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# Geo-electric mapping of groundwater potential in Elebele, Ogbia Local Government Area, Bayelsa State, Nigeria

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## Abstract

This research presents Vertical Electrical Sounding (VES) surveys conducted in Elebele, Ogbia, Bayelsa State, Nigeria. The wok is aimed to characterize subsurface lithological layers and assess their groundwater potential using Schlumberger electrode configuration. SAS 1000 Terrameter equipment set was used to acquire the surface data, five VES points were acquired. Global Positioning System (GPS) was used to capture the coordinates. The data was processed with IPI2win software and Starter 5, revealing Four distinct geoelectric layers in the study area were delineated. VES1 identified five layers with resistivity values ranging from 160.7 Ωm in Layer 1 (0.2321 meters depth) to 1603 Ωm in Layer 5 (10 meters depth), potentially forming an unconfined aquifer. VES2 revealed five layers, including a clay confining layer at 17.3 meters (Layer 4) and a coarse sand aquifer at 24.2 meters (Layer 5). VES3 and VES4 exhibited similar layering with varying resistivity, indicating potential aquifers and confining layers at different depths. VES5 found shallow coarse sand aquifers at 0.7351 meters (Layer 2) and a productive fine to medium sand aquifer at 36.8 meters (Layer 4). Correlation with borehole data highlights the importance of subsurface geology in sustainable groundwater management. Clay layers act as confining units with water storage capacity, while sand layers serve as significant aquifers due to their good permeability. Further exploration is recommended to assess aquifer viability for groundwater extraction. Understanding subsurface geology and hydrogeological characteristics is crucial for sustainable groundwater management, particularly in regions like Elebele, Ogbia, where reliable water sources are vital for the community's well-being and development.

**Keywords:** Groundwater; Geo-Electric Mapping; Confining Layer; Subsurface

## 1. Introduction

Groundwater is a vital natural resource in numerous regions worldwide, including Elebele Ogbia in Bayelsa State, Nigeria. It serves as a lifeline for the local population, fulfilling critical roles in providing potable drinking water, supporting agricultural irrigation, and facilitating various industrial processes. However, the sustainable availability of groundwater in this region faces multifaceted challenges, primarily driven by increasing population demands and the potential impacts of environmental changes, including climate variability and land use changes (Sophocleous, 2002; Gleeson et al., 2012). As the population continues to grow, the pressure on groundwater resources intensifies, potentially leading to over-extraction and the deterioration of groundwater quality (Foster et al., 2003). Additionally, changing climatic patterns, including altered precipitation and temperature regimes, can further exacerbate groundwater stress, posing a significant threat to its long-term sustainability (Taylor et al., 2013). These challenges underscore the critical need for a systematic assessment of groundwater potential in Elebele, Bayelsa State. The proposed research seeks to address this pressing issue by employing advanced geo-electric mapping techniques. Geo-electric mapping is a powerful geophysical method that utilizes electrical resistivity to investigate subsurface structures

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and hydrogeological conditions (Mauriello et al., 2007). This technique has been successfully applied in numerous groundwater studies worldwide to identify potential aquifers, map their spatial distribution, estimate depths to groundwater tables, and assess aquifer characteristics (Nwankwoala et al., 2015; Abdullahi et al., 2020). The research will involve a comprehensive approach, encompassing data collection through geophysical surveys, data analysis, and the development of a robust groundwater potential map for the Elebele region. The resulting groundwater potential map will serve as a valuable tool for sustainable water resource management, aiding in the responsible extraction and utilization of groundwater to meet the growing demands of the population while preserving the long-term health of this vital resource. In conclusion, the proposed research initiative in Elebele, Ogbia, Bayelsa State, Nigeria, addresses a critical need for the systematic assessment and mapping of groundwater potential. This endeavor is essential for safeguarding the sustainable management and utilization of groundwater resources in the face of increasing population demands and potential environmental changes. Groundwater plays a pivotal role in supporting the livelihoods of the local population, and this research will contribute to ensuring its availability for future generations. Groundwater is a vital resource for domestic, agricultural, and industrial purposes in many regions, including Elebele in Ogbia, Bayelsa State, Nigeria. However, the availability and sustainability of groundwater in this area are poorly understood, posing significant challenges for local communities and development efforts. Therefore, the problem to be addressed in this study is: "The need for a comprehensive geo-electric mapping of groundwater potential in Elebele, Ogbia, Bayelsa State, Nigeria, in order to assess the aquifer characteristics, determine the depth and thickness of groundwater-bearing formations, and identify potential sources of freshwater for sustainable utilization and management." In light of these challenges, a comprehensive geo-electric mapping study is essential to provide valuable insights into the groundwater potential of Elebele, Ogbia, Bayelsa State, Nigeria, and lay the foundation for sustainable water resource management and development in the region.

### 1.1. Study Location

Elebele Ogbia in Bayelsa State, Nigeria, is located in (Figure 1) within Latitude 4$^0$47'15''N - 4$^0$52'30''N and Longitude 6$^o$16'45''E - 6$^0$25'0''E. The area has a good road network that links to other parts of the State and the stream present is Kolo creek. The study area will be mapped, and aquifer characteristics will be determined based on geological and hydrogeological data.

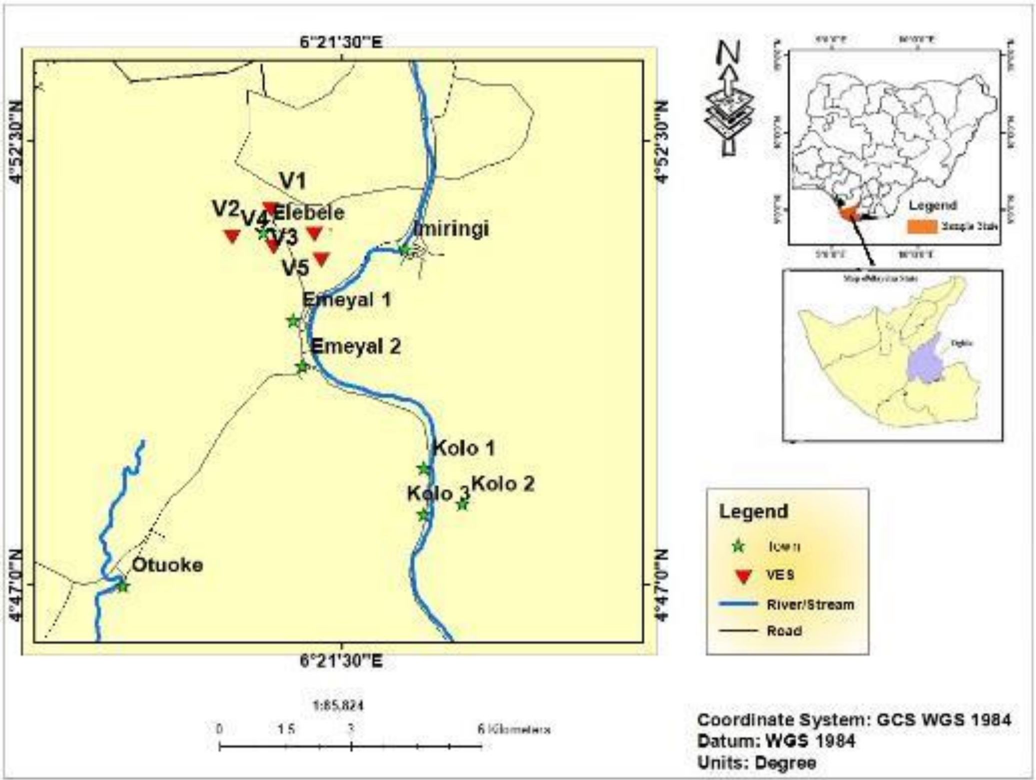


**Figure 1** Study area map

### 1.2. Geology and Stratigraphy

The geological setting of the Elebele Community falls within the Niger Delta Sedimentary Basin of Nigeria, which has been extensively studied and documented by geologists (Rayment, 2018). This sedimentary basin has undergone multiple depositional cycles throughout its geological history. One of the critical events in the formation of the Niger Delta was the Late Cretaceous (Maastrichtian) to Early Tertiary (Paleocene) Transgression. This event marked the termination of the southern advance of the upper Cretaceous proto-Niger Delta and marked the beginning of the Tertiary to Recent Niger Delta as it exists today (Rayment, 2018).

It is situated on the margin of the continent in the Gulf of Guinea in Equatorial West Africa, spanning from approximately Latitude 3° to 6° and Longitude 5° to 8°E. It covers an extensive area of about 75,000 square kilometers (Short and Stauble, 1967). The delta extends from the Calabar flank and the Abakiliki trough in Eastern Nigeria to the Atlantic Ocean. Geologists have identified three main subsurface stratigraphic units within the modern Niger Delta, namely the Akata, Agbada, and Benin Formations, arranged in order of decreasing age

## 2. Materials and Method

For the implementation of this project, a combination of fieldwork and laboratory work was employed to ensure a comprehensive approach to data acquisition and analysis. The research methodology consisted of two primary phases: fieldwork for sample collection and subsequent laboratory analysis, followed by data processing. A diverse range of materials and instruments was utilized throughout these phases, each playing a vital role in the successful execution of the study.

#### *2.1.1. Materials Utilized*

- Global Positioning System (GPS): This geolocation tool was used for precise positioning and mapping.
- Fieldnotes: These written records served as documentation of observations and findings made during fieldwork.
- Abem Terrameter SAS 1000: An advanced instrument employed for measuring electrical resistivity in subsurface layers.
- Four Electrodes: Metallic components utilized to inject current into the ground and measure potential differences.
- Measuring Tape: This tool was employed to accurately measure distances during fieldwork.
- Four Hammers: Essential instruments for securely placing electrodes into the ground.
- Battery: This power source was crucial for operating electronic equipment during field activities.

### 2.2. Data Collection

The process of gathering data involved the utilization of the Schlumberger array, a specific electrode arrangement designed for conducting Vertical Electrical Soundings (VES). In this configuration, four electrodes were organized in a linear fashion around a central point. The outer electrodes, denoted as A and B, served as current electrodes, while the inner electrodes, labeled M and N, acted as potential electrodes positioned closely together. The study encompassed the execution of Vertical Electrical Soundings using the Schlumberger array at various locations within the study area. This entailed the deployment of four electrodes aligned in a row, with the outer ones functioning as current electrodes and the inner ones as potential electrodes. The distance between these electrodes, specifically the half of the current electrode spacing (AB/2), was maintained at 80 meters. In the Elebele Community, a total of six VES profiles were conducted. During the Schlumberger array tests, the current electrode spacing was systematically increased, while the potential electrode spacing remained relatively constant. This practice ensured the acquisition of reliable measurements and data collection. The primary instrument employed for this purpose was the Abem Terrameter SAS 1000, a sophisticated device capable of digitally displaying resistance values. These values were meticulously recorded in a dedicated fieldwork journal. Additionally, the Global Positioning System (GPS) was used to ensure accurate collection of these coordinates.

### 2.3. Data Processing

The data processing phase encompassed several sequential steps aimed at extracting meaningful insights from the collected data:

- Vertical Electric Sounding Processing: To initiate this phase, three essential software tools were employed: PI2win+IP, Starter 5, and Microsoft Excel 2013. These tools facilitated the creation of sample parameter spreadsheets, which were crucial for subsequent analysis.
- Analysis Method - VES: The apparent resistivity values (ρa) obtained during fieldwork were plotted against the electrode spacing ((AB)/2) using a logarithmic scale. This process was carried out using computer software, specifically IPI2win+IP. The resulting graphs, referred to as VES sounding curves, provided valuable insights into subsurface properties.

Interpreting these field curves involved employing partial curve matching techniques. Theoretical master curves were calculated and used alongside auxiliary curves of various types (A, Q, K, and H). This approach enabled the extraction of layer parameters, which were pivotal for interpreting the sounding data. Subsequently, a one-dimensional (1-D) inversion technique was applied, utilizing the IPI2win software. This inversion technique leveraged the derived layer parameters to reconstruct subsurface properties and gain deeper insights into the geological structure.

In essence, this project harmoniously integrated fieldwork, advanced instrumentation, and sophisticated data processing techniques to unveil the intricate subsurface characteristics of the Elebele Community. The methodology involved meticulous data collection using the Schlumberger array, supported by high-precision tools like the Abem Terrameter SAS 1000 and the Global Positioning System. These efforts culminated in the systematic processing of data, unlocking valuable insights into the subsurface geology and structure of the study area

## 3. Results

The Electrical Resistivity Method is a widely used geophysical technique for assessing subsurface properties and delineating groundwater potential in various geological settings. In the case of Elebele, Ogbia, Bayelsa State, Nigeria, this method has been employed to provide valuable insights into the groundwater conditions. The data from Vertical Electrical Sounding (VES) in Elebele reveals important information about the subsurface layers and their resistivity values, thicknesses, depths, curve types, and lithology. These findings are crucial for groundwater resource management and planning in the region.

**Table 1** Apparent Resistivity, thickness and depth of VES 1 result in Elebele

| Layers | Apparent Resistivity(Ωm) | Thickness h (m) | Depth d (m) | Curve Type | Lithology |
|---|---|---|---|---|---|
| 1 | 160.7 | 0.2321 | 0.2321 | KH | Top soil |
| 2 | 335.2 | 0.864 | 1.096 | | Medium sand |
| 3 | 1.105 | 1.71 | 2.806 | | Clay |
| 4 | 14.86 | 3.682 | 6.488 | | Clay |
| 5 | 1603 | 3.5 | 10 | | Coarse sand |

**Table 2** Apparent Resistivity, thickness and depth of VES 2 result in Elebele

| Layers | Apparent Resistivity(Ωm) | Thickness h (m) | Depth d (m) | Curve Type | Lithology |
|---|---|---|---|---|---|
| 1 | 518 | 0.6 | 0.6 | | Top soil |
| 2 | 136 | 0.79 | 1.39 | | Fine sand |
| 3 | 488 | 6.09 | 7.48 | HKH | Medium sand |
| 4 | 69.3 | 9.81 | 17.3 | | Clay |
| 5 | 608 | 6.9 | 24.2 | | Coarse sand |

**Table 3** Apparent Resistivity, thickness and depth of VES 3 result in Elebele

| Layers | Apparent Resistivity(Ωm) | Thickness h (m) | Depth d (m) | Curve Type | Lithology |
|---|---|---|---|---|---|
| 1 | 25.28 | 0.6 | 0.6 | A | Top soil |
| 2 | 18.57 | 0.7897 | 1.39 | | Clay |
| 3 | 60.2 | 6.066 | 7.456 | | Clay |
| 4 | 132.1 | 9.814 | 17.27 | | Sand |
| 5 | 806 | 9.13 | 26.4 | | Coarse sand |

**Table 4** Apparent Resistivity, thickness and depth of VES 4 result in Elebele

| Layers | Apparent Resistivity(Ωm) | Thickness h (m) | Depth d (m) | Curve Type | Lithology |
|---|---|---|---|---|---|
| 1 | 12.27 | 0.6 | 0.6 | KH | Top soil |
| 2 | 27.93 | 0.7897 | 1.39 | | Clay |
| 3 | 3.347 | 1.829 | 3.219 | | Clay |
| 4 | 26.8 | 4.237 | 7.456 | | Clay |
| 5 | 533 | 6.54 | 14.01 | | Coarse sand |

**Table 5** Apparent Resistivity, thickness and depth of VES 5 result in Elebele

| Layers | Apparent Resistivity(Ωm) | Thickness h (m) | Depth d (m) | Curve Type | Lithology |
|---|---|---|---|---|---|
| 1 | 49.44 | 0.6042 | 0.6042 | KH | Top soil |
| 2 | 869.1 | 0.7351 | 1.339 | | Coarse sand |
| 3 | 40.04 | 26.37 | 27.71 | | Clay |
| 4 | 298.6 | 8.99 | 36.8 | | Fine to medium sand |

## 4. Discussion

The VES profiles from Table 1 to 5 reveal the presence of aquifer potential in several layers, primarily characterized by medium to coarse sand and, in some cases, fine sand. The clay layers, while acting as confining units, also possess significant water storage capabilities.

### 4.1. Vertical Electrical Sounding 1

From VES1, Layer 1 corresponds to the topsoil, which is characterized by relatively low resistivity (160.7 Ωm) and a shallow depth of 0.2321 meters (Table 1). This layer is typical of loose, organic-rich material found at the earth's surface, such as soil and decomposed plant matter. It does not contribute significantly to groundwater storage.

Layer 2 consists of medium sand with an apparent resistivity of 335.2 Ωm. This layer has a thickness of 0.864 meters and extends to a depth of 1.096 meters. Medium sand is known for its moderate water-holding capacity and can serve as a potential aquifer. The absence of a curve type indicates that this layer is relatively homogenous.

Layer 3 is composed of clay, as indicated by its very low resistivity of 1.105 Ωm. This layer has a considerable thickness of 1.71 meters, extending to a depth of 2.806 meters. Clay is generally impermeable and can act as a confining layer, limiting the vertical movement of groundwater. However, it may hold water within its pores, contributing to the potential for a confined aquifer.

Layer 4 is another clay layer with an apparent resistivity of 14.86 Ωm (Figure 4.1). This layer is significantly thicker, measuring 3.682 meters, and extends to a depth of 6.488 meters. Like the previous clay layer, it can restrict the movement of groundwater, possibly creating a confined aquifer zone.

Layer 5 represents coarse sand, characterized by a high apparent resistivity of 1603Ωm. This layer is relatively thick, with a thickness of 3.5 meters and a depth of 10 meters. Coarse sand typically has good water-bearing properties and may constitute a potential unconfined aquifer, allowing for the storage and movement of groundwater (Figure 3).

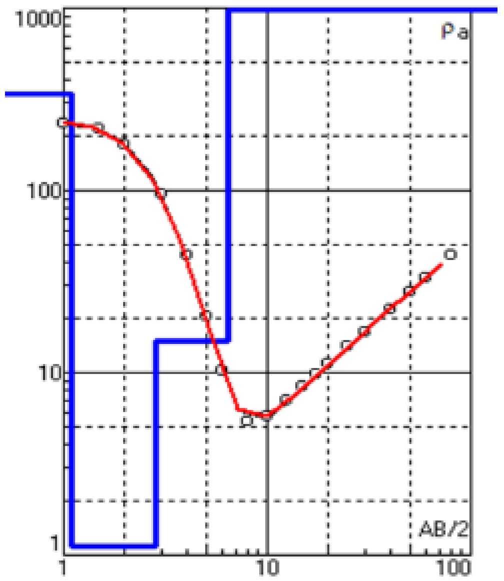


**Figure 2** Computer Modelling for VES 1

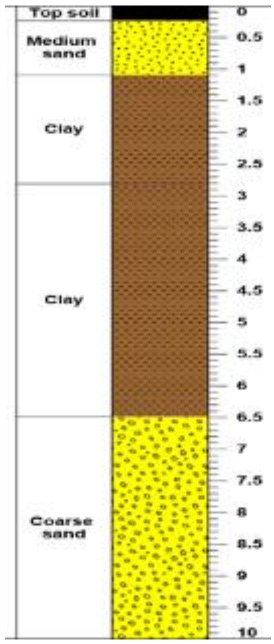


**Figure 3** Geologic section for VES 1

### 4.2. Vertical Electrical Sounding 2

Layer 1 represents the topmost layer, which is the topsoil. The apparent resistivity value of 518 Ωm indicates relatively high resistivity, typical of soil materials (Table 2). This layer is shallow, with a thickness and depth of 0.6 meters. The HKH curve type suggests a gradual increase in resistivity with depth, consistent with the expected behavior of topsoil. The topsoil is important as it can influence infiltration and recharge processes in the groundwater system. The second layer has an apparent resistivity of 136 Ωm, which is significantly lower than the topsoil. This layer is identified as "Fine Sand" and has a thickness of 0.79 meters and a depth of 1.39 meters. The lower resistivity suggests higher water content or increased porosity compared to the topsoil. Fine sand is often a favorable aquifer material, and this layer could serve as a potential source of groundwater.

Layer 3 is characterized by an apparent resistivity of 488 Ωm. It is identified as "Medium Sand" and has a substantial thickness of 6.09 meters, with a depth of 7.48 meters (Table 2). The resistivity value indicates a moderate water content, making it a potential aquifer. The thickness of this layer is encouraging for groundwater storage potential, and it could be an important source for domestic or agricultural water supply.

The fourth layer stands out with its extremely low apparent resistivity of 69.3 Ωm. Identified as "Clay," it has a thickness of 9.81 meters and a depth of 17.3 meters. Clay is known for its low permeability and limited groundwater potential (Figure 3). In this context, it can act as a confining layer, isolating the underlying aquifers from the surface and protecting them from contamination.

The fifth and final layer exhibits a remarkably high apparent resistivity of 608 Ωm, making it the most resistive layer in the VES results. It is classified as "Coarse Sand" and has a thickness of 6.9 meters, with a depth of 24.2 meters (Figure 4.4). Coarse sand typically possesses good permeability and can act as a significant aquifer.

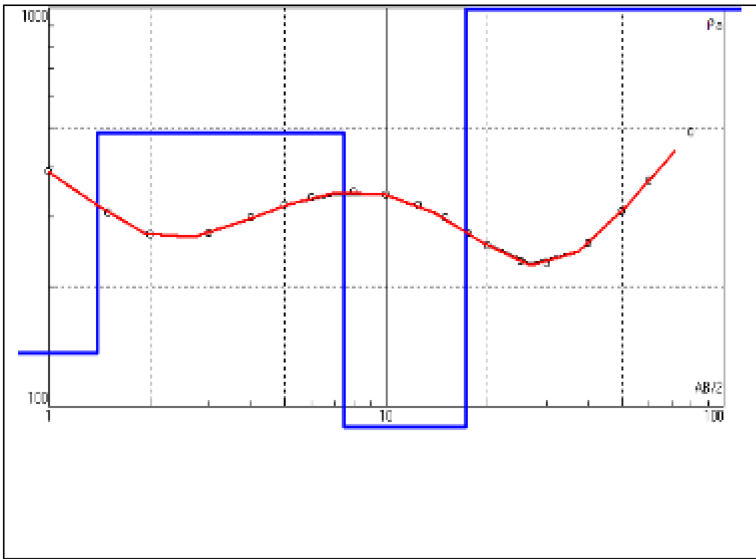


Figure 4 Computer Modelling for VES 2

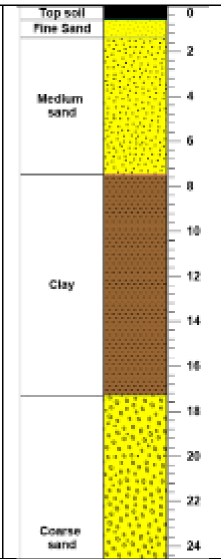


**Figure 5** Geologic section for VES 2

### 4.3. Vertical Electrical Sounding 3

Table 3 presents the apparent resistivity, thickness (h), depth (d), curve type, and lithology for each layer encountered during VES 3 in Elebele. These parameters are crucial for understanding the subsurface characteristics and the potential for groundwater occurrence.

The first layer represents the topsoil, characterized by relatively low resistivity (25.28 Ωm) and a shallow depth of 0.6 m (Figure 5). This layer consists of loose, unconsolidated materials like organic matter, sand, and clay. The low resistivity suggests high moisture content, making it unsuitable for groundwater storage.

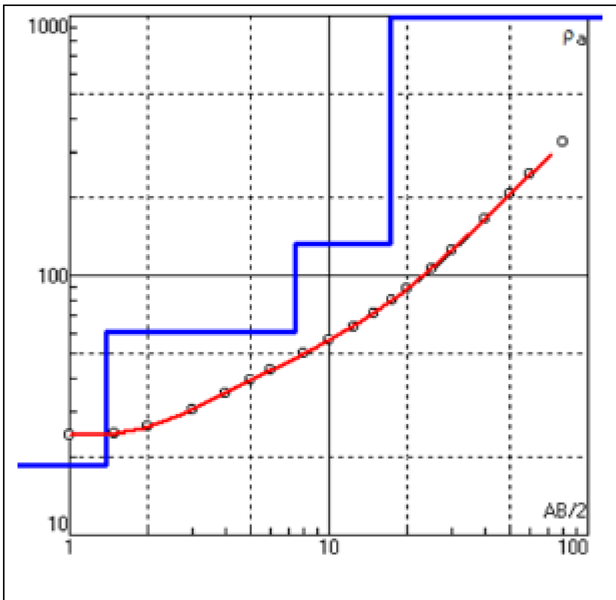


**Figure 6** Computer Modelling for VES 3

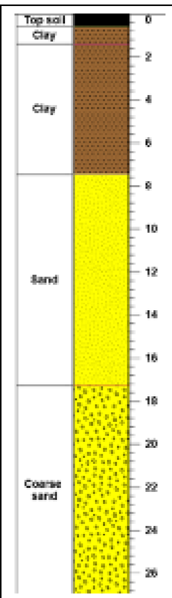


**Figure 7** Geologic section for VES 3

Layer 2 is identified as clay with an apparent resistivity of 18.57 Ωm (Table 3). This layer is relatively impermeable and may hinder groundwater movement. However, the thickness and resistivity suggest that it could serve as a confining layer that separates different aquifers.

Layer 3 also consists of clay but with higher resistivity (60.2 Ωm) and a greater thickness of 6.066 m. This layer is likely to act as a significant confining layer, further impeding the vertical movement of groundwater.

Layer 4 is composed of sand, which has a relatively higher resistivity (132.1 Ωm) compared to clay layers. The thickness of 9.814 m suggests a potentially significant aquifer (Table 3). Sand is known for its high permeability, making it a favorable layer for groundwater storage.

Layer 5 is characterized by coarse sand with a remarkably high apparent resistivity of 806 Ωm. This layer represents a potential aquifer with good storage capacity. The thickness of 9.13 m indicates a substantial water-bearing layer (Figure 7). However, the depth of 26.4 m may require deeper drilling for groundwater exploitation.

### 4.4. Vertical Electrical Sounding 4

Table 4 presents the results of Vertical Electrical Sounding (VES) 4 in Elebele, which provides critical information about the subsurface layers, their resistivity values, thickness, depth, and lithology. Let's discuss these findings and their significance in detail.

The topsoil layer has an apparent resistivity of 12.27 Ωm, which is relatively low as seen in Table 44. This indicates the presence of loose, water-saturated materials near the surface, typical of topsoil. The thickness and depth values of 0.6 m each suggest a shallow layer with a high likelihood of moisture content, making it a potentially viable source for shallow groundwater.

Layer 2 exhibits an apparent resistivity of 27.93 Ωm (Figure 7), which is higher than that of the topsoil. This increase in resistivity indicates the presence of denser, less conductive materials, which is typical of clay. The thickness of 0.7897 m and depth of 1.39 m suggest that this clay layer acts as an aquitard, limiting the downward movement of groundwater (Figure 9). However, it may also serve as a potential source of groundwater storage.

Similar to Layer 2, Layer 3 also consists of clay, with a lower apparent resistivity of 3.347 Ωm (Table 4.4). The greater thickness (1.829 m) and depth (3.219 m) suggest that this layer is thicker than Layer 2. While clay layers usually impede the flow of groundwater, their ability to store water makes them significant for potential groundwater supply.

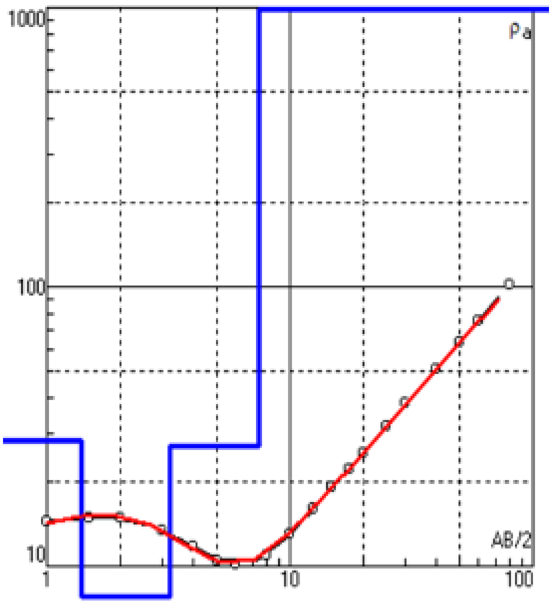


**Figure 8** Computer Modelling for VES 4

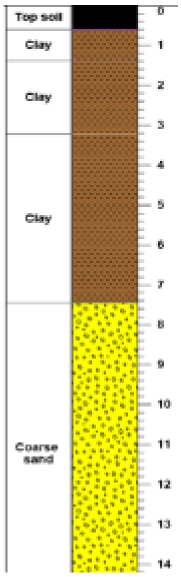


**Figure 9** Geologic section for VES 4

Layer 4 continues the trend of clay, with an apparent resistivity of 26.8 Ωm (Figure 4.7). This layer is notably thicker (4.237 m) and deeper (7.456 m) than the previous clay layers (Figure 4.8). Such thickness and depth indicate a substantial barrier to groundwater flow, but they also imply a substantial storage capacity for groundwater.

Layer 5 stands out with an apparent resistivity of 533 Ωm, significantly higher than the clay layers. This high resistivity suggests the presence of coarse, well-draining material, such as coarse sand. The substantial thickness (6.54 m) and depth (14.01 m) indicate a potential aquifer, capable of storing and transmitting groundwater efficiently (Figure 9).

### 4.5. Vertical Electrical Sounding 5

Table 5 provides valuable information obtained from VES 5, including apparent resistivity, layer thickness (h), depth (d), curve type, and lithology. Let's break down the findings:

The topsoil layer in Elebele has a relatively low resistivity of 49.44 Ωm (Table 5)., indicating its porous and conductive nature. It is essential for agricultural activities but typically unsuitable for groundwater storage due to its low thickness and limited water-holding capacity.

Layer 2 displays a significantly higher apparent resistivity of 869.1 Ωm as seen in (Figure 4.9), suggesting a more resistive material. The thickness of 0.7351 m implies the presence of a relatively shallow, coarse sand aquifer, which may have the potential for groundwater storage. This layer is of particular interest for further investigation.

Layer 3 exhibits a low apparent resistivity of 40.04 Ωm (Table 5). indicating the presence of clay. The substantial thickness of 26.37 m suggests a continuous clay layer with low permeability, which is generally unsuitable for groundwater extraction. However, clay layers can act as aquitards, confining aquifers above or below.

Layer 4 presents a resistivity value of 298.6 Ωm, indicating the presence of fine to medium sand. The thickness of 8.99 m suggests the existence of a potentially productive aquifer (Figure 11). This layer, located at a depth of 36.8 m, may hold considerable groundwater reserves.

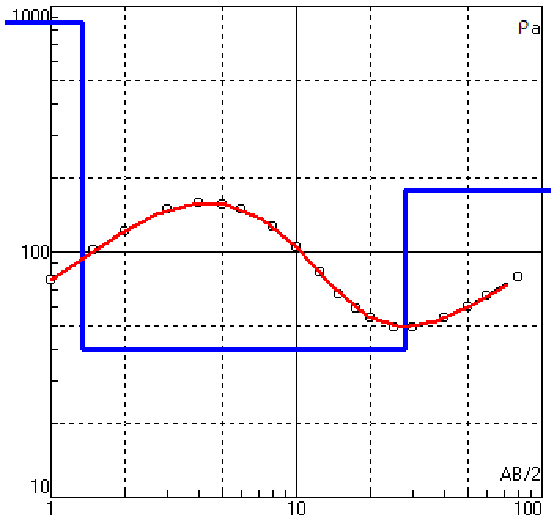


**Figure 10** Computer Modelling for VES 5

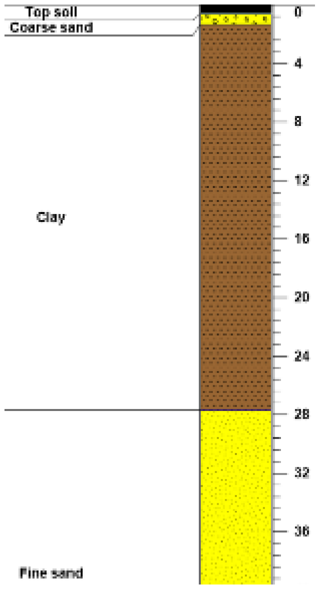


**Figure 11** Geologic section for VES 5

### 4.6. Correlation

The correlation of borehole data, as depicted in Figure 12 highlights the importance of comprehending subsurface geology and hydrogeological characteristics in Elebele. This understanding is crucial for the sustainable management of groundwater resources. Figure 12 displays various geological sections revealing variations in sedimentary layers, ranging from medium to coarse sand, and occasionally fine sand. The clay layers, serving as confining units, not only restrict water movement but also have substantial water storage capacity. Meanwhile, fine to medium and medium to coarse sand layers generally exhibit good permeability and can function as significant aquifers.

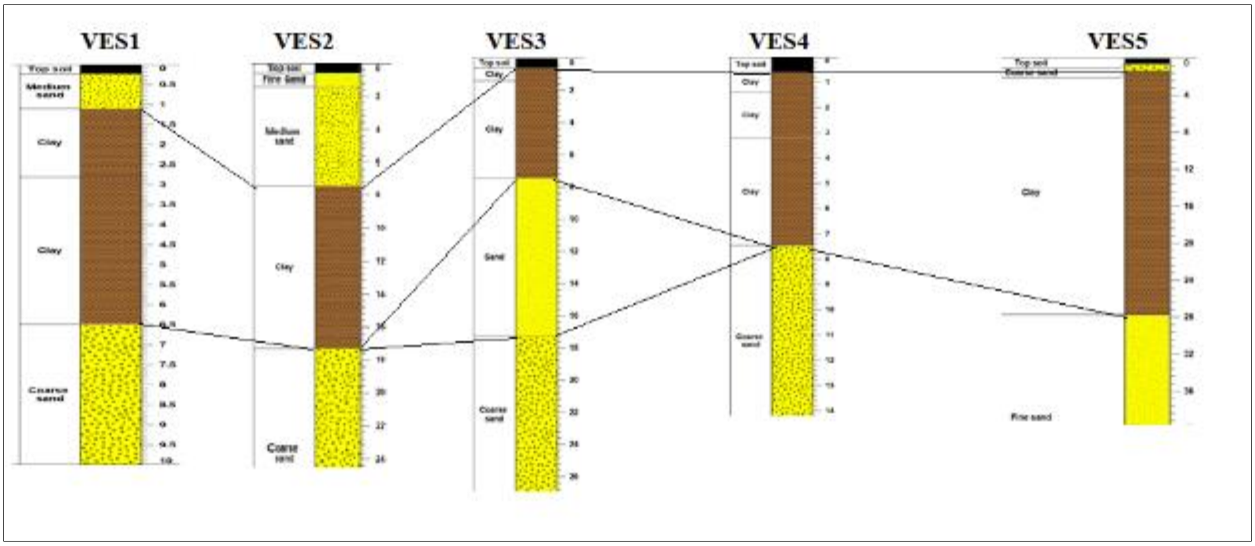


**Figure 12** Borehole log of the study area

## 5. Conclusion

The geoelectric mapping carried out in Elebele, Ogbia, Bayelsa State, Nigeria, has yielded significant insights into groundwater potential. The analysis of Vertical Electrical Sounding (VES) profiles has provided valuable information about the underground geological and hydrogeological features. These profiles have identified aquifer potential in multiple layers, primarily comprising medium to coarse sand, and occasionally fine sand. These layers are capable of storing and facilitating the movement of groundwater. The topsoil layers in all VES profiles exhibit low resistivity and are relatively shallow, consisting of loose, organic-rich materials that do not significantly contribute to groundwater storage.

Several VES profiles have revealed medium sand layers with moderate water-holding capacity, suggesting their potential as aquifers for groundwater storage. Clay layers, characterized by very low resistivity, act as confining units, limiting the vertical movement of groundwater while also retaining water within their pores, which can contribute to confined aquifers. Coarse sand layers with high resistivity demonstrate favorable water-bearing properties and may function as potential unconfined aquifers, allowing both groundwater storage and flow.

The thickness of these aquifer and confining layers is a critical factor in evaluating their capacity for groundwater storage, with thicker layers generally indicating a greater potential for groundwater retention. The depth at which these aquifer layers are located is also important for practical groundwater extraction, as deeper aquifers may require more extensive drilling.

The correlation of these findings with borehole data underscores the significance of understanding subsurface geology and hydrogeological characteristics for sustainable groundwater resource management. Variations in sedimentary layers, encompassing medium to coarse sand and occasional fine sand, highlight the diverse aquifer potential in the region.

Therefore, the VES profiles offer essential information for assessing and managing groundwater resources in Elebele. The identification of aquifer potential in various layers, coupled with an understanding of their characteristics, provides a solid foundation for making informed decisions regarding groundwater extraction and sustainability. Continuous investigation and monitoring of these aquifers are essential for effective water resource management in the area.

## Compliance with ethical standards

### *Disclosure of conflict of interest*

No conflict of interest to be disclosed.

## References


[1] Abdullahi, M. S., Ogungbenro, S. B., & Al-Arifi, N. S. (2020). Application of electrical resistivity method in groundwater exploration: A case study of the Federal University of Petroleum Resources, Effurun, Nigeria. Journal of African Earth Sciences, 164, 103875.

[2] Eteh Desmond, Francis Emeka Egobueze and Francis Omonefe. (2019): Determination of Flood Hazard Zones Using Geographical Information Systems and Remote Sensing Techniques: A Case Study in Part Yenagoa Metropolis. Journal of Geography Environment and Earth Science International 21(1): 1-9: DOI: 10.9734/jgeesi/2019/v21i130116

[3] Etu-Efeotor J.O; (1981). Preliminary hydrogeochemical investigations of surface water in part of the Niger Delta: bulletin of the Nigeria mining GeoScience Association, V.18,p.103-110

[4] Etu–Efeotor, J. O. (1997). Fundamentals of petroleum geology. Paragraphic publications, Port Harcourt, Nigeria, Press page 135.

[5] Eyankware MO, Ogwah C, Selemo AOI (2020) Geoelectrical Parameters for the Estimation of Groundwater Potential in Fracture Aquifer at Sub-Urban Area of Abakaliki, SE Nigeria. Int J Earth Sci Geophys 6:031 Volume 6, Issue 1. DOI: 10.35840/2631-5033/1831

[6] Foster, S., Loucks, D. P., & Burke, J. (2003). Groundwater recharge and sustainability in the developing world. Water Resources Management, 17(2), 73-90.

[7] Giao, P. H., Chung, S. G., Kim, D. Y., & Tanaka, H. (2003). Electric imaging and laboratory resistivity testing for geotechnical inVEStigation of Pusan clay deposits. Journal of Applied Geophysics, 52(4), 157-175. DOI: 10.1016/s0926- 9851(03)00002-8.

[8] Gleeson, T., Wada, Y., Bierkens, M. F., & van Beek, L. P. (2012). Water balance of global aquifers revealed by groundwater footprint. Nature, 488(7410), 197-200.

[9] Keller, G. V., and Frischknecht, F. C., (1966) Electrical methods in geophysical prospecting: New York, Pergamon Press, 519 p.

[10] Mauriello, P., Rizzo, E., & Lapenna, V. (2007). Geophysical methods applied to groundwater exploration in a Mediterranean karstic area: the Lesina Marina case history (southern Italy). Hydrogeology Journal, 15(1), 15-24.

[11] Nwankwoala, H. O., Nwankwo, C. N., & Eluozo, S. N. (2015). Application of electrical resistivity method to groundwater exploration in Owerri, Imo State, Nigeria. Journal of Environment and Earth Science, 5(7), 73-83.

[12] Nwokocha Charles, E.D. Uko, Ngah S.A. (2018). Aquifer Delineation in Omuma Local Government Area of Rivers State, Nigeria Using Vertical Electrical Sounding Techniques. IOSR Journal of Applied Physics (IOSR-JAP) e-ISSN: 2278-4861.Volume 10, Issue 2 Ver., PP 65-70

[13] Oborie E, Nwankwoala HO. (2012). Relationship between geoelectrical and groundwater parameters in parts of Ogbia, Bayelsa State, Central Niger Delta. Continental Journal of Earth Sciences. Vol. 7(1): 29 – 39.

[14] Oborie, Ebiegberi & Udom, Goddy & Nwankwoala, Hycienth. (2013). Geoelectrical delineation of aquifers in Yenagoa and Ogbia areas of Bayelsa State, Nigeria.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, 163-172.

[15] Offodile, ME (1992). An approach to groundwater study and development in Nigeria. Mecon Services Ltd; Jos

[16] Oki, O. A, and Eteh D. R., (2019): Application of VES for aquifer Characterization in Ishiayi Community, Ahoada West Local Government Area of Rivers State, Southern Nigeria. American Journal of Engineering Research (AJER) Vol.-8 Issue-5, pp-115-120

[17] Okiongbo K. S. and Akpofure, E. (2021) "Determination of Aquifer Properties and Groundwater Vulnerability Mapping Using Geoelectric Method in Yenagoa City and Its Environs in Bayelsa State, South South Nigeria," *Journal of Water Resource and Protection*, Vol. 4 No. 6, 2012, pp. 354-362. doi: 10.4236/jwarp.2012.46040.

[18] Ozcep, F., Tezel, O., & Asci, M. (2009). Correlation between electrical resistivity and soil-water content: Istanbul and Golcuk. International Journal of Physical Sciences, 4(6), 362-365.

[19] Rayment RA (2018) Ammonitologist sensu latissimo and founder of Cretaceous Research Bengtson. P Cretaceous Research-1926-2016,88, 5-35.

[20] Reijers, T. J. A. (2011). Stratigraphy and Sedimentology of the Niger Delta. Geologic, The Netherlands, 17(3), p.133-162

[21] Robinson Edwin S. and Cahit Coruh, (1988) Basic Exploration Geophysics," Virginia Polymeric Institute and State University, pp 445-478.

[22] Short, K.C; Stauble ,A.J (1967) Outline of the geology of the Niger Delta. Bull. AAPG. 51: 761- 779.

[23] Sophocleous, M. (2002). Interactions between groundwater and surface water: The state of the science. Hydrogeology Journal, 10(1), 52-67.

[24] Syed, B. A. B. S. O. & Siddiqui, F. I. (2012). Electrical Resistivity Based NonDestructive Testing Method for Determination of Soil's Strength Properties. Advanced Materials Research, 488-489, 1553-1557. DOI: 10.4028/www.scientific.net/AMR.488-489.1553.

[25] Taylor, R. G., Scanlon, B., Döll, P., Rodell, M., Van Beek, R., Wada, Y., ... & Richey, A. S. (2013). Ground water and climate change. Nature Climate Change, 3(4), 322-329.

[26] Udom, G.J; Esu, EO; Ekwere, SJ (1998). Quality status of groundwater in Calabar Municipality, Southeastern Nigeria. Global Journal of Pure and Applied Sciences. 4(2), pp. 163-169.