sounding (VES) and borehole (BH) logs. GRT method applied Schlumberger 1-D vertical electrical sounding (VES). ABEM Terameter SAS 300 B resistivity meter was used to acquire 10 VES data while IPI2Win software tool was used to estimate the primary geo-electric indices. Lithostratigraphic analyses from two borehole (BH) logs further elucidate aquifer characteristics, facilitating the identification of desirable aquifer layers for groundwater storage and transmission. The best shallowest aquifer for the first BH log is fine to medium sand (whitish) with a thickness of 21m and ranges from 9m to 30 m. The aquifer in the second BH log is the whitish medium coarse sand, which is 9m thick and is situated between depths of 6 to 15m. Primary and secondary geoelectric parameters were employed to generate maps of hydrodynamic properties for the shallowest aquifer unit widely exploited in the region, enabling efficient groundwater management. The resistivity values for the most superficial aquifer varied between 265 and 919 Ωm and, the thickness of this layer ranged from 6.9 to 26.7 meters, with depths spanning from 8.6 to 43.3 meters. The findings revealed a range of potential index parameters such as transmissivity (2.366-5.734 m^2/day), transverse resistance (1828.5-23576.1 Ωm^2), and hydraulic conductivity (0.205-0.480 m/day), indicating favorable groundwater potential but inadequate protective capability, as indicated by the longitudinal conductance index (0.013109-0.030237 Siemens). Given the significant population residing in the local government due to its economic activities, it is recommended to implement well-managed waste disposal measures to prevent the infiltration of leachates as well as other organic and inorganic wastes into the naturally vulnerable underlying aquifer units.

KEYWORDS

Hydrodynamic properties, Groundwater Potential, Vulnerability, Ogba–Egbema–Ndoni, Core Samples.

1. INTRODUCTION

Water is invaluable to living things and the most abundant in the earth's atmospheric system (Tamunobereton-ari et al., 2015). It is a beneficial natural resource extends beyond the fact that it is necessary not just for human survival but also for the survival of the natural environment (Jumbo et al., 2021). As the name suggests, groundwater is fresh water drawn from the beneath the surface of the earth trapped in the pore spaces of the bulk formation materials, among which are rocks and soil. It stands as a substantial water reservoir for numerous metropolises, remote regions, emerging nations, dry and semi-dry zones, and industrial hubs alike. It is the universe's greatest liquid freshwater reserve (Wakode et al., 2018). Since groundwater is heavily used to satisfy a variety of needs, including those related to agriculture, industry, and home use, it is likely the most exploited natural resource. Groundwater infiltrates soil largely by percolation, which occurs when precipitation travels downward through the soil's pore spaces due to gravity usually from streams and man-made recharges (Ibuot et al., 2022). An aquifer is a saturated zone in the subsurface that delivers water to wells or boreholes.

Groundwater vulnerability is a phrase used to describe the natural earth qualities that influence how easily groundwater can be polluted by human activity. More technically, groundwater vulnerability refers to the characteristics of intrinsic geological and hydrogeological properties of a location that influence the ease with which groundwater can be contaminated. The notion of aquifer vulnerability is used to assess an aquifer's susceptibility to being negatively impacted by an applied pollutant load from the land surface (Foster et al., 2013). The idea of vulnerability of aquifers aids in guiding effective groundwater management and protection strategies. The risk of contamination to groundwater systems from industrial growth, urbanization, and agriculture is growing globally. The fast advancement of human society places significant pressure on the groundwater supplies that are accessible, leading to a severe water crisis characterized by scarcity and

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declining quality (Carrard et al., 2019).

Geophysical approaches, such as the surface resistivity method, are beneficial for estimating aquifer geohydraulic characteristics quickly, easily, and affordably (George et al., 2017). It is a proven approach for detecting potential aquifers for a steady and uninterrupted water supply (Adeniji et al., 2013). This method has the benefit of having no detrimental effect on the environment and resulting in less uncertainty in interpretations. The considerable expenses linked to conducting pumping tests at water well sites, coupled with the costs of borehole drilling and the intrusive nature of these processes, frequently present limitations, prompting individuals to engage in unauthorized water drilling. Even if just a few boreholes exist in a given location, computing aquifer parameters between them might be erroneous, particularly over long distances, due to geological variances. With the Schlumberger array, which has electrodes arranged symmetrically on both sides, it is typically possible to achieve higher resolution, deeper probing, and shorter field deployment times. Surface geoelectrical measurements provide insights of aquifer parameters like as hydraulic conductivity and electrical resistivity, which can predict these values in locations lacking boreholes. In order to characterize ground water resources in ONELGA, Rivers State, this study estimates parameters such as transmissivity, transverse resistance, hydraulic conductivity and longitudinal conductance index using geo-electrical resistivity technology. The study determines lithology and thickness using borehole logging from two locations in the study region. It also evaluates the potential and susceptibility of shallow groundwater resources that have been extensively utilized by the local population of the Local Government Area.

2. GEOLOGY AND HYDROGEOLOGY OF THE STUDY AREA

The study area encompasses the Ogba-Egbema-Ndoni Local Government Area (LGA) in Rivers State, Nigeria, previously referred to as Old Ahoada LGA. This LGA falls within the Rivers West Senatorial District, with Omoku serving as its administrative center. Since the early 1960s, the ONELGA region has been host to the largest oil and gas exploration and exploitation activities in the state, while its economic activities are primarily centered around agriculture, fishing, and trade. Figure 1 illustrates a schematic map of Rivers State, highlighting ONELGA's location. Rivers State is situated within the Niger Delta complex, characterized by the presence of fine to coarse sand deposits typical of river channel formations. The geological structure of the region is primarily composed of two distinct formations: the Quaternary Deltaic plain (comprising upper and lower sections) and the Tertiary Benin and Ameki Formations. The deltaic plain is characterized by layers of coarse to medium-grained unconsolidated sands, interspersed with peaty debris, as well as soft silt, clay, and shale layers (Jaja et al., 2022). Aquifers within the sandy beds of this formation are known for their productivity. According to the Rivers State Ministry of Water Resources, the deepest water tables in the saturated zone of Rivers State, particularly in the selected case study sites, range from 5 to 10 meters for the shallow aquifer and 15 to 35 meters for the deep aquifer. The deep aquifer exhibits a high recharge capacity attributed to the region's consistent and well-distributed precipitation throughout the year (Tamunobereton-ari et al., 2014; Tamunobereton-ari et al., 2018).

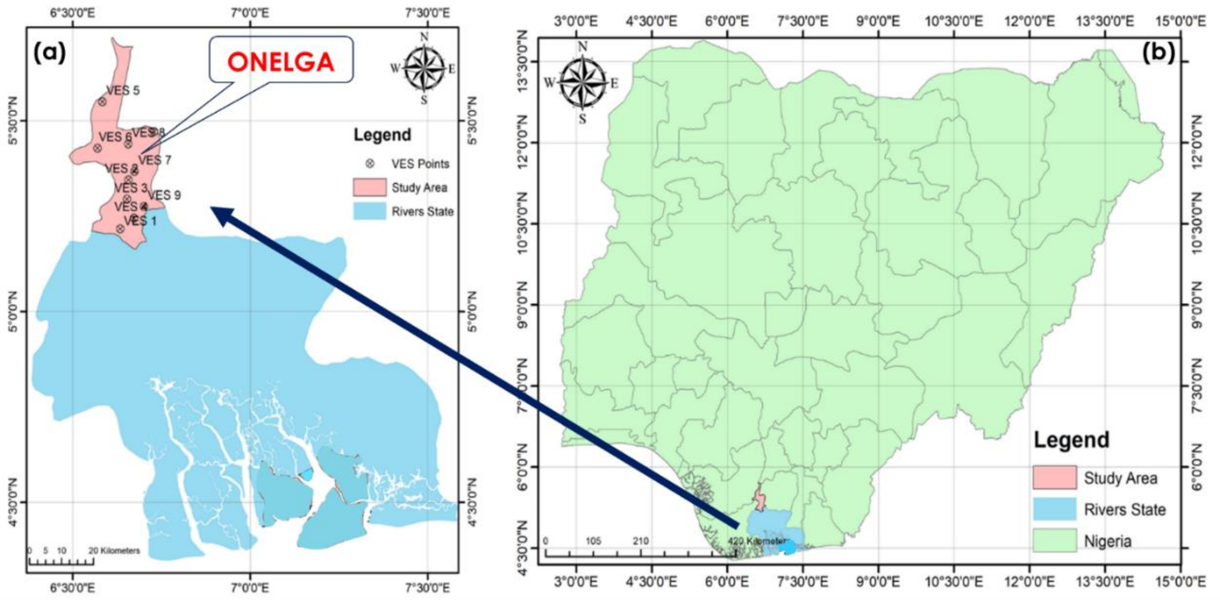


Figure 1: Schematic map of (a) Nigeria, showing Rivers State (b) Rivers State showing Ogba–Egbema–Ndoni (ONELGA).

3. MATERIALS AND METHODS

3.1 Materials

The study was made feasible by a number of important materials and devices carefully chosen to ensure effective data collection and analysis. These included specialist software applications like ArcGIS for map contouring and IPI2Win for VES inversion. Accurate coordinate and elevation measurements were made using a Global Positioning System (GPS) radar, while precise VES measurements were made using ABEM Terrameter SAS 1000 and its accessories. The research also gave a lot of attention to comprehending the geology and position of ONELGA, which provided a fundamental understanding that was essential for the interpretation of the data that was gathered. Overall, the careful selection and use of these instruments and materials, together with a practical interpretational method, were crucial in guaranteeing the effectiveness and precision of the data collection process and subsequent analysis.

3.2 VES Technique

The geo-sounding procedure, which included a 1-D vertical electrical sounding (VES), was carried out in ONELGA with an ABEM Terrameter SAS 300 B resistivity meter and accessories. Ten (10) VES stations were sounded in accordance with the area's infrastructure (Fig. 2). The VES approach used a Schlumberger array with a maximum current electrode spread (AB) of 500 m. Taking all the essential safeguards, earth apparent resistance R_{app} , were measured in each VES. For the VES approach, the apparent resistivities ρ_{app} were assessed using the formulae presented below in equation 1 (Zohdy et al., 1974; Akpan et al., 2013).

$$\rho_{app} = \pi \cdot \left[\frac{\left(AB/2\right)^2 - \left(AB/2\right)^2}{MN} \right] \cdot R_{app} \tag{1}$$

where AB and MN are respectively current electrode separation and potential electrode separation. The entire term multiplied by R_{app}in Schlumberger in order to obtain the apparent resistivities ρ_{app} in equation 1 represents the configuration geometric factor. The dataset was manually smoothed to remove erroneous readings that deviated from the overall curve trend, which was accomplished by drawing a graph of apparent resistivities on a logarithmic scale against half of the current electrode separations. The IPI2Win Version 3.0 program, a 1-D least square computer-assisted forward modeling tool, was then used to quantitatively evaluate the curves. The software program defined key geoelectric indices such as layer resistivity, thickness, and depth, as well as the root-mean square (which was less than 5%), which served as an indicator of the degree of goodness of fit between the theoretical and field-derived curves, providing detailed insights into the interpreted curve (see figures 2 and 3). Table 1 displays the geographic data alongside measured and predicted hydrokinetic parameters pertaining to the shallowest aquifer, positioned atop the deeper aquifers within the unconfined aquifer system.

3.3 Determination of Secondary Geo-Electric Parameters

Equations 2, 3, 4, and 5 depict secondary geoelectric properties which are: longitudinal conductance, transverse resistance, transmissivity, and hydraulic conductivity. Hydraulic conductivity refers to a rock's ability to allow water to pass through it. Hydraulic conductivity and groundwater reservoir risk have a positive correlation (Ekanem et al., 2019; George, 2020). The velocity at which water may penetrate an aquifer's unit width at a given hydraulic gradient is referred to as transmissivity (T). The degree of resistance to the flow of electrical current through subsurface formations is measured as transverse resistance. In groundwater research, longitudinal conductance is the ratio of layer thickness to resistivity.

$$S_L = \sum_i^n \frac{h_i}{\rho_i} \tag{2}$$

$$T_R = \sum_i^n \rho_b . h \tag{3}$$

$$T = K_h b \tag{4}$$

$$K_h = \frac{T}{h} \tag{5}$$

where S_L is the longitudinal conductance, h is the thickness of the layer (in the direction of current flow), and ρ_b is the bulk resistivity of the layer, T_R is Transverse Resistance, T is the transmissivity, K_h is the hydraulic conductivity of the aquifer.

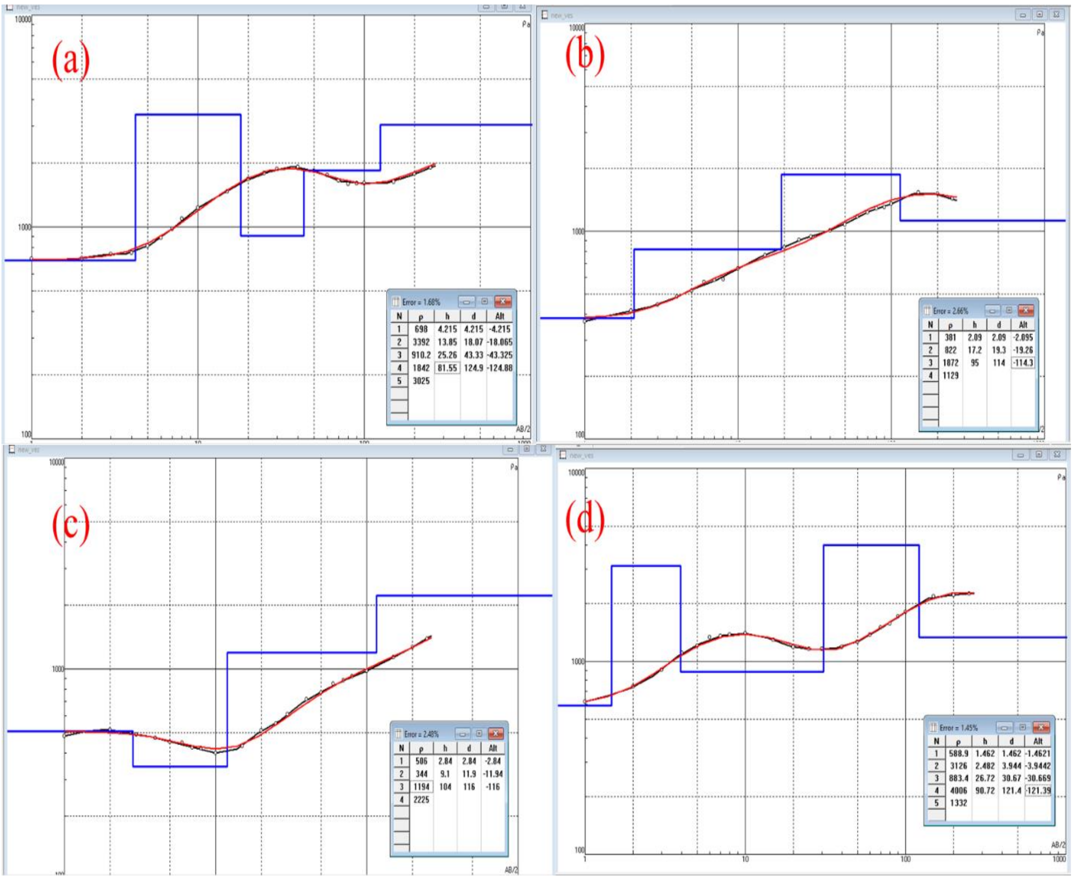
3.4 Borehole Logging

To determine the lithostratigraphic succession of the geology in the study location, core samples were collected from already dug boreholes along the profiles for analyses to obtain relevant lithologic information and for precise interpretation. Once collected, core samples were analyzed in a laboratory to determine various properties, such as grain size, mineral composition, and hydraulic conductivity. These analyses would help understand the potential for groundwater flow, storage, and contamination in the subsurface. It also helped in understanding the geological formations and the depth of aquifers.

4. DATA ANALYSIS, RESULTS AND DISCUSSION

4.1 VES Data Interpretation

The analysis of VES data using electrical resistivity was done to effectively estimate subsurface resistivity distribution from surface measurements. The procedure entails passing current through two electrodes known as current electrodes denoted by A and B, and taking measurement of potential difference between another pair of electrodes (M and N) known as potential electrodes. The Schlumberger electrode separation design was used because the aim of the research was to find aquifers at depth. The highest current electrode separations reached four to five layers of the subsurface. Vertical Electrical Sounding (VES) data from across the research region indicated a succession of geological differences within and across distinct strata (Hodlur et al., 2006; Thomas et al., 2020). The resistivity of the first layer ranged from 265 to 919 Ωm, with a mean value of 655 Ωm. The thickness ranged from 6.9 to 26.7 m, with a mean value of 14.2 meters. This layer is unsaturated and transitions to the water table, which represents the top of layer 2. Layer 2 thickness ranges from 8.6 to 43.3 m, with an average of 18.7 m. Layers three, four, and five are below layer two and are pierced by current at their maximum electrode spacing. Figure 4 displays the resistivity, thickness, and depth distribution data of the uppermost aquifer.



Error = 1.68%

N	ρ	h	d	Alt
1	698	4.215	4.215	-4.215
2	3392	13.85	18.07	-18.065
3	910.2	25.26	43.33	-43.325
4	1842	81.55	124.9	-124.88
5	3025			

Error = 2.66%

N	ρ	h	d	Alt
1	381	2.09	2.09	-2.095
2	822	17.2	19.3	-19.26
3	1872	95	114	-114.3
4	1129			

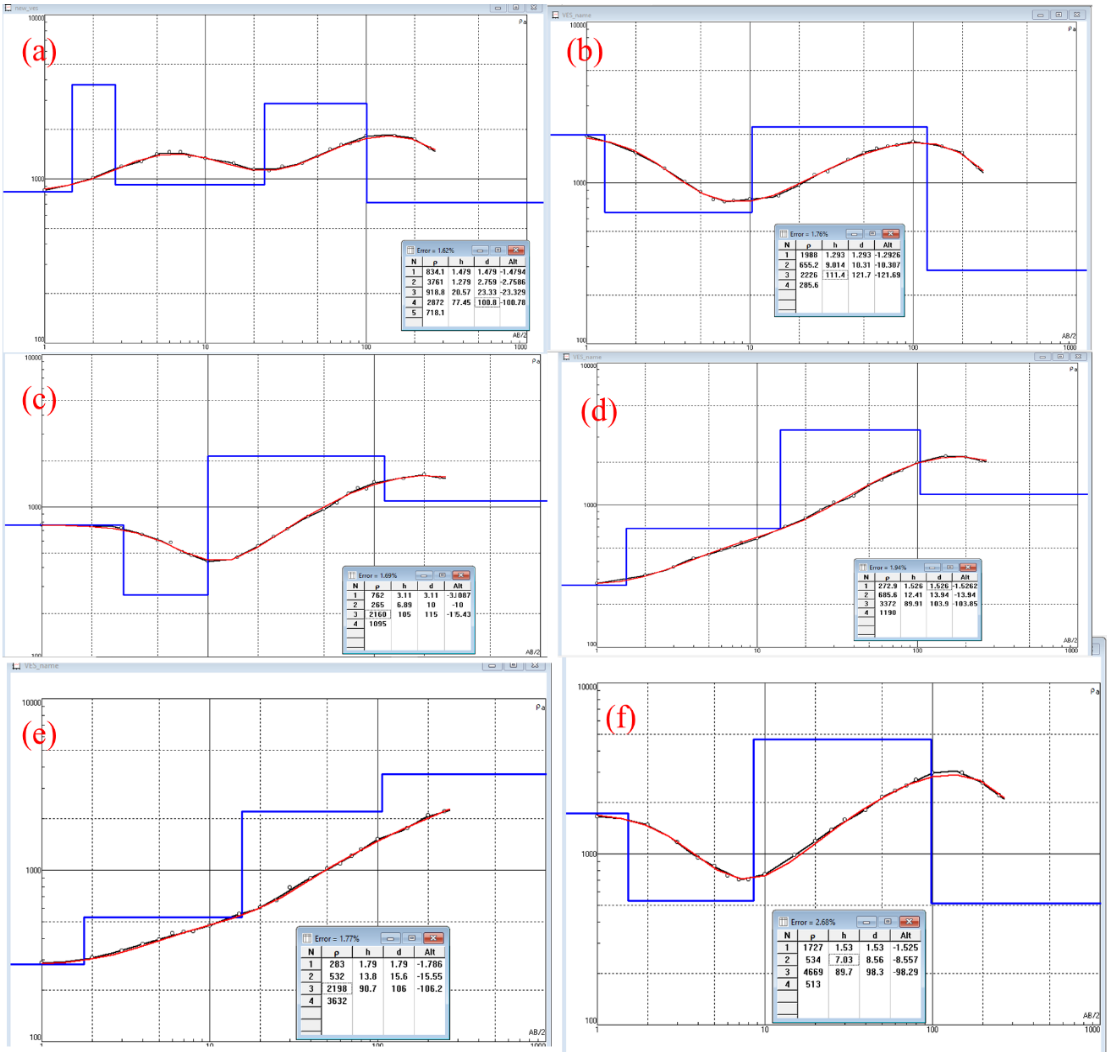
Error = 2.48%

N	ρ	h	d	Alt
1	506	2.84	2.84	-2.84
2	344	9.1	11.9	-11.94
3	1194	104	116	-116
4	2225			

Error = 1.45%

N	ρ	h	d	Alt
1	588.9	1.462	1.462	-1.4621
2	3126	2.482	3.944	-3.9442
3	883.4	26.72	30.67	-30.669
4	4006	90.72	121.4	-121.39
5	1332			

Figure 2: Interpreted VES curve at (a)VES 1 (Akabuka), (b)VES 2 (Omoku), (c) VES 3 (Ogbidi) and (d)VES 4 (Ogbogu)



(a) Error = 1.62%

N	ρ	h	d	Alt
1	834.1	1.479	1.479	-1.4794
2	3761	1.279	2.759	-2.7586
3	918.8	20.57	23.33	-23.329
4	2872	77.45	100.8	-100.78
5	718.1			

(b) Error = 1.76%

N	ρ	h	d	Alt
1	1988	1.293	1.293	-1.2926
2	655.2	9.014	10.31	-10.307
3	2226	111.4	121.7	-121.69
4	285.6			

(c) Error = 1.69%

N	ρ	h	d	Alt
1	762	3.11	3.11	-3.1087
2	265	6.89	10	-10
3	2160	105	115	-115.43
4	1095			

(d) Error = 1.94%

N	ρ	h	d	Alt
1	272.9	1.526	1.526	-1.5262
2	685.6	12.41	13.94	-13.94
3	3372	89.91	103.9	-103.85
4	1190			

(e) Error = 1.77%

N	ρ	h	d	Alt
1	283	1.79	1.79	-1.786
2	532	13.8	15.6	-15.55
3	2198	90.7	106	-106.2
4	3632			

(f) Error = 2.68%

N	ρ	h	d	Alt
1	1727	1.53	1.53	-1.525
2	534	7.03	8.56	-8.557
3	4669	89.7	98.3	-98.29
4	513			

Figure 3: Interpreted VES curve at (a)VES 5 (Ndoni), (b) VES 6 (Obagi) (c) VES 7 (Obite), (d) VES 8 (Mgbede) (e) VES 9 (Ikiri) (f) VES 10 (Ebocha)

4.2 Distribution of Aquifer Resistivity, Thickness and Depth

Figure 4 shows the distribution of aquifer resistivity, aquifer thickness, and aquifer depth throughout the research region. ArcGIS software was used to build the picture map with information gathered from the data. The effect of water on the resistivity of geologic units is shown by the inferred trend in the resistivity distribution map (figure 4a). Current flows preferentially along paths with low resistivity, indicating areas where fluid may be temporarily or permanently trapped in the pores of rocks or soils. The resistivity of the shallowest aquifers ranges from 265 to 919Ωm. The plot in fig 4a shows that Ndoni and Akabuka VES have relatively high values of bulk resistivities, indicating the presence of less conductive materials such as clay or silt, whilst lower resistivity values (like Obite and Ogbidi) may indicate the presence of more conductive materials such as sand or gravel. The thickness map is similar to the depth map since thickness increases proportionally with depth as seen in fig. 4b and 4c. These claims are congruent with the findings (Ibuot et al., 2019; George, 2020).

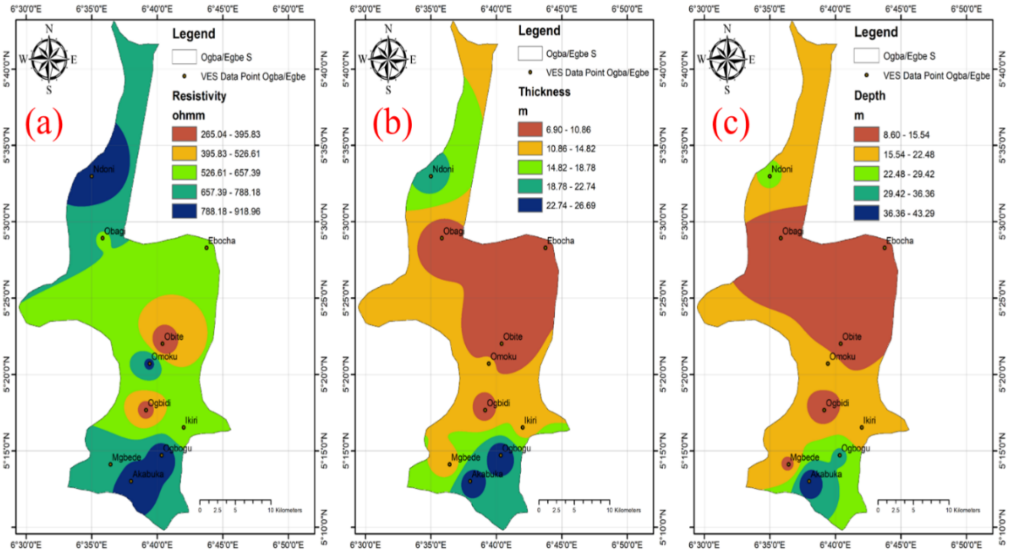


Figure 4: Image map showing distribution of (a) Aquifer resistivity, (b) Aquifer thickness, and (c) Aquifer depth within the research area.

4.3 Distribution of Hydraulic Parameters in the Study Area

Figure 5 a, b, and 6 a, b depict the map distributions of hydraulic conductivity, transmissivity, longitudinal conductivity, and transverse resistance for the shallowest aquifers. The hydraulic conductivity map (figure 5a) indicates low to moderate values across the research region. VES 3 (Ogbidi) and VES 7 (Obite) have the maximum hydraulic conductivity. Transmissivity (figure 5a) and transverse resistance (figure 6b) are geoelectric parameters that are connected. Whereas transmissivity is a metric used to quantify the capacity of a porous media, such as soil or rock, to convey usually water, transverse resistance indicates the amount of groundwater potential. Gheorghe considered transmissivity to be aquifer potential (Gheorghe, 1978). High potentiality of the hydrogeological unit is a result of both high transmissivity and high transverse resistance values (Tables 3 and 5). Transmissivity and transverse resistance are shown by the maps in Figures 5b and 6b, respectively. Figure 6a displays longitudinal conductance, which is a clear sign of the aquifer's ability to provide protection. The investigated aquifers exhibit good ground water potential; nevertheless, because of the relatively low longitudinal conductance of the aquifer covering (0.004-0.6218 Siemens), the protective capacity of the entire aquifer system is poor. This means the aquifer is an open aquifer system and vulnerable to contaminants.

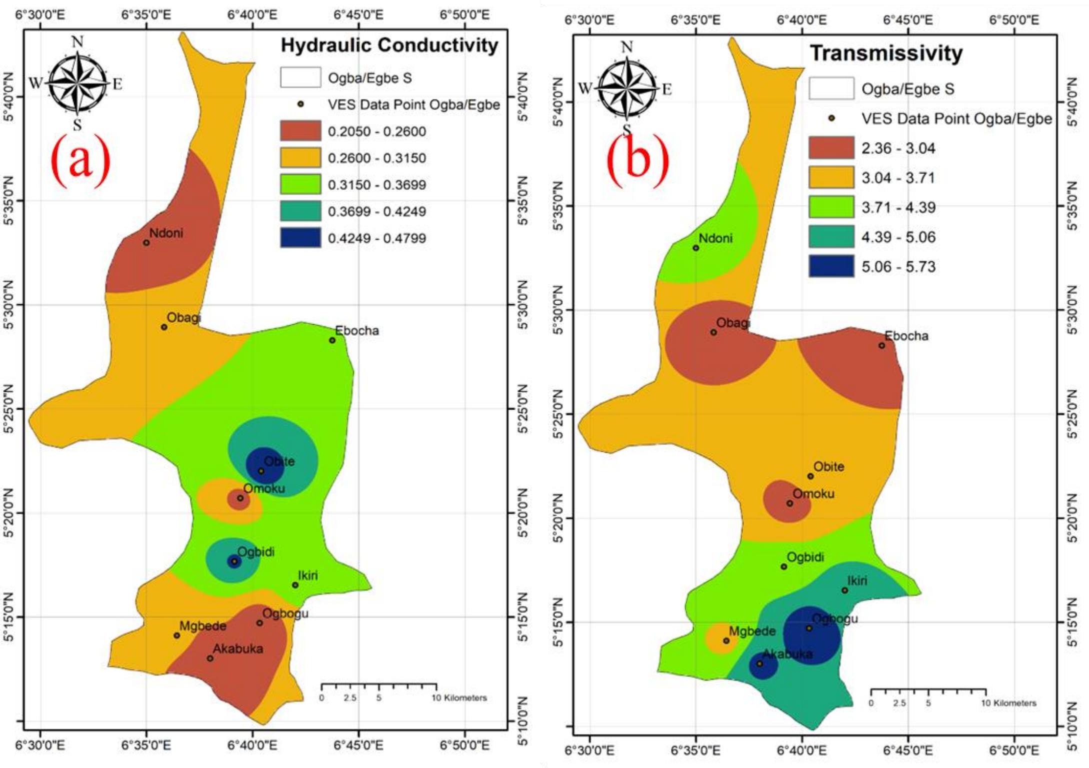


Figure 5: The map of (a) hydraulic conductivity distribution and (b) transmissivity of the shallowest aquifers

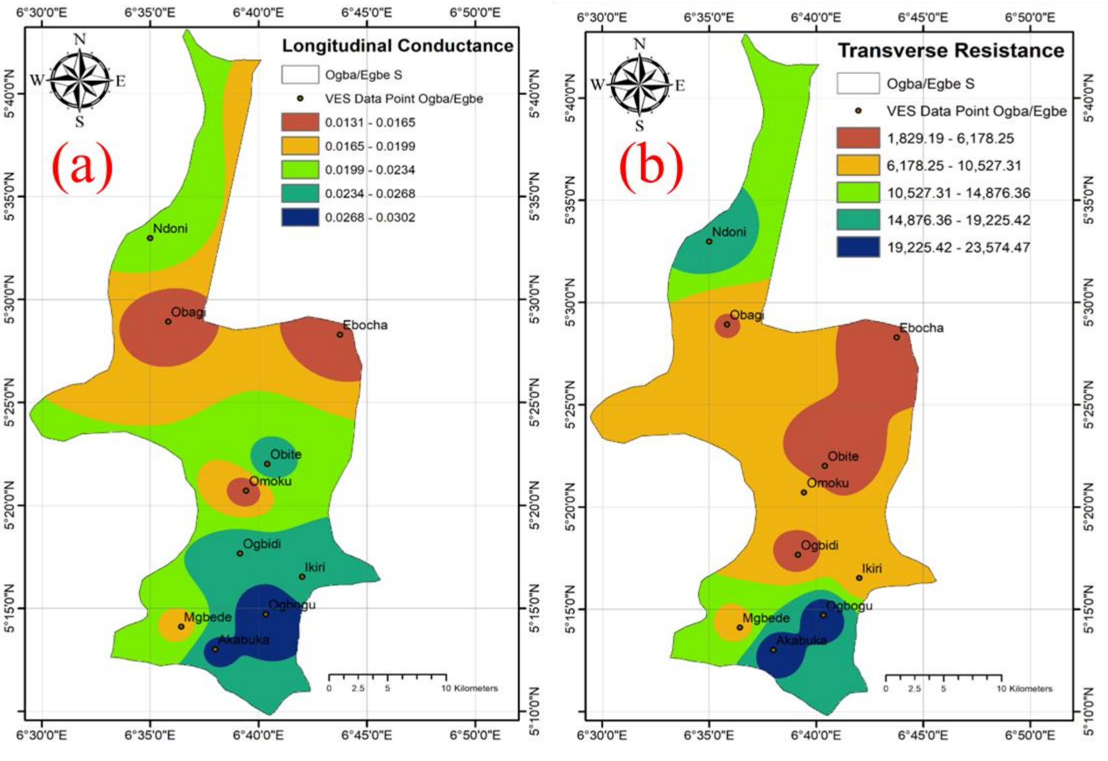


Figure 6: Image map showing (a) Longitudinal Conductivity (b) and Transvers Resistance of the topmost aquifer in the open aquifer system.

Table 1: Summary of Vertical Electrical Sounding (VES) results in the studied locations.

VES No.	Location	Layer Resistivity Ωm)					Layer thickness (m)				Layer Depth (m)				
		ρ_1	ρ_2	ρ_3	ρ_4	ρ_5	h_1	h_2	h_3	h_3	d_1	d_2	d_3	d4	Curve Type
1	Akabuka	698	3392	910	1842	3025	4.2	13.8	25.3	81.55	4.2	18.1	43.3	125	KHA
2	Omoku	381	822	1872	1129	…	2.1	11.2	95	…	2.1	19.3	114	…	AK
3	Ogbidi	506	344	1194	225	…	2.8	9.1	11.9	…	2.8	11.9	116	…	HK
4	Ogbogu	589	3126	883	4006	1332	1.5	2.5	26.7	90.7	1.5	3.9	30.7	121.4	KHK
5	Ndoni	834	3761	919	2872	718	1.5	1.3	20.6	77.5	1.5	2.8	23.3	101	KHK
6	Obagi	1988	655	2226	285	…	1.2	9	111.4	…	1.3	10.3	121.7	…	HK
7	Obite	762	265	2160	1095	…	3.1	6.9	105	…	3.1	10	115.4	…	HK
8	Mgbede	273	686	3372	1190	…	1.5	12.4	89.9	…	1.5	13.94	103.9	…	AK
9	Ikiri	283	532	2198	3632	…	1.8	13.8	90.7	…	1.8	15.6	106	…	AA
10	Ebocha	1727	534	4669	513	…	1.5	7	89.7	…	1.5	8.6	98.3	…	HK

Table 2: Actual and calculated hydrokinetic properties of the aquifer

VES NO	Location	Resistivity	Thickness	Depth	Longitudinal Conductance	Transverse Resistance	Hydraulic Conductivity	Transmissivity
1	Akabuka	910	25.3	43.3	0.027802	23023	0.207	5.246
2	Omoku	822	11.2	19.3	0.013625	9206.4	0.232	2.604
3	Ogbidi	344	9.1	11.9	0.026453	3130.4	0.433	3.938
4	Ogbogu	883	26.7	30.7	0.030237	23576.1	0.215	5.734
5	Ndoni	919	20.6	23.3	0.022415	18931.4	0.205	4.222
6	Obagi	655	9	10.3	0.013740	5895	0.289	2.600
7	Obite	265	6.9	10	0.026037	1828.5	0.480	3.309
8	Mgbede	686	12.4	13.94	0.018075	8506.4	0.277	3.440
9	Ikiri	532	13.8	15.6	0.025939	7341.6	0.339	4.677
10	Ebocha	534	7	8.6	0.013108	3738	0.338	2.366
	Mean	**655**	**14.2**	**18.694**	**0.021740**	**10517.7**	**0.3015**	**3.8136**
	Range	**265-919**	**6.9-26.7**	**8.6-43.3**	**0.013109-0.030237**	**1828.5-23576.1**	**0.205-0.48**	**2.366-5.734**

4.4 Aquifer Protectivity and Potential Capacity

Table 5 shows the aquifer's protective capacity and potential rating within the study location. In order to determine the aquifer's protective capacity, longitudinal conductance analysis was performed in the layers above the aquifer at different sounding locations, employing the classification method introduced (Oladapo et al., 2004). Transmissivity criteria, as outlined by Krasny for assessing groundwater supply potential, are detailed in table 4 (Krasny, 1993). It is crucial to remain cognizant that all sounding points indicate poor protective capacities alongside good groundwater potential suitable for minor withdrawals. A low rating of groundwater supply potential suggests that the groundwater is suitable for minor withdrawals, such as local water supply for individual use, but is inadequate for withdrawals of significant regional importance or even for smaller regional or local water supply needs (e.g., small community, industrial plants, etc.).

Table 3: Protective Capacity Rating of Longitudinal Conductance (Oladapo et al., 2004).

Longitudinal Conductance	Protective capacity Rating
>10.00	Excellent
5 .00 -10.00	Very Good
0.70 -4.90	Good
0.20 -0.69	Moderate
0.10 – 0.19	Weak
< 0.10	Poor

Table 4: Transmissivity Standards (Krasny, 1993).

Transmissivity (m2/ day)	Designation	Groundwater Supply Potential
1000	Very high	Withdrawal of significant regional significance
100 – 1000	High	Withdrawal of less significant regional content
10 – 100	Intermediate	Withdrawal of the nearby water source for the plants, small town, etc.
1 – 10	Low	Minor withdrawals for private use of the nearby water supply
0.1 – 1	Very Low	Withdrawal of the local water supply for personal use
< 0.1	Impermeable	Finding local water sources is challenging.

Table 5: Aquifer System Protective Capacity (ASPS) & Potential Rating

VES	Location	Transverse resistance R (Ωm^2)	Longitudinal conductance S (mhos)	ASPC rating	Transmissivity (m^2/day)	Designation
1	Akabuka	39403	0.0476	Poor	5.246	Low
2	Omoku	15864.6	0.0235	Poor	2.604	Low
3	Ogbidi	4093.6	0.0346	Poor	3.938	Low
4	Ogbogu	27108.1	0.0346	Poor	5.734	Low
5	Ndoni	21412.7	0.0253	Poor	4.222	Low
6	Obagi	6746.5	0.0157	Poor	2.600	Low
7	Obite	2650	0.0377	Poor	3.309	Low
8	Mgbede	9562.84	0.0203	Poor	3.440	Low
9	Ikiri	8299.2	0.0293	Poor	4.677	Low
10	Ebocha	4592.4	0.0161	Poor	2.366	Low

4.5 Lithogy Logs from ONE 1 (5°23'32.7"N, 6°40'36.3"E) and ONE 2 (5°25'30.2"N 6°41'14.2"E).

The lithologic logs from borehole drilling core samples for Obrikom and Lamb Ranch are presented in Figure 7 (a) and (b) respectively. In Figure 7 (a), the lithology of the research area, as determined by hand lens observation of drill cuttings, is described from top to bottom as follows: Top Lateriste Soil (Redish) with a thickness of 6m, Silty Clay (Greyish) with a thickness of 3m, Fine/Medium Sand (Whitish) with a thickness of 21m, Coarse Sand (Brownish) with a thickness of 24m, Clay Sand (Dark) with a thickness of 36m, and Medium Sand (Brownish) with a thickness of 60m. The best shallowest aquifer is Fine/Medium Sand (Whitish) with a thickness of 21m and ranges from 9m to 30 m. The combination of porosity, permeability, particle size, chemical stability, and thickness makes the whitish Fine/Medium Sand a desirable aquifer material capable of storing and transmitting groundwater effectively.

In Figure 7 b (ONE 2), the lithological sequence consists of Silty Laterite (Light Red) with a thickness of 3m, followed by Fine Sand (Light Brown) with a thickness of 3m, Whitish Medium Coarse Sand with a thickness of 9m, Brownish Very Coarse Sand with a thickness of 21m, and White Brownish Gravelly Sand with a thickness of 24m, ending with Coarse Sand Whitish with a thickness of 12m. Based on this sequence, the aquifer in this location is most likely the Whitish Medium Coarse Sand, which is 9m thick and is situated between depths of 6 to 15m.

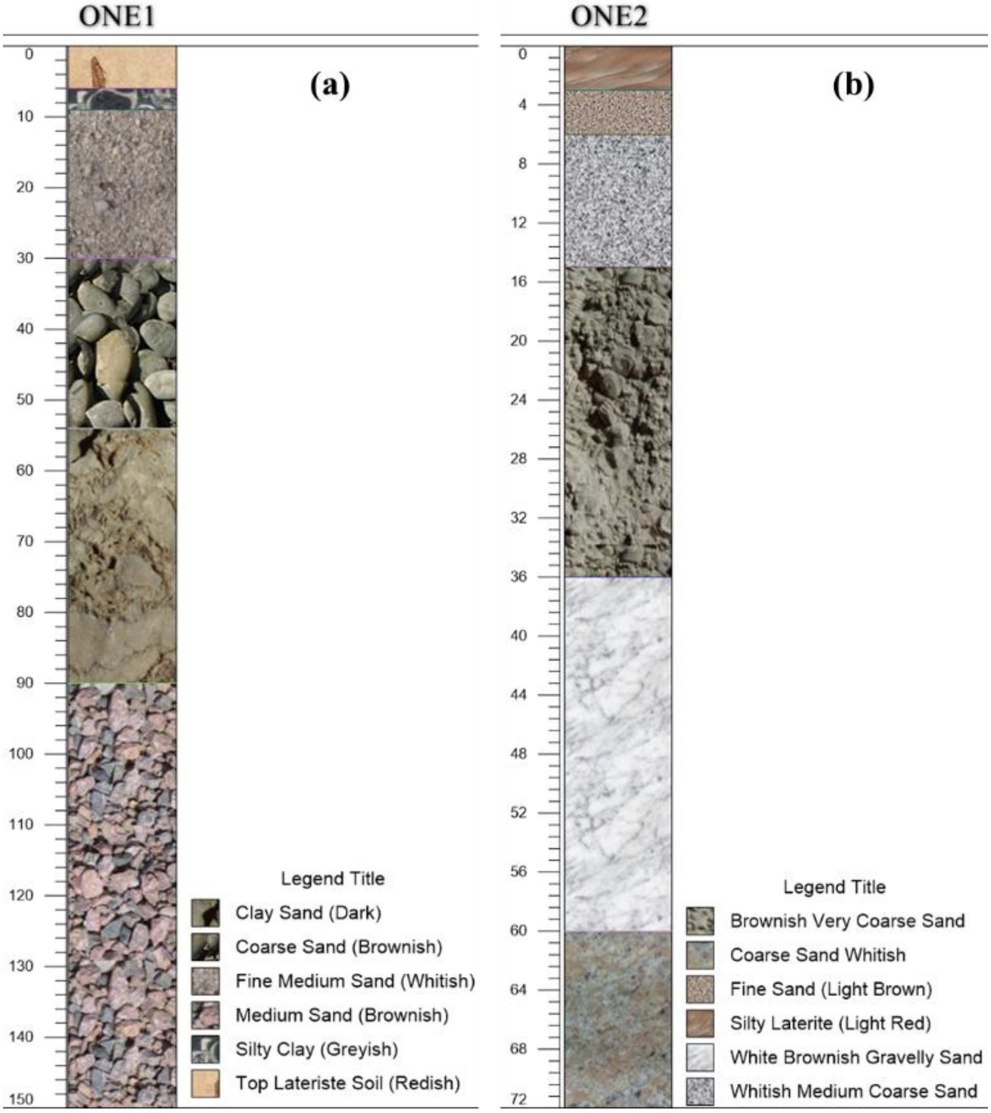


Figure 7: Lithologic Logs from the borehole drilling core samples for (a) Obrikom (b) Lamb Ranch

5. CONCLUSION

The investigation into the groundwater potentials and vulnerability of ONELGA in Rivers State, Nigeria, has been successfully completed. The study utilized a geo-sounding approach, specifically the 1-D vertical electrical sounding (VES), to evaluate primary and secondary hydrogeological attributes and characterize ONELGA's groundwater reserves. Ten VES surveys were conducted utilizing the Schlumberger arrangement, employing maximum electrode spacing for current of AB/2 between 100 and 300 meters. The ABEM Terameter SAS 300 B resistivity meter, along with associated equipment, was chosen for data acquisition due to the greater reliability of the SAS (Signal Averaging System) compared to single-shot systems. Data interpretation involved both manual methods and the utilization of computer-based VES modeling software called IPI2win. ArcGIS software was employed to generate contour and rating maps for the identified parameters.

Hydrokinetic parameters, including longitudinal conductivity, transmissivity, transverse resistance, and hydraulic conductivity, were derived from geoelectrical parameters obtained during fieldwork. The study uncovered several aquifer parameters for assessing groundwater conditions, such as transmissivity (ranging from 2.366 to 5.734 m^2/day), transverse resistance/aquifer potential scale (ranging from 1828.5 to 23576.1 Ωm^2), and hydraulic conductivity (ranging from 0.205 to 0.480 meters per day). The longitudinal electrical conductivity coefficient (which ranges from 0.013109 to 0.030237 Siemens) indicates that these measurements point to favorable groundwater potential but insufficient protection. The lithological logs from borehole drilling core samples at Obrikom and Lamb Ranch exhibit distinct sequences, with the optimal shallowest aquifer being Fine/Medium Sand (Whitish), measuring 21 meters thick and ranging from 9 to 30 meters in depth.

Additionally, at Lamb Ranch, the aquifer likely consists of Whitish Medium Coarse Sand, approximately 9 meters thick, situated between depths of 6 to 15 meters. The aquifers display promising groundwater extraction potential but poor protection from both the VES and well logging analysis. Given the significant residential interest in the area due to economic activities, it is recommended to implement effective waste disposal measures to prevent the infiltration of leachates and other wastes into the vulnerable hydrogeological units storing groundwater. Additionally, water from boreholes in the region should undergo treatment before domestic use, especially for drinking, to mitigate vulnerability to organic and inorganic pollutants, serving as a precautionary measure against waterborne diseases.

REFERENCES

Adeniji, A.E., Obiora, D.N., Omonona, O.V., and Ayuba, R., 2013. Geoelectrical evaluation of groundwater potentials of Bwari basement area, Central Nigeria. International Journal of Physical Sciences, 8 (25), Pp. 1350–1361.

Akpan, A.E., Ugbaja, A.N., and George, N.J., 2013. Integrated geophysical, geochemical and hydrogeological investigation of shallow groundwater resources in parts of the Ikom-Mamfe Embayment and the adjoining areas in Cross River State, Nigeria. Environmental Earth Sciences.

Carrard, N., Foster, T., and Willetts J., 2019. Groundwater as a source of drinking water in Southeast Asia and the Pacific: A multi-country review of current reliance and resource concerns. Water, 11 (8), Pp. 1605. https://doi.org/10.3390/w11081605

Ekanem, A.M., George, N.J., Thomas J.E., and Nathaniel, E.U., 2019. Empirical relations between aquifer geohydraulic–geoelectric properties derived from surficial resistivity measurements in parts of Akwa Ibom State, Southern Nigeria. Natural Resources Research.

Ekanem, K.R., George, N.J., and Ekanem, A.M., 2022. Parametric characterization, protectivity and potentiality of shallow hydrogeological units of a medium-sized housing estate, Shelter Afrique, Akwa Ibom State, Southern Nigeria. Acta Geophysica, 70, Pp. 879–895. https://doi.org/10.1007/s11600-022-00737-3

Foster, S., Chilton, J., Nijsten, G., and Richts, A., 2013. Groundwater—a global focus on the 'local resource'. Current Opinion in Environmental Sustainability, 5 (6), Pp. 685–695. https://doi.org/10.1016/j.cosust.2013.10.010

George, N.J., 2020. Appraisal of hydraulic flow units and factors of the dynamics and contamination of hydrogeological units in the littoral zones: A case study of Akwa Ibom State University and its Environs, Mkpat Enin L.G.A, Nigeria. Natural Resources Research. https://doi.org/10.1007/s11053-020-09673-9

George, N.J., Akpan, A.E., and Akpan, F.S., 2017. Assessment of spatial distribution of porosity and aquifer geohydraulic parameters in parts of the Tertiary – Quaternary hydrogeoresource of South-Eastern Nigeria. NRIAG Journal of Astronomy and Geophysics, 6, Pp. 422–433.

Gheorghe, A., 1978. Processing and synthesis of hydrological data. Abacus Press June Bridge Wells, Kent, Pp. 122–136.

Hodlur, G.K., Dhakate, R., and Andrade, R., 2006. Correlation of vertical electrical sounding and borehole-log data for delineation of saltwater and freshwater aquifers. Geophysics, 71 (1), Pp. 12JF-Z15. https://doi.org/10.1190/1.2169847

Ibanga, J.I., and George, N.J., 2016. Estimating geohydraulic parameters, protective strength, and corrosivity of hydrogeological units: A case study of ALSCON, Ikot Abasi, Southern Nigeria. Arabian Journal of Geosciences. https://doi.org/10.1007/s12517-016-2390-1

Ibuot, J.C., Aka, M.U., Inyang, N.J., and Agbasi, O.E., 2022. Georesistivity and physicochemical evaluation of hydrogeologic units in parts of Akwa Ibom State, Nigeria. International Journal of Energy and Water Resources. Advance online publication. https://doi.org/10.1007/s42108-022-00191-3

Jaja, G.E., Davies, O.A., and Baatee, V., 2021. Geophysical Investigation on the Depth of Saline/Fresh Water in Sandy Islands in Parts of Rivers State, Nigeria. International Journal of Scientific and Research Publications, 11 (8), Pp. 82. https://doi.org/10.29322/IJSRP.11.08.2021.p11613

Jumbo, E.B., Uko, E.D., and Tamunobereton-ari, I., 2021. Groundwater level distribution in Bonny Local Government Area, Rivers State, Nigeria. International Journal of Scientific Research in Physics and Applied Sciences, 9 (5), Pp. 5–15.

Kogbe, C.A., 1989. Review of the stratigraphy, sedimentation and structure of the Niger Delta. In Geology of Nigeria (2nd ed., pp. 311–324).

Kouli, M., Lydakis-Simantiris, N., and Soupios, P., 2007. GIS-based aquifer modeling and planning using integrated geoenvironmental and chemical approaches. Technological Educational Institute of Crete, Department of Natural Resources and Environment, Crete, Greece.

Krasny, J., 1993. Classification of transmissivity magnitude and variation. Groundwater, 31, Pp. 230–236. https://doi.org/10.1111/j.1745-6584.1993.tb01815.x

Niwas, S., Tezkan, B., and Israil, M., 2011. Aquifer hydraulic conductivity estimation from surface geoelectrical measurements for Krauthausen test site, Germany. Hydrogeology Journal, 19 (2), Pp. 307–315. https://doi.org/10.1007/s10040-010-0689-7

Okiongbo, K.S., and Oborie, E., 2015. Investigation of relationships between geoelectric and hydraulic parameters in a Quaternary alluvial aquifer in Yenagoa, Southern Nigeria. Ife Journal of Science, 17 (1), Pp. 163–172.

Oladapo, M.I., Mohammed, M.Z., Adeoye, O.O., and Adetola, B.A., 2004. Geoelectrical investigation of the Ondo state housing corporation estate Ijapo Akure, Southwestern Nigeria. Journal of Mining and Geology, 40 (1), Pp. 41–48.

Oladunjoye, M., and Jekayinfa, S., 2015. Efficacy of Hummel (Modified Schlumberger) Arrays of Vertical Electrical Sounding in Groundwater Exploration: Case Study of Parts of Ibadan Metropolis, Southwestern Nigeria. International Journal of Geophysics, Pp. 24. https://doi.org/10.1155/2015/612303

Short, K.C., and Stauble, A.J., 1967. Outline of geology of Niger Delta. American Association of Petroleum Geologists Bulletin, 51, Pp. 761–779.

Tamunobereton-ari, I., Alabraba, M.A., Ngeri, A.P., Amakiri, A.R.C., 2018. Litho-Hydraulic Effects on Groundwater Safety in Parts of Rivers State, Niger Delta, Nigeria. Journal of Scientific and Engineering Research, 5 (2), Pp. 263-274.

Tamunobereton-ari, I., Amakiri, A.R.C., and Ngeri, P.A., 2015. Pollution Risk of Groundwater in Rivers State: A Function of Lithology and Pollutant Load of the Area. Asian Journal of Science and Technology, 6 (10), Pp. 1852-1859.

Tamunobereton-ari, I., Omubo-Pepple, V. B., and Amakiri, A.R.C., 2014. Characterization and Delineation of Aquifer in Part of Omoku, Rivers State, Nigeria. IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG), 2 (4), Pp. 30-37.

Thomas, J.E., George, N.J., Ekanem, A.M., and Nsikak, E.E., 2020. Electrostratigraphy and hydrogeochemistry of hyporheic zone and water-bearing caches in the littoral shorefront of Akwa Ibom State University, Southern Nigeria. Environmental Monitoring and Assessment, 192 (7), Pp. 505. https://doi.org/10.1007/s10661-020-08436-6

Wakode, H.B., Baier, K., Jha, R., and Azzam, R., 2018. Impact of urbanization on groundwater recharge and urban water balance for the city of Hyderabad, India. International Soil and Water Conservation Research, 6 (1), Pp. 51-62.

Zohdy, A.A.R, Eaton, G.P., and Mabey, D.R., 1974. Application of Surface Geophysics to Groundwater Investigations, Techniques of Water Resources Investigations, United States Geological Survey (USGS), Chap. D1, Book 2, Pp. 66.