Evaluation of Resistivity Data for Delineating Potential Potable Water Accumulation Zone at Choba, Rivers State Nigeria

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ABSTRACT

This study employs the evaluating of resistivity curve for delineating subsurface geologic information at Long Tennis Field at the University of Port Harcourt, using vertical electrical sounding (VES) and the geoelectric section depicted in the accompanying image, five distinct lithological layers' topsoil, coarse sand, clay, gravel, and conglomerate were identified based on their resistivity values and thickness. The resistivity profile exhibits an A-type curve, indicating a progressive increase in resistivity with depth, which is characteristic of stratification within the Benin Formation of the Niger Delta Basin. Notably, the highly resistive layer at approximately 90m depth, as shown in the image, suggests a potential uncontaminated aquifer, making it a viable target for groundwater extraction. Conversely, the third layer, exhibiting the lowest resistivity, may indicate the presence of conductive materials due to increased moisture content or contamination. The findings of this research are significant for groundwater exploration, environmental assessments, and infrastructure development, offering crucial insights into lithological variations that influence fluid movement and retention. Additionally, the study underscores the importance of geophysical methods in evaluating subsurface conditions for sustainable urban planning and hydrogeological investigations. The image reinforces the interpretation of subsurface variations, visually illustrating the resistivity distribution across depths. Future work should incorporate borehole validation and hydrochemical analyses to improve aquifer characterization and ensure optimal groundwater utilization. These findings contribute to the broader understanding of sedimentary dynamics within the Niger Delta region, enhancing geotechnical stability assessments and supporting effective land-use strategies.

Keywords: resistivity, delineating, subsurface, vertical electrical sounding (VES), hydrogeological, potable water.

INTRODUCTION

The continuous demand for sustainable development, water resource management, and infrastructural stability (Nnurum et al., 2025) has made near-surface geophysical investigations increasingly important in geoscience and engineering disciplines. Among these, the electrical resistivity method stands out as one of the most widely used non-invasive techniques for probing the Earth's subsurface. It has proven highly effective in mapping stratigraphic boundaries, detecting aquifer systems, characterizing soil and rock properties, and delineating geologic structures such as faults and voids (Udoh et al., 2023; Loke, 2001; Telford et al., 1990).

The method is based on the principle that different subsurface materials exhibit varying resistivity depending on their composition, porosity, moisture content, and saturation levels (Nnurum et al., 2025). Materials such as dry sands and gravels typically have high resistivity values, whereas clays and saturated zones exhibit lower resistivity. However, DC resistivity measurements are carried out with electrodes. This way, the ratio between measured voltage and injected current is independent of the ground resistance of the electrodes. However, the estimation of the electrode resistance may be important in some situations (Oghonyon and Edeh, 2024). By measuring the apparent resistivity across an array of electrodes placed at the surface, a vertical or lateral image of subsurface features can be generated. The measured electrical response is influenced by the resistivity of the various subsurface materials. Materials with high water content, such as saturated sands and gravels, typically exhibit lower resistivity values compared to drier formations or those containing clay minerals. By analyzing the collected data and employing specialized software, geophysicists can create a model of the subsurface resistivity distribution, providing valuable insights into geological formations and water content (Oghonyon *et al*, 2024). This technique, when applied with precision, offers a cost-effective and environmentally friendly alternative to invasive drilling, particularly in urban or institutionally sensitive areas such as university campuses (Evwienure et al., 2025; Sharma, 1997; Dahlin, 2001).

In this context, the Lawn Tennis Field at the University of Port Harcourt provides an ideal location for resistivity-based subsurface investigations. The field, located within a dynamic urban campus environment, may be subject to both natural geologic processes and anthropogenic modifications such as landscaping, drainage systems, and infrastructure development (Nnurum et al., 2021). Understanding the subsurface condition of this area is vital for several reasons: it enhances knowledge of the local geologic framework, aids in safe infrastructural planning (Nnurum et al., 2021), and contributes to environmental monitoring and groundwater resource assessments.

Furthermore, this study is also driven by academic motivation, serving as a practical training opportunity for undergraduate and graduate geoscience students to apply theoretical knowledge to real-world field conditions. The resistivity curve generated during this study will be analyzed to interpret the depth, thickness, and composition of subsurface layers. Particular attention will be given to identifying zones of weathered material, compact sands, and potential aquifer units, which are commonly found in the Benin Formation underlying this region.

The Niger Delta's shallow subsurface is known for its heterogeneity, influenced by fluvial-deltaic depositional processes (Nnurum et al., 2024). Therefore, resistivity profiling becomes essential in distinguishing between such complex units. This work, through careful interpretation of resistivity data, contributes to the growing repository of subsurface geologic knowledge of the University environment and its surroundings, ultimately supporting better planning, management, and scientific understanding.

Geologic Settings

The University of Port Harcourt is geographically situated within Choba Town, Obio/Akpor Local Government Area of Rivers State, in the south-southern part of Nigeria. Geologically, this area lies within the Niger Delta Sedimentary Basin, one of the most prolific hydrocarbon-producing basins in Africa. The basin itself evolved during the Late Cretaceous to Recent periods through a combination of tectonic subsidence and sedimentary infilling associated with the opening of the South Atlantic Ocean (Reijers, 2011; Doust & Omatsola, 1990).

The litho-stratigraphy of the Niger Delta Basin comprises three major formations, namely;

1. Akata Formation (deep marine shales) – Paleocene to Recent, the summary of it is shown in the table below in Table 2.
2. Agbada Formation (alternating sands and shales) – Eocene to Recent, summary is shown in Table 3.
3. Benin Formation (continental sands and gravels) – Miocene to Recent as seen in Table 1 below and summary of Benin formation in Table 4.

The University of Port Harcourt is underlain predominantly by the Benin Formation, which is the most superficial and widely exposed unit in the area. The Benin Formation is a non-marine fluviatile sequence made up of coarse- to medium-grained sands, gravel, pebbles, ferruginous sandstone, silty clay, and intermittent clay horizons (Short & Stauble, 1967). This formation, often exceeding 2000 meters in thickness, plays a crucial role as a major aquifer system within the region due to its high porosity and permeability.

In the study area as seen in Figure 1, the Lawn Tennis Field subsurface stratigraphy is typically characterized by a lateritic topsoil followed by sandy or silty clay layers, underlain by medium to coarse sands, and potentially gravels at greater depths. This pattern reflects the depositional environment of the Benin Formation, which was shaped by fluvial and alluvial processes during delta progradation. The presence of lateritic crust on the surface also indicates prolonged exposure and weathering, common in tropical humid zones such as southern Nigeria (Orajaka, 1975; Nnurum et al., 2025).

Moreover, the terrain of the University environment is relatively flat with gentle slopes, contributing to poor surface drainage in some locations, which can influence the resistivity response due to moisture accumulation. The hydrogeologic regime of the area is dominated by shallow unconfined aquifers that are recharged seasonally. Groundwater is typically encountered at depths ranging from 10 to 30 meters, depending on the local topography and lithological variations. Clay lenses within the sands can locally cause perched water tables or impede vertical percolation.

From a geophysical standpoint, the lateral and vertical heterogeneity of the subsurface materials leads to distinct resistivity contrasts, which are essential for interpreting resistivity curves. Sandy and gravelly units exhibit higher resistivity values, while clayey and water-saturated layers yield lower resistivity responses. Therefore, the geological framework of the Benin Formation within the Lawn Tennis Field provides an excellent setting for resistivity studies aimed at identifying lithological interfaces, aquifer zones, and potential engineering hazards.

Table 1: shows the stratigraphy sequence of the Niger Delta (from Short and Stauble, 1967)

Formation	Lithological Description	Age	Thickness(m)
Benin	Loose continental sands, and gravels.	Miocene - Recent	0 – 2100
Agbada	Paralic sequence of sand and shales	Eocene – Miocene	2100 – 4500
Akata	Pro delta marine shales and clays with some turbidite sand bodies	Paleocene – Recent	4500 – 6000

Table 2: summary of Akata Formation

Features	Description
Age	Paleocene to Recent
Lithology	Predominantly dark grey to black shales, with minor silts and sands
Environment	Deep marine, pro delta to distal delta front
Position	Lies beneath the Agbada formation
Thickness	Can exceed 7000m in the basin depocenter
Source Rock	Main source rock for hydrocarbons in the Niger Delta
Depositional Settings	Marine transgression over continental crust during early basin subsidence

Table 3: summary of Agbada Formation

Features	Description
Age	Eocene to Miocene
Lithology	Alternating layers of sandstones, siltstones, and shales
Environment	Deltaic to shallow marine (fluvio-deltaic system)
Position	Lies above Akata formation and below Benin Formation
Thickness	Can exceed 4500m in the central delta depocenter
RESERVOIR ROLE	Main reservoir rock for hydrocarbons in the Niger Delta
Depositional Settings	Transition zone between continental (Benin Fm.) and marine (Akata Fm.)
HYDROCARBON SYSTEM	Traps hydrocarbon generated in Akata Formation; excellent reservoir seal pairing
POROSITY/PERMEABILITY	High in sandstone units; ideal for hydrocarbon storage and flow

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Table 4: summary of Benin Formation

Features	Description
Age	Miocene to Recent
Lithology	Predominantly coarse-grained, unconsolidated continental sandstones
Environment	Continental/fluvial- deposited by river channels and flood plains
Position	Lies above Agbada Formation
Thickness	Can exceed 2000m in places
RESERVOIR ROLE	Act more as an aquifer
Depositional Settings	Alluvial plain and upper delta plain facies
HYDROGEOLOGICAL ROLE	Major fresh water aquifer in the Niger Delta
cementation	Generally poorly consolidated, with little to no cementation

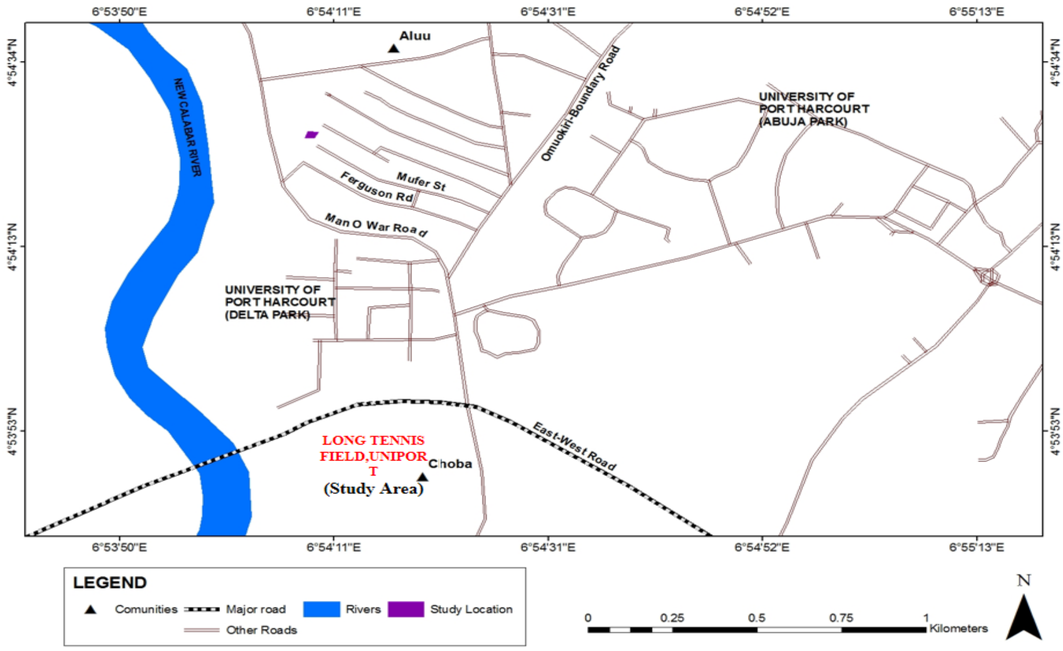

Figure 1: The location map of the study area

METHODOLOGY

The electrical resistivity survey employed the Vertical Electrical Sounding (VES) method, using the Schlumberger electrode array configuration. In this study, a total current electrode spacing (AB) of 200meters was adopted, corresponding to a half current electrode spacing (AB/2) of 100meters. This configuration ensures adequate depth penetration and resolution of subsurface lithological variations beneath the Choba, Rivers State Nigeria.

Data Collection: Data acquisition involved systematic expansion of the current and potential electrodes following the Schlumberger configuration. Resistivity measurements were taken at multiple depth intervals to provide comprehensive coverage of the subsurface strata. A schlumberger electrode configuration was used for resistivity measurement at different depth. The current electrode and potential electrode was systematically expanded following the array configuration mentioned above to probe deeper layers and resistivity readings were recorded for multiple depth intervals, ensuring comprehensive data coverage with minimal or negligible error while maintaining precautions.

Data Processing and Analysis: the raw resistivity data were processed using geophysical software(1P12WIN), generating apparent resistivity values and a 2D resistivity curve (Figure 1) was plotted to visualize subsurface variations. Table 1 below provided resistivity, depth, and thickness values for each identified layer. Calculation of the geometric factor (K) for each electrode spacing based on the Schlumberger array formula.

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Multiplication of the geometric factor (K) by the measured field resistance values to obtain the apparent resistivity.

After fieldwork, quality control measures were rigorously applied:

Data Organization: for Schlumberger array data, the apparent resistivity values were arranged and documented in Microsoft Word format. If Wenner array configuration had been used, the data would have been organized in Excel format.

The processed data were then imported into the geophysical interpretation software 1P12WIN to plot the apparent resistivity values against half current spacing (AB/2), thereby generating the resistivity sounding curve.

This procedure enabled identification of subsurface resistivity variations and delineation of lithological boundaries.

Limitations of this study include:

Absence of hydrochemical analysis data, which could have provided insights into groundwater quality.

Lack of well log data, as the survey was conducted prior to borehole drilling, making it a purely surface geophysical investigation.

Unavailability of biostratigraphic data, which limited detailed correlation with regional stratigraphic frameworks.

Despite these constraints, the methodology effectively provided a preliminary evaluation of subsurface conditions and potential aquifer zones, contributing valuable data for further groundwater development and geological assessment.

RESULTS

The interpretation of resistivity curve in Figure 2 begins after the acquisition of data, which is done at long tennis court field, uniport. Then it is subjected to analysis or processing of the data and to the last known as the interpretation of the data. The Table 5 below indicates the apparent resistivity, depth and thickness of the curve and the geoelectric representation was input for clearer interpretation as seen in Figure 3.

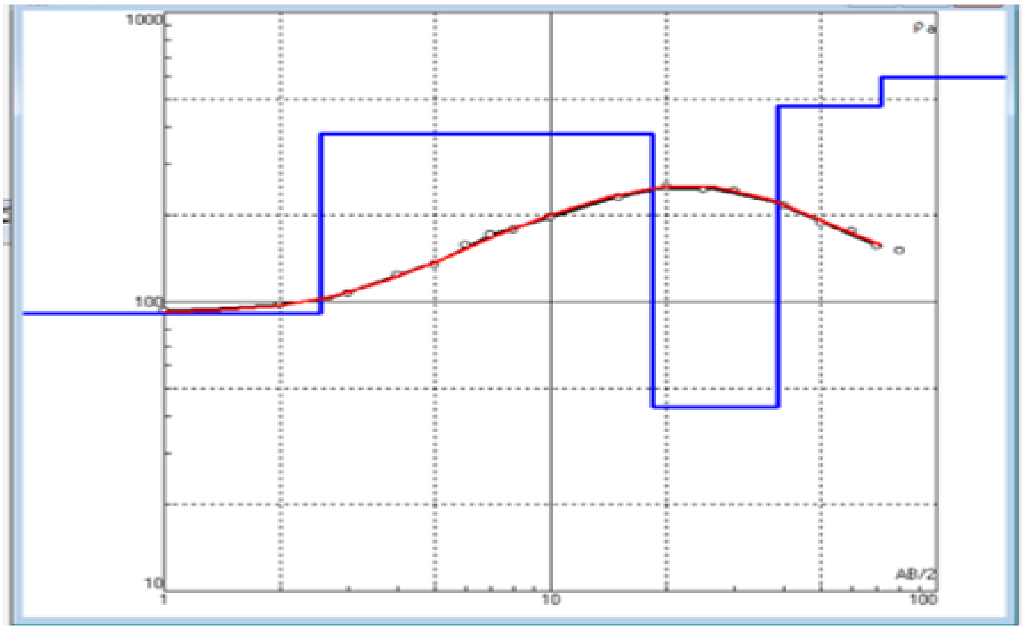

Figure 2: A vertical electrical sounding-1 curve gotten from the long tennis field, uniport.

Table 5: Table showing the apparent resistivity, depth and thickness of the curve

S/n	Resistivity (Ωm)	Depth (m)	Thickness (m)	Altitude
1	91.2	2.535	2.535	-2.5351
2	380.2	18.37	15.83	-18.366
3	43.25	38.73	20.36	-38.727
4	474.3	71.78	33.05	-71.781
5	597.1			

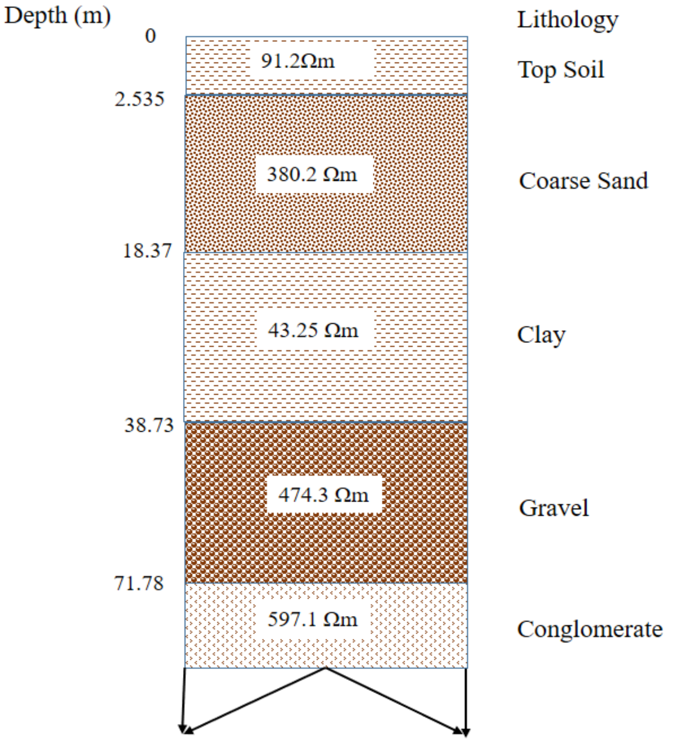

Figure 3: Geoelectric section of the Curve

DISCUSSION

The geophysical electrical resistivity method is a fundamental approach for understanding the subsurface geophysical and geological information about the subsurface lithological characteristics. The concept gives clues to the nature of the soils at depth, the depth to potential aquifer beds, the depth to variations in lithology, etc. All of these properties are interpreted from the resistivity data for subsurface evaluation. However, the resistivity data was acquired from tennis-court field, University of Port-Harcourt using the resistivity method.

The data was processed to obtain the apparent resistivity components of the layers, so that, a plot of apparent resistivity values and half-current electrode spacing values can be done using a software. The software produced a 2D resistivity curve and table of values called geophysical parameters. The parameters were used to generate a geo-electric section for evaluation.

The resistivity curve in figure 1 revealed a five (5) sub-surface stratigraphic layers and four thickness, suggesting a complex lithological structure beneath the Choba field. This vertical electrical sounding (VES) technique provides insight into varying resistivity properties of different geological formations at increasing depth. The resistivity trend is in the form of $\ell_1<\ell_2>\ell_3<\ell_4<\ell_5$. The resistivity trends observed in Figure 2 follows an A-type curve pattern, defined by progressive increase in resistivity with depth. This suggests a relatively simple layering of lithological units, where

Layer 1 has the lowest resistivity, due to surface moisture and topsoil composition.

Layer 2 exhibits a higher resistivity than both the overlying and underlying layers.

Layer 3 shows a notable drop in resistivity, indicating the presence of highly conductive materials, possibly due to contamination.

Layer 4 present a significant increase in resistivity (474.3Ωm), confirming the presence of more compact lithological formations significantly greater than layer 3(the best potential aquifer zone after layer 5).

Layer 5 has the highest resistivity value (597.1Ωm), potentially indicating the presence of highly resistive materials and may indicate the presence of a consolidated, dry rock unit or **a potential quality aquifer zone** estimated to be 105m and it is discontinuous. Inferred from adding the preceding layer's thickness to its depth.

The vertical electrical sounding (VES) method successfully delineates the subsurface lithological characteristics of the long tennis field in the university of Port Harcourt. The alternating resistivity values indicate variations in soil composition, moisture content, and possible fluid-filled layers within the geological strata.

The geoelectric section of the curve represents the subsurface composition based on electrical resistivity measurements. It provides a profile of different lithological layers each with its unique resistivity value, depth, and geological characteristics.

The topsoil, at about 2.5m depth, has a resistivity of 91.2Ωm, indicating a typical surface layer with mixed composition.

The coarse sand layer extends to around 18.4m deep, with a much higher resistivity of 380.2Ωm, suggesting a more porous and permeable formation.

The clay layer, at 38.73m, has a notably lower resistivity (43.25Ωm), characteristic of materials with high water content and low permeability.

The gravel layer, reaching 71.78m, has a resistivity of 474.3Ωm, often associated with more consolidated, permeable deposits.

The deepest layer identified as conglomerate has a resistivity of 597.1Ωm, likely indicating a mixture of rock fragments cemented together.

The least resistivity property is the third layer and this could be due to the presence of conductive materials because of a contaminant which led to the decrease in resistivity as depth increases. At a depth 90m (an estimated depth), the resistivity property is high at 597.1Ωm for delineating potential potable water accumulation. Furthermore, the fluid type elaborates the fact that, that is the depth with the highest resistivity. Having a high resistivity explains a profound knowledge of having a chance in quality aquifer free from contamination. It is advisable to cite a borehole at layer 4 (474.3Ωm).

Understanding these resistivity variations is critical for groundwater exploration, environmental assessments, and infrastructure development. The presence of potential aquifer zones at deeper depths could be promising for water resource management, but further test or verification is advisable.

This finding enhance understanding of subsurface conditions at Choba, Rivers State Nigeria.

CONCLUSION

The electrical resistivity survey conducted at the long Tennis field, university of Port Harcourt successfully delineates five subsurface layers, revealing an A-type resistivity curve. The resistivity profile provides valuable insights into the lithological and hydrogeological characteristics of the area.

The layer 3 exhibits the lowest resistivity, suggesting highly conductive materials, possibly due to contamination or clay-rich deposits wile layer 5 at 90ma n layer 4 at 71.78m depth shows the highest resistivity (597.1Ωm) and (474.3Ωm) respectively indicating a potential uncontaminated aquifer suitable for groundwater storage.

The progressive increase in depth supports the interpretation of a complex geological stratigraphy, impacting fluid movement and retention.

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