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Determination of Clay and Sand Volume Using Vertical Electrical Sounding

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Abstract:- This study presents the results of an electrical resistivity survey conducted in Agudama Epie, Yenagoa local government area, Bayelsa State, Nigeria. The primary objective of the survey was to estimate the volume of clay and sand within a rectangular land parcel measuring 100 m by 200m in the study area. The survey employed the Schlumberger electrode configuration and utilized nine vertical electrode sounding (VES) points.Data was collected using a Terrameter SAS 1000 and was processed using IPI2win software. The geophysical analysis revealed the presence of four distinct geoelectric layers across the study area, identified as layers 1 to 4 in the VES profiles. Layer 2, characterized by clay, exhibited an average thickness of 21.2 meters, while layer 3, consisting of sand, had an average thickness of 8.15 meters. The apparent resistivity values ranged from 8.45 to 79.43 ohm-meter to a depth of 10.14 meters for the clay layer and 8499.86 to 15013.11 ohm-meter to a depth of 33.5 meters for the sand layer. The study estimated a substantial presence of approximately 746,240 tonnes of clay and approximately 261,126 tonnes of sand in Agudama Epie. This discovery offers significant economic potential, including job creation, the establishment of small and medium-sized enterprises, and opportunities within the construction industry. The local extraction and processing of clay can drive economic growth and facilitate the production of concrete and building materials. Additionally, the availability of sand in the region can reduce transportation costs and stimulate local construction projects, thereby fostering economic activity and infrastructure development.

Keywords:- *Volume of Sand; Volume of Clay; Quantification; Electrical Resistivty, Electrode Configuration*

I. INTRODUCTION

Geological investigations play a crucial role in gaining a comprehensive understanding of the subsurface composition of various regions, thereby exerting a substantial influence on a range of practical applications, including urban development, construction endeavors, and efficient resource management [1]. In the current study, Agudama Epie in Yenagoa is situated in Bayelsa State, Southern Nigeria, stands out due to its distinctive geological formations, a consequence of its proximity to the coast and its Sedimentary history [2]. The accurate delineation of sand and clay volumes within this locality carries profound implications for several crucial domains, including the facilitation of urban expansion, the effective exploration of groundwater reservoirs, and the meticulous planning of land utilization patterns [3]. The scientific community has harnessed geophysical methods as invaluable tools for probing into the subsurface structures in a non-intrusive and efficient manner [2]. Among these methods, the Vertical Electrical Sounding (VES) technique has emerged as a prominent choice, widely embraced for its simplicity in deciphering lithological boundaries [4]. This technique has taken center stage in the present study, seeking to investigate its efficacy in characterizing the intricate distribution of sand and clay strata present in Agudama-Epie within the Yenagoa region by utilizing the versatility on the potentials of VES, this research endeavor not onlyto strengthen our geological insights but also fosters a more informed decision-making landscape.

The peculiar geology of Yenagoa and its environs cannot be understated, particularly in the context of its coastal adjacency and sedimentary legacy [2]. These factors have endowed the region with a diverse geological tapestry that demands meticulous scrutiny. Urban expansion plans and sustainable development efforts necessitate a comprehensive understanding of the geological composition to ensure that construction initiatives harmonize with the underlying geological conditions[5]. Moreover, the delineation of sand and clay deposits holds the key to unlocking vital groundwater reservoirs, which are pivotal for addressing water scarcity issues, especially in regions characterized by an arid climate [6]. Furthermore, the effective utilization of land resources is contingent upon a meticulous grasp of subsurface properties, enabling informed decisions regarding land allocation and usage [7]. The Vertical Electrical Sounding (VES) technique, a mainstay of geophysical exploration, is uniquely poised to meet these challenges head-on. By virtue of its non-destructive nature and ability to penetrate subsurface layers, VES holds the potential to unravel intricate geological strata, including the elusive boundaries between sand and clay [8]. This method involves the measurement of electrical resistivity variations in the subsurface, providing valuable insights into the lithological transitions and layer thicknesses[9]. By harnessing VES, this study seeks to decode the subsurface architecture of the Yenagoa region, thereby enabling us to ascertain the extent and distribution of sand and clay deposits.

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- *Physiography and Geology of the Study Area*

The area under investigation is located in Agudama Epie Community in Yenagoa Local Government, Bayelsa State. The area lies within Latitude 4058'0"N - 4056'25"N and Longitude 6o20'45"E - 6021'30"E. The area has a good road network that links to other parts of the state along Isaac Boro expressway Yenagoa, Bayelsa State. The Geology of the area is within the Niger Delta Sedimentary belt of Nigeria has been geologically described byReijers, (2011)[10]. This basin evolved through several depositional cycles. The Late Createaceous (Maastrichtian) to Early Tertiary (Paleocene) Transgression terminated the southern advance of the upper Cretaceous proto-Niger Delta and heralded the Tertiary to Recent Niger Delta as it waned.[11]. The Niger Delta is situated on the continental margin of the Gulf of Guinea in Equatorial West Africa between Latitude 3o and 6o and Longitude 5o and 8oE. It covers all areas of about 75,000Km2[12]. It extends from the Calabar flank and the Abakiliki trough in Eastern Nigeria to the Atlantic Ocean. [12] recognized three subsurface stratigraphic units in the modern Niger Delta which are, Akata Agbada and Benin Formations in order of decreasing age.

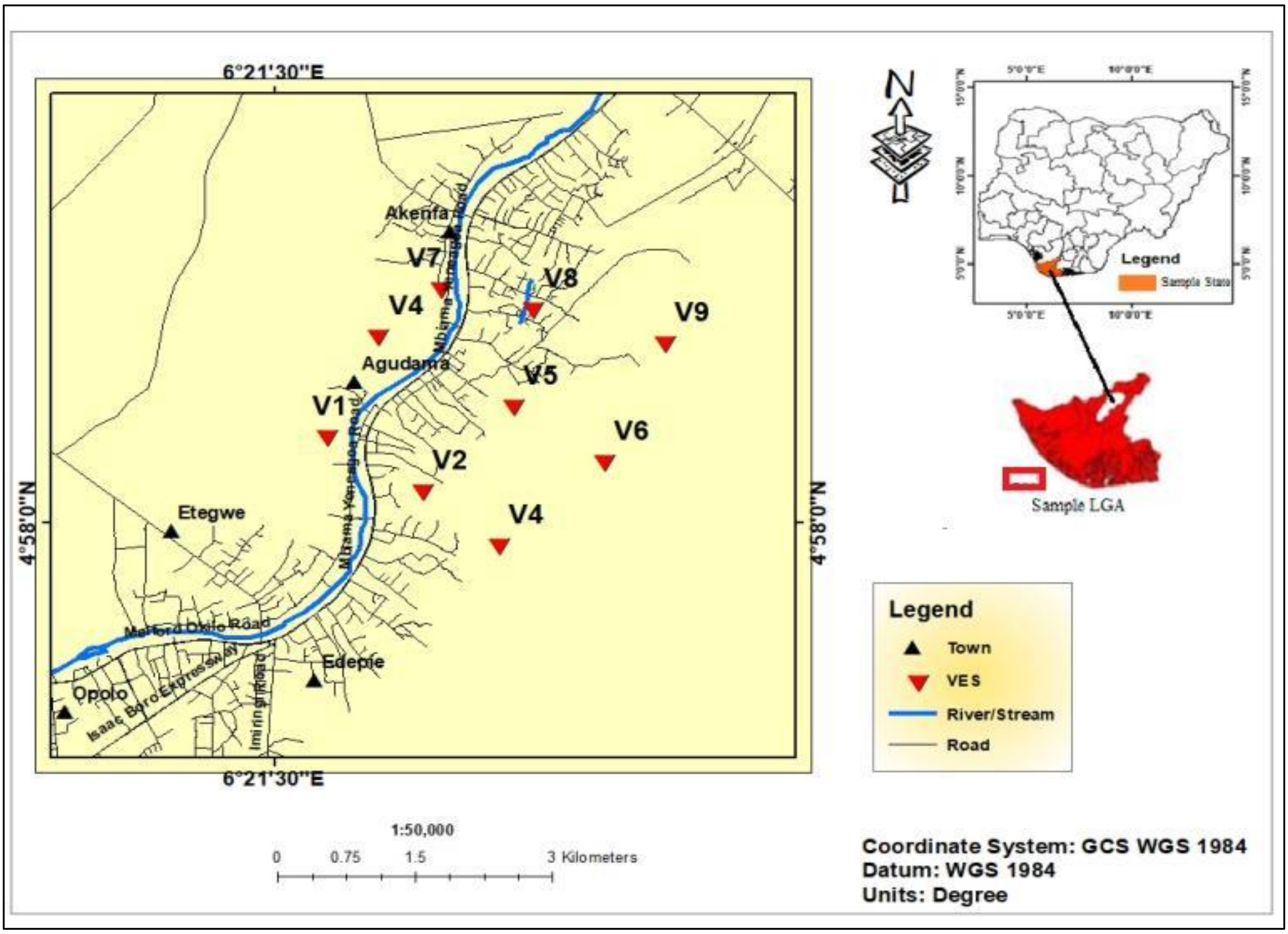

Fig 1: Map of the Study Area

II. MATERIALS AND METHOD OF STUDY

A. Materials

In the pursuit of this project, a combination of fieldwork and laboratory work was employed to ensure comprehensive data acquisition and analysis. The research methodology comprised two key phases: fieldwork involving sample collection and subsequent laboratory analysis and data processing. A wide array of materials and instruments was employed throughout these phases, each contributing to the successful execution of the study.

- *Materials Used: Include:*

- Global Positioning System (GPS): A geolocation tool used for accurate positioning and mapping.
- Fieldnotes: Written records of observations and findings made during fieldwork.
- Abem Terrameter SAS 1000: An advanced instrument for measuring electrical resistivity in the subsurface.
- Four Electrodes: Metallic components used to inject current and measure potential in the ground.
- Measuring Tape: Utilized to measure distances accurately during fieldwork.

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- Four Hammers: Tools for securely placing electrodes into the ground.
- Battery: Power source for operating electronic equipment during field activities.

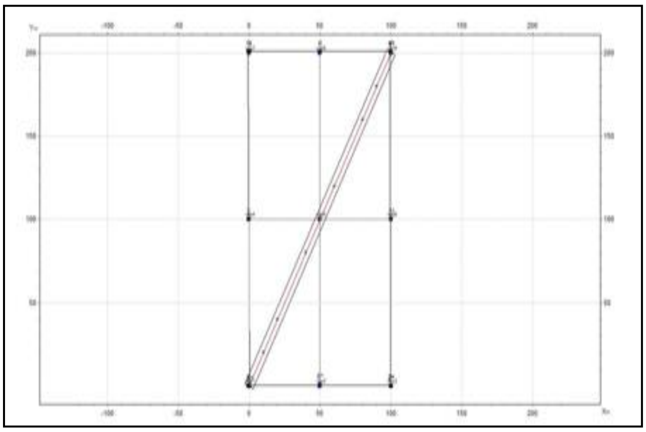
Fig 2: The Survey Grid is Measuring 100m by 200m

B. Data Collection

The data collection process involved the implementation of the Schlumberger array, a specific electrode configuration used to conduct Vertical Electrical Soundings (VES). In this configuration, four electrodes were arranged in a linear manner around a central midpoint. The outer electrodes, labeled A and B, were designated as current electrodes, while the inner electrodes, labeled M and N, served as potential electrodes placed in close proximity. The study encompassed the execution of Vertical Electrical Soundings using the Schlumberger array at various locations within the study area. This involved the deployment of four co-linear electrodes, with the outer ones functioning as current electrodes and the inner ones as potential electrodes. The distance between these electrodes, specifically the current electrode spacing (AB/2), was maintained at 80 meters, and occasionally extended to 160 meters. Nine VES profiles were conducted in the Agudama-Epie Community. During the Schlumberger array tests, the current electrode distance was systematically increased, while the potential electrode distance remained relatively constant. This practice ensured reliable measurements and data collection. The primary instrument employed for this purpose was the Abem Terrameter SAS 1000, a sophisticated device capable of displaying resistance values digitally. These values were meticulously recorded in a dedicated fieldwork journal. Additionally, the Global Positioning System (GPS) aided in the accurate collection of these coordinates.

C. Data Processing

The data processing phase encompassed several steps, primarily geared towards extracting meaningful insights from the collected data:

- **Vertical Electric Sounding Processing:** To initiate this phase, two key software tools were employed: PI2win+IP and Microsoft Excel 2013. These tools facilitated the preparation of sample parameter spread sheets essential for subsequent analysis.
- **Method of Analysis - VES:** The apparent resistivity values (ρa) obtained from the fieldwork were plotted against the electrode spacing ((AB)/2) using a logarithmic scale. This procedure was executed through the use of computer software, specifically IPI2win+IP. The resulting graphs, known as VES sounding curves, offered valuable information about subsurface properties.

The interpretation of these field curves involved the application of partial curve matching techniques. Theoretical master curves were calculated and utilized in conjunction with auxiliary curves of various types (A, Q, K, and H). This approach allowed for the extraction of layer parameters, pivotal for interpreting the sounding data. Subsequently, a one-dimensional (1-D) inversion technique was employed, utilizing the IPI2win software. This inversion technique leveraged the derived layer parameters to reconstruct subsurface properties and provide deeper insights into the geological structure.

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

➢ *Theory of Geoelectric Method Of Exploration*

- *Electrical Resistivity*

Electrical resistivity is a crucial parameter in the geoelectric method, as it provides insights into the subsurface composition and properties. It is defined as the measure of a material's resistance to the passage of electric current through it. This property plays a significant role in the behavior of natural and artificially induced electrical fields within soils [13, 14].

For a simple cylindrical body, the electrical resistivity (ρ) is determined by the formula:

$$\rho = R * A / L \quad (1)$$

Where R represents the electrical resistance (Ω), A is the cross-sectional area (m^2), and L is the length of the cylinder (m). The relationship between resistance, potential (V), and current (I) is described by Ohm's law:

$$R = V / I \quad (2)$$

This concept highlights the interplay between resistance, potential, and current in understanding electrical properties [15]. Measurement of electrical resistivity typically involves four electrodes. Two electrodes (A and B) are used to inject current into the ground, while the other

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two electrodes (M and N) record the resulting potential difference. This arrangement allows for the accurate determination of electrical resistivity values [16].

In field measurements, it is important to note that the apparent resistivity (ρa) obtained may not directly represent the true resistivity structure of the Earth. To account for this discrepancy, vertical electric sounding (VES) is employed, especially when investigating resistivity variations with depth. In VES, the electrode spacing is gradually increased from a central point to capture a more accurate depiction of subsurface resistivity [17].

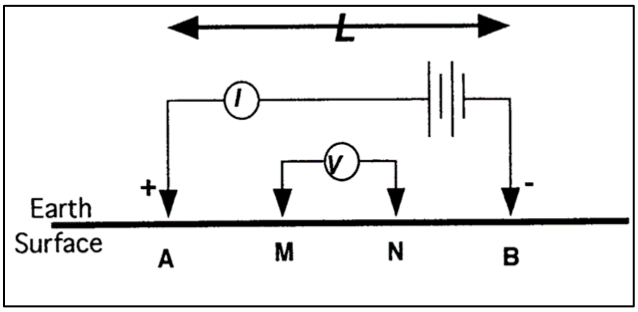

Fig 3: Schlumberger Array Configuration

Figure 4: The estimated range of resistivity values of common rock types (Keller &Frisschknecht, 1966) [9].

- AB = Currentt Electrodes
- MN= Potential Electrodes
- L= Length (m)
- I= Electric current (Ampere)
- V= Potential Difference (Volt)

For field measurement of electrical resistivity,[16] mentioned that the measured apparent resistivity will be transformed into a mode of the true resistivity structure since the apparent resistivity does not show the true resistivity structure of the Earth. Vertical Electric Sounding is used when resistivity variation with depth is of concern [4]. This method can be applied to the Vertical electrical sounding resistivity survey method.[17] explain for the VES method, the electrode spacing is gradually extended on both sides apart from the central point.

- *Relationship between Geology and Resistivity*

The geoelectric method's ability to unveil subsurface properties relies on the relationship between resistivity and geological features. Variations in electrical resistivity primarily stem from factors such as lithology, clay content, fluid content, porosity, and water saturation within rock formations. These factors influence the movement of charged particles and electric current flow in the subsurface [18].

Materials in the Earth's subsurface can be broadly categorized as conductors or insulators based on their resistivity values. Electric current primarily travels through electrolytic conduction, involving charged particles moving through groundwater-filled pores within permeable soil masses. This phenomenon underscores the significance of fluid content and porosity in controlling resistivity behavior [18].

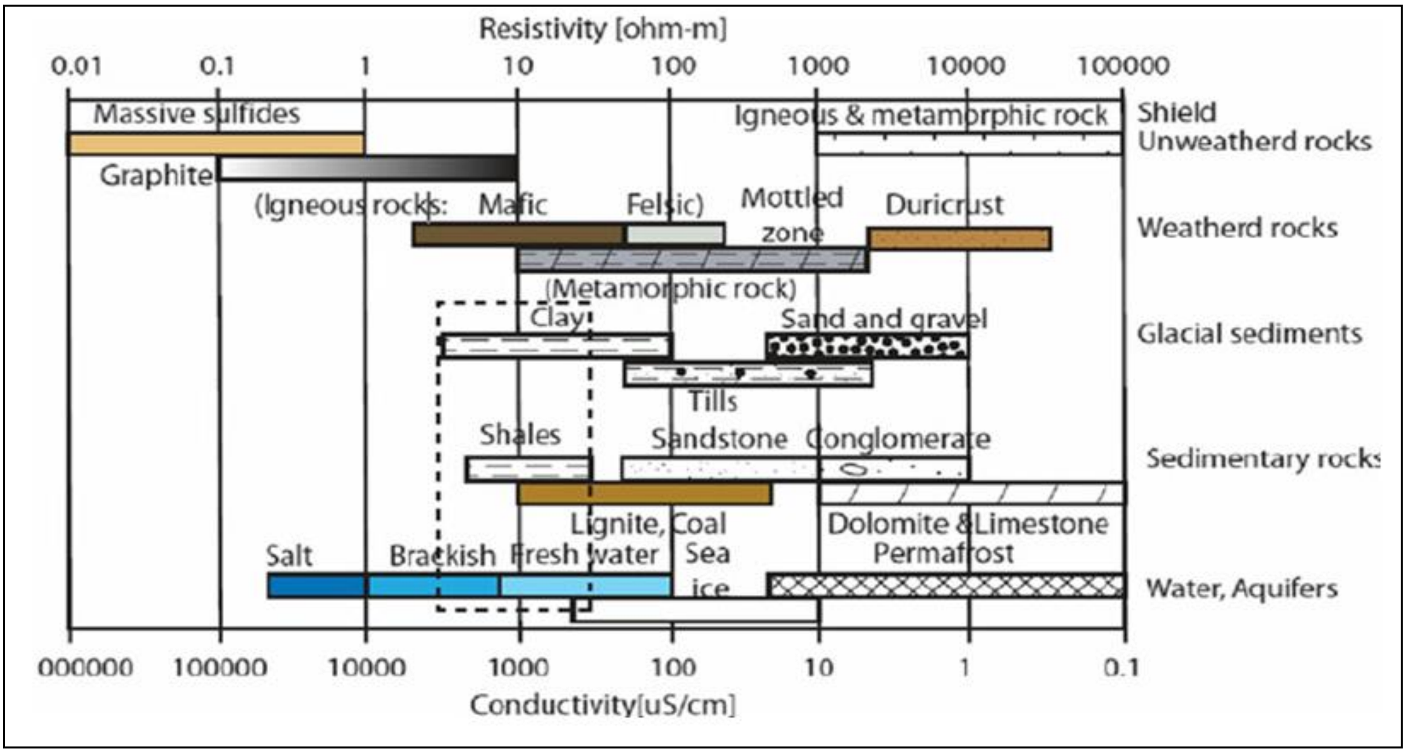

Fig 4: The Estimated Range of Resistivity Values of Common Rock Types[19].

Figure 4 provides a visual representation of resistivity values across different earth materials and rock types. These figures help illustrate how specific geological characteristics can influence the electrical properties of subsurface materials. The values of resistivity obtained in field measurements are often represented as apparent resistivity (ρa), which is calculated as the average of two equi potential surfaces [18].

III. RESULTS

The Table below provides information on the resistivity (ρ), thickness (h), and depth (d) of various subsurface layers, including topsoil, clay, sand, and saturated sand.

Table 1: Summary of VES Model Results and their Corresponding Thicknesses and Depth for Agudama-Epie

VES No	Layer 1 (Top soil)			Layer 2 (Clay)			Layer 3 (Sand)			Layer 4 (water Saturated Sand)		
	ρ (Ωm)	h (m)	d (m)	ρ (Ωm)	h (m)	d (m)	ρ (Ωm)	h (m)	d (m)	ρ (Ωm	h (m)	d (m)
VES 1	24.70	0.99	0.99	9.06	9.16	10.14	8499.86	19.71	29.85	747.66	-	-
VES 2	24.65	1	1	8.45	8.58	9.58	5219.72	20.72	30.30	409.04	-	-
VES 3	196.84	1.03	1.03	14.54	8.15	9.18	15013.1	22.89	32.08	276.17	-	-
VES 4	78.85	1.12	1.12	20.18	7.80	8.93	7423.15	21.38	30.30	377.11	-	-
VES 5	21.62	1.03	1.03	79.43	8.15	9.18	3205.40	22.89	32.08	630.96	-	-
VES 6	90.79	1.50	1.50	21.71	7.67	9.17	4436.69	24.32	33.50	268.79	-	-
VES 7	20.09	1.49	1.49	46.84	7.96	9.45	6415.91	23.55	33.00	265.17	-	-
VES 8	147.62	1.15	1.15	58.54	8.21	9.35	2876.23	22.72	32.08	146.12	-	-
VES 9	146.12	1.22	1.22	28.76	7.71	8.93	5510.32	23.15	32.08	105.57	-	-

Where ρ is bulk resistivity, h is thickness and d is the depth

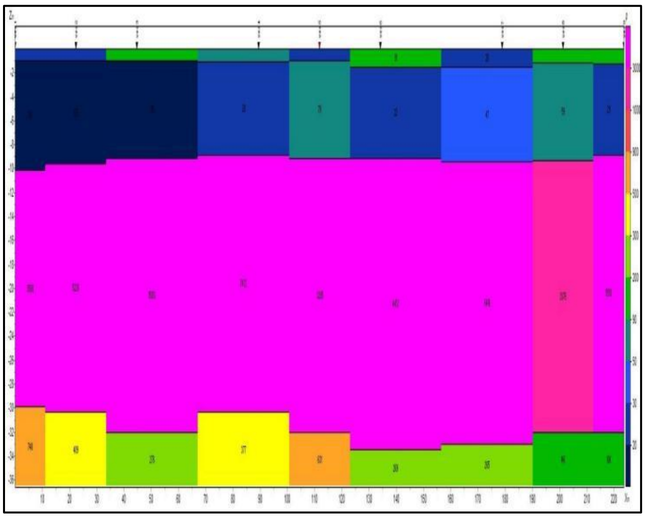

Fig 5: The Resistivity Cross Section Showing the 4-Layer Model Results for Each Profile

IV. DISCUSSION

This discussion and interpretation of the result, Characterizing the distribution of sand and clay layers including quantification and volume calculation which is crucial for understanding the subsurface geology and hydrogeological conditions in a specific area for mining activities. In Analysis, discussion and distribution of the results are presented in table 1 Also summarizes the Vertical Electrical Sounding (VES) model results for Agudama-Epie in Yenagoa, Bayelsa state, Nigeria.

A. VES 1

- **Layer 1 (Top Soil):** The topsoil layer, with a resistivity (ρ) of 24.7 Ωm, has a thickness (h) and depth (d) of approximately 0.99 meters each in Table .1 and Figure 4.. This layer typically consists of organic matter and loose materials and is characterized by relatively low resistivity due to its high moisture content and lower mineral content. The RMS error for this layer is 1.035%, indicating a reasonably good fit of the VES model.
- **Layer 2 (Clay):** Beneath the topsoil layer, we encounter a clay layer with a resistivity (ρ) of 9.06 Ωm. The thickness (h) and depth (d) of this clay layer are 9.16 meters and 10.14 meters, respectively in Figure 4.1. Clay is known for its relatively low resistivity, and its presence in the subsurface is often associated with the retention of water and the formation of impermeable barriers. The RMS error for this layer is not provided in the Table .1, but it can be assumed that the VES model fit is reasonably accurate given the overall low RMS error for the entire dataset.
- **Layer 3 (Sand):** Beneath the clay layer, there is a sand layer with a resistivity (ρ) of 8499.86 Ωm. This sand layer is notably different from the clay layer in terms of resistivity and is indicative of higher mineral content and lower moisture content. The thickness (h) and depth (d) of the sand layer are 19.71 meters and 29.85 meters, respectively as seen in Table 4.1 and Figure 4.1. Sand is known for its higher resistivity compared to clay, and its presence suggests a more permeable and well-draining layer. The RMS error for this layer is not provided, but it can be assumed that the VES model fit is reasonably accurate.

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- **Layer 4 (Water-Saturated Sand):** The final layer, Layer 4, represents water-saturated sand with a resistivity (ρ) of 747.66 Ωm. This layer is situated below the sand layer and is characterized by its relatively low resistivity see Figure 4.1, indicating the presence of groundwater. The thickness (h) and depth (d) of the water-saturated sand layer are not specified in the Table 4.1, but it can be inferred that this layer extends to a considerable depth below the sand layer. The presence of water-saturated sand suggests the potential for a confined aquifer in the study area.

B. VES 2

- **Layer 1 (Top Soil):** The topsoil layer is the shallowest layer in the subsurface profile, with a resistivity (ρ) of 24.65 Ωm. It has a thickness (h) of 1 meter and is situated at a depth (d) of 1 meter below the surface as seen in Table 4.1 and Figure 4.1. This layer typically consists of organic material, loose particles, and other debris. The relatively low resistivity suggests that the topsoil is likely to contain moisture and may have higher clay or silt content, making it conducive to supporting vegetation.
- **Layer 2 (Clay):** The clay layer follows beneath the topsoil, with a resistivity (ρ) of 8.45 Ωm. It is significantly more resistive than the topsoil, indicating that it contains less moisture and has higher clay content. This layer has a thickness (h) of 8.58 meters and is located at a depth (d) of 9.58 meters below the surface as seen in Table .1 and Figure 4.. The substantial thickness of the clay layer suggests that it plays a significant role in controlling groundwater flow and may affect construction activities in the area.
- **Layer 3 (Sand):** Beneath the clay layer, there is a sand layer with a resistivity (ρ) of 5219.72 Ωm. This layer is highly resistive, suggesting that it is composed of well-sorted, clean sand with low moisture content. The sand layer is relatively thick, with a thickness (h) of 20.72 meters, and is situated at a depth (d) of 30.3 meters see Figure 4.1. The presence of a thick and resistive sand layer can be advantageous for groundwater recharge and may also be important for construction purposes, as it can provides Table 4.1 foundation conditions.
- **Layer 4 (Saturated Sand):** The deepest layer in the subsurface profile is the saturated sand layer, characterized by a resistivity (ρ) of 409.04 Ωm as seen in Table 4.1 and Figure 4.1. This layer represents the water-saturated portion of the sand below the water Table 4.1. Specific depth information (h) and depth (d) are not provided for this layer, indicating that it extends to a significant depth beyond the range of the VES measurements. The resistivity value suggests the presence of groundwater, which is essential for sustaining local ecosystems and potentially for water supply purposes.
- **RMS Error:** The Root Mean Square (RMS) error value for VES 2 is 1.348%. The RMS error is a measure of how well the VES data fits the model as seen in Table 4.1. A lower RMS error indicates a better fit between the observed and modeled resistivity values. In this case, the RMS error is relatively low, suggesting that the VES data is reasonably consistent with the interpreted subsurface layering.

C. VES 3

- **Layer 1 (Topsoil):** Layer 1 represents the topsoil, which is typically composed of organic matter, and loose materials. The resistivity value of 196.84 Ωm suggests that this layer has relatively low electrical resistivity as seen in Table 4.1 and Figure 4.1, which is consistent with the conductive nature of topsoil due to its moisture content and organic content. The thickness and depth of 1.03 meters indicate the shallow depth of this layer.
- **Layer 2 (Clay):** Layer 2 represents a clay layer. The resistivity value of 14.54 Ωm is relatively low, indicating the presence of clay, which is known for its high moisture content and electrical conductivity as seen in Table .1 and Figure 4.. The thickness of 8.15 meters suggests that this clay layer is quite thick, and it extends to a depth of 9.18 meters beneath the surface.
- **Layer 3 (Sand):** Form Table 1 and Figure 4. in VES 3, Layer 3 represents a sand layer. The resistivity value of 15013.11 Ωm is significantly higher than that of the clay layer, indicating that sand has low electrical conductivity. Sand layers often have high resistivity due to their low moisture content and granular nature. The thickness of 22.89 meters suggests a substantial depth of sand beneath the clay layer, reaching down to 32.08 meters below the surface.
- **Layer 4 (Water-Saturated Sand):** Layer 4 represents water-saturated sand, but the Table .1 does not provide specific thickness (h) and depth (d) values for this layer. The resistivity of 276.17 Ωm is higher than that of the clay layer but lower than that of the dry sand layer (Table .1 and Figure 4.). Water-saturated sand has moderate electrical conductivity due to the presence of water. It is crucial to determine the thickness and depth of this layer for a comprehensive geological assessment.
- **RMS Error:** The Root Mean Square (RMS) error value of 1.035% represents the accuracy of the VES measurements. A lower RMS error indicates a better fit between the model and actual data, suggesting a relatively reliable interpretation of the subsurface layers in this study.

D. VES 4

- **Layer 1 (Top Soil):** The topsoil layer is characterized by a relatively high resistivity of 78.85 Ωm. It is quite shallow, with a thickness and depth of 1.12 meters see Table .1 and Figure 4.. This layer typically consists of loose, organic-rich material and is generally less conductive due to its higher resistivity.

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- **Layer 2 (Clay):** The clay layer below the topsoil has a lower resistivity of 20.18 Ωm, indicating the presence of moisture or higher conductivity materials. It is relatively thicker, with a thickness of 7.8 meters and a depth of 8.93 meters as seen in Table .1 and Figure 4.. Clay layers are known for retaining moisture and can affect drainage in the area.
- **Layer 3 (Sand):** The sand layer is characterized by an extremely high resistivity of 7423.15 Ωm, indicating the presence of dry, coarse-grained materials (Table .1 and Figure 4.). This layer is substantially thicker, with a thickness of 21.38 meters and a depth of 30.3 meters. The high resistivity suggests good drainage characteristics and a lack of significant moisture content.
- **Layer 4 (Saturated Sand - Water):** Layer 4 represents saturated sand, which means it contains a significant amount of groundwater. Unfortunately, the thickness and depth of this layer are not provided in the Table 1. The resistivity of 377.11 Ωm suggests the presence of conductive groundwater, which is essential for understanding the local hydrogeological conditions.
- **RMS Error:** The Root Mean Square (RMS) Error is a measure of the accuracy of the VES model results. In this case, the RMS error is relatively low (1.856%), indicating a reasonably good fit between the model and the actual data.

E. VES 5

- Layer 1 (Topsoil): Layer 1, the topsoil, is characterized by a relatively low resistivity value of 21.62 Ωm. This indicates that it contains a certain degree of moisture and organic matter. The layer has a thickness and depth of 1.03 m (Table .1 and Figure 4.). It is essential to consider the topsoil's properties for construction and agricultural purposes.
- Layer 2 (Clay): Layer 2 represents a clay layer with a resistivity of 79.43 Ωm, indicating higher electrical resistivity than the topsoil. This suggests lower moisture content and higher clay content. The layer's thickness is 8.15 m, and its depth extends to 9.18 m below the surface as seen in Table .1 and Figure 4.. Clay layers are often important in geotechnical studies as they can significantly impact construction projects due to their swelling and shrinking properties.
- Layer 3 (Sand): Layer 3 is characterized by sand with a high resistivity value of 3205.4 Ωm, indicating good electrical conductivity. This suggests that the layer is well-drained and has lower clay and moisture content. The sand layer's thickness is substantial, measuring 22.89 m, with a depth extending to 32.08 m below the surface as seen in Table .1 and Figure 4.. The presence of a thick sand layer may have implications for groundwater movement and construction practices.
- Layer 4 (Saturated Sand, Water-Bearing Layer): Layer 4 represents a saturated sand layer, which is also the water-bearing layer. The resistivity of 630.96 Ωm suggests that this layer contains groundwater. Specific thickness and depth information for this layer are not provided in the Table .1. However, the presence of a water-bearing layer is crucial for assessing groundwater availability and potential for borehole development.
- RMS Error: The Root Mean Square (RMS) error is a measure of how well the VES model fits the observed data. In this case, the RMS error is 1.91%, indicating the overall accuracy of the model in characterizing the subsurface layers. A lower RMS error suggests a better fit between the model and actual measurements.

F. VES 6

- **Layer 1 (Topsoil):** The topsoil layer has a resistivity of 90.79 Ωm. Resistivity is a measure of how well a material resists the flow of electrical current. In this case, the high resistivity suggests that the topsoil is relatively dry and composed of materials with low electrical conductivity, such as dry soil, rocks, and organic matter. The thickness of the topsoil layer is 1.5 meters (m) surface as seen in Table .1 and Figure 4.. This is a relatively shallow layer and is typical for the uppermost layer of the Earth's crust. The topsoil layer starts at a depth of 1.5 m below the surface.
- **Layer 2 (Clay):** The clay layer has a resistivity of 21.71 Ωm. This resistivity is significantly lower than that of the topsoil, indicating that clay has higher electrical conductivity compared to the topsoil (Table 4.1 and Figure 4.1). Clay is known for its ability to retain water and conduct electricity. The thickness of the clay layer is 7.67 m. This suggests a substantial presence of clay in the subsurface, which can have implications for construction projects, as clay can expand and contract with changes in moisture content. The clay layer starts at a depth of 1.5 m below the surface and extends to a depth of 9.17 m.
- **Layer 3 (Sand):** The sand layer has a very high resistivity of 4436.69 Ωm. This is significantly higher than the resistivity of both the topsoil and clay layers. Sand is known for its low electrical conductivity, and this high resistivity indicates the presence of dry, coarse-grained sands. The sand layer is quite thick, with a thickness of 24.32 m (Table .1 and Figure 4.). The presence of a substantial sand layer can be significant for groundwater exploration, as it can act as an aquifer, allowing the storage and movement of groundwater. The sand layer begins at a depth of 9.17 m and extends to a depth of 33.5 m.
- **Layer 4 (Water Saturated Sand):** The water-saturated sand layer has a resistivity of 268.79 Ωm. The resistivity of saturated sand is higher than that of water but lower than dry sand, indicating the presence of water in the pore spaces of the sand layer. The thickness of the water-saturated sand layer is not provided in the Table .1, but it starts at a depth of 33.5 m, suggesting that it extends to greater depths.
- **RMS Error:** The Root Mean Square (RMS) Error is a measure of the goodness of fit of the VES model to the actual data. In this case, the RMS error is 1.327%, which indicates that the VES model provides a

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reasonably accurate representation of the subsurface layers' resistivity and thicknesses.

G. VES 7

- **Layer 1 (Topsoil):** The topsoil layer has a resistivity (ρ) of 20.09 Ωm, a thickness (h) of 1.49 meters, and a depth (d) of 1.49 meters as seen in Table .1 and Figure 4.. This layer typically consists of organic matter, debris, and weathered materials. It is relatively shallow and has a low resistivity, indicating its high conductivity due to its composition.
- **Layer 2 (Clay):** The clay layer beneath the topsoil has a significantly higher resistivity of 46.84 Ωm. It is much thicker, with a thickness (h) of 7.96 meters and a depth (d) of 9.45 meters. Clay layers are known for their low hydraulic conductivity and can act as barriers to groundwater flow. The high resistivity suggests low moisture content and good electrical insulating properties, which are characteristic of clay-rich sediments.
- **Layer 3 (Sand):** Below the clay layer, we encounter the sand layer with a resistivity (ρ) of 6415.91 Ωm. This layer is notably thicker, measuring 23.55 meters in thickness (h) and located at a depth (d) of 33 meters (Table 1 and Figure 4.). Sand layers typically have higher hydraulic conductivity than clay, making them important aquifers. The high resistivity may indicate variations in grain size or mineral content within the sand layer.
- **Layer 4 (Saturated Sand - Water-Bearing Layer):** The deepest layer, identified as saturated sand (water-bearing layer), exhibits a resistivity (ρ) of 265.17 Ωm. This layer is thinner, with a thickness (h) that is not specified in the Table .1 but is assumed to be greater than 33 meters given its depth (d). The low resistivity indicates the presence of water in this layer. Saturated sand is a critical aquifer as it holds groundwater, and its properties can impact the availability of water resources in the region.
- **RMS Error:** The Root Mean Square (RMS) error is a measure of the model's accuracy. In this case, the RMS error is 1.232%, which is relatively low. This suggests that the VES model used to characterize these subsurface layers is relatively reliable and provides a good fit to the observed data.

H. VES 8

- **Layer 1 (Top Soil):** Layer 1 represents the topsoil, which is the uppermost layer of the Earth's surface. Topsoil typically consists of organic matter, decaying plant material, minerals, and nutrients. The resistivity value of 147.62 Ωm indicates that it has relatively low resistivity, consistent with the conductive nature of soils due to their moisture content and mineral composition. The thickness and depth values suggest a shallow topsoil layer of approximately 1.15 meters see Table .1 and Figure 4..
- **Layer 2 (Clay):** Layer 2 is characterized as clay, which is a type of fine-grained soil with a high proportion of very small mineral particles. The resistivity value of 58.54 Ωm suggests that clay has higher resistivity compared to topsoil, which is consistent with its lower moisture content and finer particle size. The thickness and depth values indicate a relatively thick layer of clay, extending to a depth of 9.35 meters. This layer can significantly affect groundwater flow and may pose challenges for construction due to its low permeability.
- **Layer 3 (Sand):** Layer 3 is identified as sand, a coarser-grained sedimentary material often associated with higher permeability compared to clay. The resistivity value of 2876.23 Ωm is significantly higher than that of clay, indicating the presence of relatively dry, coarse-grained material. The thickness and depth values suggest a substantial layer of sand with a thickness of approximately 22.72 meters, extending to a depth of 32.08 meters surface as seen in Table 1 and Figure 4.. This sand layer could serve as an important aquifer, allowing for the storage and movement of groundwater.
- **Layer 4 (Saturated Sand):** Layer 4 represents saturated sand, indicating that it is fully saturated with groundwater. The resistivity value of 146.12 Ωm is lower than that of unsaturated sand (Layer 3), which is consistent with the higher electrical conductivity of water compared to air or dry soil. The Table .1 does not provide specific thickness and depth values for this layer, which is a limitation. Understanding the thickness and depth of this saturated sand layer is crucial for assessing groundwater availability and potential extraction.
- **RMS Error:** The Root Mean Square (RMS) error value of 1.366% indicates the accuracy of the VES model in representing the subsurface layers. A lower RMS error signifies a better fit between the model and the actual field measurements. In this case, the relatively low RMS error suggests that the VES model results are likely reliable for characterizing the subsurface layers in the study area.

I. VES 9

- **Layer 1 (Top Soil):** The topsoil layer is characterized by a relatively low resistivity of 146.12 Ωm, indicating the presence of moisture or organic matter as seen in Table .1 and Figure 4.. The thickness of this layer is 1.22 meters, and it starts at a depth of 1.22 meters below the surface. This layer is likely to contain organic material, and loose soil.
- **Layer 2 (Clay):** The clay layer beneath the topsoil has a significantly lower resistivity of 28.76 Ωm, indicating the presence of clayey material, which is generally characterized by its high moisture content and low electrical resistivity. The thickness of the clay layer is 7.71 meters, and it starts at a depth of 8.93 meters below the surface (Table .1 and Figure 4.). Clay layers are known to retain water and can influence groundwater flow and aquifer properties.

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- **Layer 3 (Sand):** The sand layer is distinguished by its high resistivity of 5510.32 Ωm, suggesting that it consists of well-sorted, dry, and coarse-grained sediments. This layer is relatively thick, with a depth ranging from 8.93 meters to 32.08 meters below the surface as seen in Table .1 and Figure 4.. Sand layers are important in hydrogeology, as they can serve as aquifers, allowing the movement of groundwater.
- **Layer 4 (Water Saturated Sand):** The last layer represents water-saturated sand, as indicated by its resistivity of 105.57 Ωm. This layer is not characterized by thickness or depth in the Table .1, but it is assumed to be present below the sand layer. Water-saturated sand layers can serve as aquitards, limiting the movement of groundwater between aquifers.
- **RMS Error:** The Root Mean Square (RMS) error of 1.327% indicates the level of accuracy or uncertainty associated with the VES measurements. A lower RMS error suggests higher confidence in the obtained values.

➢ *The Determination of Clay and Sand Content*

The determination of clay and sand content in the Agudama Epie area using VES has provided valuable insights into the potential for clay extraction and the feasibility of sand mining. The calculation of clay and sand quantification based on the collected data shows that there are substantial reserve of clay and sand in the surveyed region. The results obtained from the nine VES surveys are presented in Table .1 and visualized in Figures 5. and figure 6. These findings revealed the presence of four geological layers in each VES profile, indicating the complex subsurface structure of the study area.

➢ *Calculation of Clay Quantification*

The calculation of clay quantification involved estimating the volume and mass of clay present in the study area. This was achieved using the following steps:

- **Area Calculation**: The study area was determined to be a rectangle with a length (L) of 200 meters and a width (W) of 100 meters. Therefore, the area of the study area (A) was calculated as follows:
  A = L x W A = 200 m x 100 m A = 20,000 m²
- **Average Thickness**: The average thickness of the geological layers identified through the VES measurements was found to be 21.20 meters.
- **Volume Calculation**: The volume of clay in the study area was estimated by multiplying the area (A) by the average thickness (T):
  Volume = A x T Volume = 20,000 m² x 21.20 m Volume = 424,000 m³
- **Mass Calculation**: The density of clay was determined to be 1760 kg/m³. Using this density value, the mass of clay occupying the study area was calculated:

  Mass = Density x Volume Mass = 1760 kg/m³ x 424,000 m³ Mass = 746,240,000 kg Mass = 746,240 tonnes

Hence, the quantity of clay present in the mapped area is approximately 746,240 tonnes.

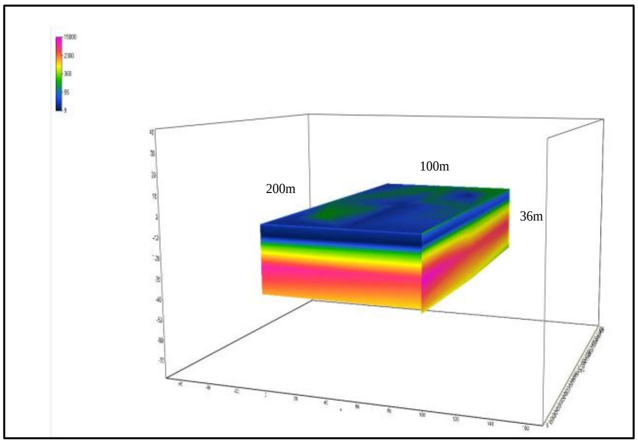

Fig 6: 3D View of Clay and Sand Area in Agudama Epie

➢ *Calculation of Sand Quantification*

Similar to the clay quantification, the estimation of sand quantification followed a series of calculations:

- **Area Calculation**: The study area was determined to be a rectangle with a length (L) of 200 meters and a width (W) of 100 meters, resulting in an area (A) of 20,000 m².
- **Average Thickness**: The average thickness of the geological layers identified through the VES measurements for sand was found to be 8.15 meters.
- **Volume Calculation**: The volume of sand in the study area was estimated by multiplying the area (A) by the average thickness (T):
  Volume = A x T Volume = 20,000 m² x 8.15 m Volume = 163,000 m³
- **Mass Calculation**: The density of sand was determined to be 1.602 g/cm³, which is equivalent to 1602 kg/m³. Using this density value, the mass of sand occupying the study area was calculated:
  Mass = Density x Volume Mass = 1602 kg/m³ x 163,000 m³ Mass = 261,126,000 kg Mass = 261,126 tonnes

Hence, the quantity of sand present in the mapped area is approximately 261,126 tonnes.

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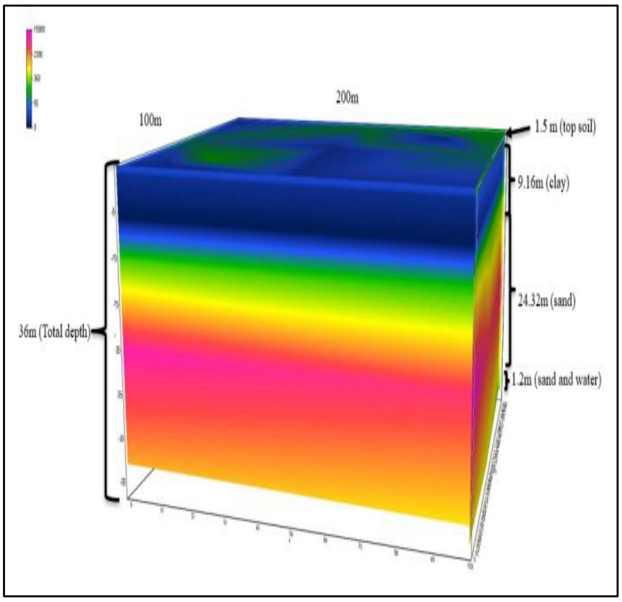

Fig 7: 3D View Indicating Clay and Sand with Respect to Layer Thickness in Agudama Epie

V. CONCLUSION

In conclusion, the Vertical Electrical Sounding (VES) geophysical survey conducted in Agudama Epie, Yenagoa, Bayelsa state, Nigeria, has provided invaluable insights into the subsurface characteristics of the region. Through the analysis of resistivity data and the interpretation of geoelectric layers, we have gained a comprehensive understanding of the stratified subsurface, which includes topsoil, clay, sand, and water-saturated sand layers.

One of the most significant findings of this study is the presence of distinct layers of clay and sand, which have varying resistivity, thicknesses, and depths. This information is of utmost importance for several reasons. Firstly, it is crucial for assessing the region's groundwater resources. The presence of clay layers can act as aquitards, limiting the vertical movement of water, while sand layers may serve as aquifers, allowing the storage and movement of groundwater. Understanding the distribution and characteristics of these layers is essential for effective groundwater management and the sustainable supply of clean water to the local population.

Furthermore, the identification of clay and sand layers has significant implications for various industries and economic development in the area. Clay is a versatile natural resource with applications in construction, ceramics, agriculture, and cosmetics. The substantial presence of clay in Agudama Epie, estimated at approximately 746,240 tonnes presents an opportunity for economic development and industrial growth. The local extraction and processing of clay can lead to job creation and the establishment of small and medium-sized enterprises, contributing to the region's socio-economic development.

Similarly, the presence of sand, estimated at approximately 261,126 tonnes, opens up opportunities for the construction industry, particularly in the production of concrete and building materials. Sand is a fundamental component in construction, and its availability in the region can reduce transportation costs and promote local construction projects. This, in turn, can stimulate economic activity and infrastructure development.

REFERENCES

[1]. Etiko, Anne. (2024). Urban Geology and Infrastructure Resilience. Journal of Physical Sciences. 5. 26-38. 10.47941/jps.1628.

[2]. Okiongbo, K.S. & Oborie, E. (2015). Investigation of relationship between geo-electric and hydraulic parameters in a Quaternary alluvial aquifer in Yenagoa, Southern Nigeria. Ife Journal of Science, Vol. 17 (1), pp. 163 – 172.

[3]. Kadiri, W. A., & Oyalowo, B. A. (2011). Land alienation and sustainability issues in the peri-urban interface of South West Nigeria. *Development*, 54(1), 64–69.

[4]. Oborie, E., Udom, G.J. and Nwankwoala, H.O. (2014).Characterization of Aquifers in Yenagoa and Ogbia areas of Bayelsa State, Nigeria: A Geoelectrical Approach.Advanced Journal of Physical Sciences, Vol. 3(2), pp.31-39

[5]. Ümit Y. (2024). Urban planning and development in harmony with the geosciences Journal of Scientific Reports-A (No. 56) 145-154.

[6]. Vörösmarty, C.J.; Green, P.; Salisbury, J.&Lammers, R.B. (2000). Global Water Resources: Vulnerability from Climate Change and Population Growth. *Science*, *289*, 284–288.

[7]. Kutty, B.A. G. M. Abdella, G. M.,. Kucukvar, M, Onat, C.N.& Bulu, M., "A system thinking approach for harmonizing smart and sustainable city initiatives with United Nations sustainable development goals," Sustainable Development, vol. 28, no. 5, pp. 1347-1365, 2020.

[8]. Egai, O.A. & Oborie, E. (2021). Geophysical Characterization of Oil Spill Sites in Parts of Niger Delta Using Electrical Resistivity Tomography, Southern Nigeria. Journal of Environment and Earth Science,Vol.11 (2), pp. 67-75.

[9]. Oborie, E. & Oghale, L.(2024). Estimation of Aquifer Transmissivity Using Geoelectrical Sounding and Pumping Test. Journal of Research in Environmental and Earth Sciences, Vol.10(1) pp: 26-33.

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

[11]. Doust, H. &Omatsola, E. (1990). Niger Delta. In: Edwards andSantagrossi(eds): Divergent/Passive Margins Basins. AAPG Mem., 48: 201-238

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

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24APR1250

[13]. Syed, B.A. & Siddiqui, F.I. (2012). Electrical Resistivity Based NonDestructive Testing Method for Determination of Soil's Strength Properties. Advanced Materials Research, 488-489, 1553-1557.
[14]. Ozcep, F., Tezel, O. & Asci, M. (2009). Correlation between electrical resistivity and soil-water content: Istanbul and Golcuk. International Journal of Physical Sciences, vol. 4, pp. 362-365
[15]. Samouelian, A. Cousin, I., Tabbagh, A. Bruand, A. & Richard, G. (2005). Electrical resistivity survey in soil science: a review. Soil and Tillage Research, vol. 83, pp. 173-193.
[16]. Okorobia E. M, Uko, E. D. Bright A. & Onengiyeofori A. D. (2020). Delineation of concentration of Ferruginous Minerals in Aquifers In Yenagoa, Bayelsa State, Nigeria, Using Geoelectric Vertical Electrical Sounding and Physicochemical Techniques. Earth Sciences Malaysia, 4(2): 59-70.
[17]. 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, Vol. 52, pp. 157-175.
[18]. Robinson, E.S. & Cahit C. (1988) Basic Exploration Geophysics," Virginia Polymeric Institute and State University, pp 445-478
[19]. Keller, G.V. and Frischknecst, F.C. (1966) Electrical Methods in Geophysical Prospecting.Pergamon Press, London.