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Geoelectrical Investigation of Groundwater Potential around the Cattle Yard, Ovia North-East Local Government Area, Edo State, Nigeria

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ABSTRACT
Groundwater scarcity around the Cattle Yard in Ovia North-East Local Government Area, Edo State, Nigeria, necessitates investigation to identify geoelectric conditions that may support groundwater occurrence. A vertical electrical sounding (VES) survey was conducted using a Parsi (A.C) Earth Resistivity Meter, and the Schlumberger electrode configuration with a maximum current electrode separation (AB) of 500m. The geodetic coordinates of the vertical electrical station were recorded using a Global Positioning System (GPS). The VES data collected during the field survey were processed and interpreted using IPI2WIN software. Six subsurface geoelectric layers were interpreted with layer boundaries occurring at depths of approximately 0.916m, 1.02m, 2.34m, 7.47m, and 24.40m. Resistivity values range from 0.675Ωm to 126912Ωm, indicating marked electrical heterogeneity. The interpreted units comprise materials tentatively associated with cemented sandstone or gravel, dry sand or lateritic gravel, wet or saturated sand, and lateritic or sandy material. The fifth layer with a resistivity of 146 Ωm and a thickness of 16.9m may represent a relatively conductive sandy or lateritic interval that could have groundwater bearing potential. However, resistivity alone cannot establish saturation or aquifer productivity. The sixth layer has an undefined thickness and depth and exceptionally low resistivity of 0.675 Ωm. It is therefore interpreted conservatively as a highly conductive zone that may reflect clay rich material, mineralized water or another conductive lithology. The results provide a preliminary geoelectrical basis for groundwater assessment, but confirmation through borehole drilling, lithological logging and groundwater quality testing is required before development decisions are made.

Keywords: Geoelectrical Investigation, Groundwater Potential, Electrical Resistivity, Vertical Electrical Sounding (VES)

INTRODUCTION

Water constitutes an essential prerequisite for the sustenance and flourishing of life; in its absence, biological systems are unable to survive or develop (Odigwe et al., 2025). Recent assessments indicate that freshwater represents approximately 3.5% of the Earth's total water reserves, whereas oceans account for nearly 96.5% of the global water volume (Singh et al., 2020). Groundwater represents a fundamental element of the earth's natural water resources, characterized by its occurrence below the surface, where it occupies the pore spaces in soil and fractures within geological rock formations (Benard, 2003). Over the past ten years, groundwater has become increasingly popular in many regions due to its capacity to store and provide a lasting supply of portable water (Akor et al., 2023). Groundwater has been identified as the most dependable natural resource for addressing rural water supply challenges in Sub-Saharan Africa, as evidenced by findings in a technical report by the British Geological Survey (MacDonald et al., 2008). Groundwater investigation commonly integrates geological, borehole, hydrogeological and geophysical information. Electrical resistivity methods are particularly useful because the measured electrical response of the subsurface is influenced by lithology, water saturation, porosity, pore-water conductivity and clay content. Therefore, vertical electrical sounding can provide a rapid and relatively economical means of estimating the vertical difference of subsurface resistivity and identifying intervals that permit further hydrogeological investigation. Nevertheless, resistivity is not uniquely diagnostic of groundwater occurrence; low resistivity may result from rich materials or saline/mineralized water, while high resistivity may occur in dry or well cemented materials. Accordingly, groundwater interpretation should consider resistivity together with layer thickness, depth, geological setting, depth and independent borehole or hydrochemical evidence. Former geoelectrical investigations in Nigerian sedimentary terrains have demonstrated the usefulness of resistivity methods for identifying prospective groundwater bearing formations, while also emphasizing the importance of geological and borehole constraints. For instance, geoelectrical studies in southwestern and southeastern Nigeria have used combinations of resistivity, lithological information and hydrogeological data to evaluate aquifer geometry and groundwater potential (Aizebeokhai et al., 2021; Ehirim & Ebeniro, 2013; Oyeyemi et al., 2023). Recent work on the Benin Formation has likewise shown that alternating sandy, gravelly, and clay rich units produce substantial spatial and vertical resistivity variability (Nwozor et al., 2025a, 2025b).

The study area around the Cattle Yard in Ovia North-East Local Government Area is located within the Niger Delta sedimentary basin and is associated with the Benin Formation. The area experiences water supply challenges, making an assessment of subsurface conditions relevant to

possible groundwater development. The local geological setting is dominated by unconsolidated to partly consolidated sands, lateritic materials, gravels, and interbedded clayey units. Such heterogeneity makes direct interpretation of individual resistivity values inappropriate without considering layer thickness and geological context. Consequently, this study uses vertical electrical sounding (VES) with a Schlumberger configuration to delineate subsurface geoloelectric layers and assess potential groundwater-bearing zones around the Cattle Yard. Particular attention is given to the distinction between conductive zones and demonstrable aquifers, because the available vertical electrical sounding dataset does not independently establish groundwater quality, borehole productivity or hydraulic yield. This study aims to delineate subsurface geoelectric layers and assess potential groundwater bearing zones around the Cattle Yard in Ovia North-East Local Government Area using vertical electrical sounding.

MATERIALS AND METHODS

Study Area and Geological Setting

The investigation was conducted at approximately longitude 5° 37′ 23.52″ E and latitude 6° 32′ 12.12″ N in Ovia North-East Local Government Area, Edo State, Nigeria. The study location lies within the sedimentary succession of the Niger Delta Basin and is associated with the Benin Formation. The formation is typically dominated by sands and gravels with variable proportions of lateritic and clayey materials. Such lithological variability can produce substantial changes in electrical resistivity with depth. Therefore, the regional geological context provides a basis for interpreting the vertical electrical sounding (VES) response, but individual lithological assignments remain tentative where independent borehole control is unavailable. Exposures of these units are visible in erosion-prone zones, quarry sites, and road cuttings within the region. Lignite streaks and wood fragments are also common within the sequence (Alile et al., 2011).

Equipment and Field Survey

One vertical electrical sounding (VES) station was occupied around the Cattle Yard. The equipment comprised a Parsi (A.C) Earth Resistivity Metre, cables, four stainless steel electrodes, hammer, Global Positioning System receiver, and measuring tape. The Schlumberger electrode configuration was used. The maximum current electrode separation (AB) was 500m, while the potential electrode separation (MN) was varied as required during the sounding. Field observations were conducted under favourable weather conditions, and care was taken to maintain electrode contact and accurate electrode spacing. The station coordinates were recorded with a Global Positioning System receiver.

Data Processing and Interpretation

The measured resistance values were converted to apparent resistivity and plotted against half the current electrode spacing AB/2. The data were interpreted using IPI2WIN through iterative adjustment of the layered earth model until the calculated sounding curve provided a satisfactory fit to the observed data. No independent borehole lithological assignments are regarded as tentative and are based primarily on resistivity ranges and the known geological setting.

For the Schlumberger configuration, the apparent resistivity was calculated using the relation:

$$\rho_a = K \times R \quad (1)$$

$$K = \frac{((AB/2)^2 - (MN/2)^2)\pi}{2(\frac{MN}{2})} \quad (2)$$

Where:

K = Constant

R = Resistance in Ohms as obtained from the Terrameter

AB = the current electrode spacing in meters

MN = the potential electrode spacing in meters

The geometric factor values in Table 1 were calculated from this expression.

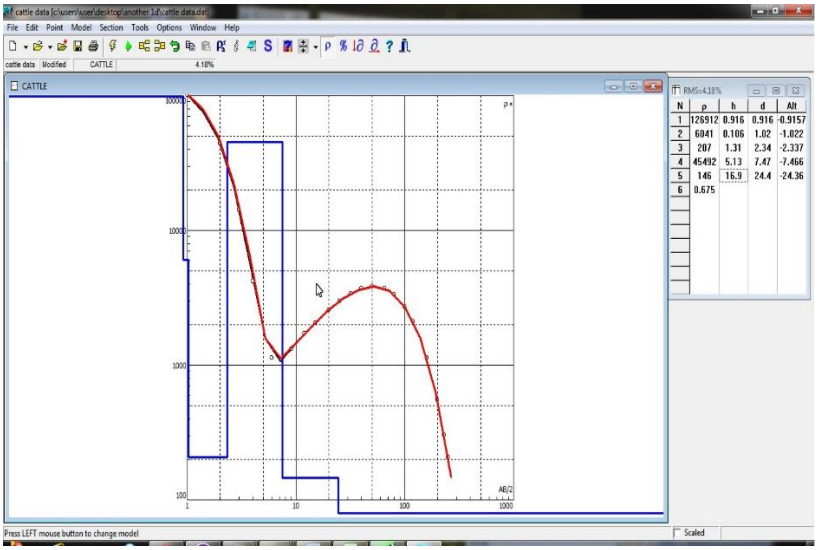


Figure 1: Vertical Electrical Sounding (VES) Curve

Criteria for Groundwater Potential Interpretation

Interpretation of groundwater potential was based on the combined consideration of resistivity, depth, layer thickness, and geological setting. No single resistivity threshold was used as proof of groundwater occurrence. In particular, very low resistivity values were treated cautiously because clay rich layers and highly mineralized water can both produce strong conductive responses. A potentially favourable groundwater bearing interval is therefore measured to require a combination of plausible lithology, suitable depth, adequate thickness, and a resistivity response compatible with

saturated permeable material. Confirmation requires borehole and hydrochemical evidence.

RESULTS AND DISCUSSION

Vertical Electrical Sounding (VES) Apparent Resistivity Data

Table 1 present the measured electrode spacing, geometric factors and calculated apparent resistivity's. The apparent resistivity values range from 5.50Ωm to 133,374,745 Ωm in the tabulated field data, demonstrating a very large dynamic range in the observed response. The broad range reflects strong subsurface electrical heterogeneity and also indicates why individual apparent resistivity measurements should not be equated directly with specific lithology's or groundwater conditions. Figure 1 therefore present the observed and interpreted Vertical Electrical Sounding (VES) curves obtained from IPI2WIN.

Table 1: Field Apparent Resistivity Data from the Vertical Electrical Sounding (VES) Station

	SP, V and I = 0		
Current Electrode Spacing (AB)	**Potential Electrode Spacing (MN)**	**Constant (K)**	**RESISTIVITY (Ω-m)**
2	0.5	5.89	116632
4	0.5	24.74	44532
6	0.5	56.16	1061348
8	0.5	100.14	1161604
12	2	55.00	5.50
18	2	125.67	15.08
24	2	224.63	3055
30	2	351.86	5946407
40	2	627.00	602
50	2	980.18	11860141
64	2	1606.92	19122403
80	5	1001.38	17023505
100	5	1566.87	27420213
130	5	2651.35	981
160	5	4016.13	1245
200	10	3132	783
240	10	4516.04	63224552
320	10	8034.62	133374745
400	14	8962.50	1434
460	14	11860.71	3321
500	14	14014.29	29.43

Interpreted Geoelectric Model

The IPI2WIN interpretation produced a six-layer model (Table 2). The first layer has a thickness of 0.916m and a resistivity of 126,912 Ωm and is tentatively associated with cemented sandstone or gravel. The second layer is 0.106m thick, occurs to a depth of 1.02m, and has a resistivity of 6,041 Ωm; it may represent dry sand, gravel or lateritic material. The third layer has a thickness of 1.31m, extends to 2.34m depth, and has a resistivity of 207 Ωm. Its relatively moderate resistivity is compatible with moist or saturated sandy material, although the vertical electrical sounding (VES) response alone does not prove saturation. The fourth layer extends from 2.34m to 7.47m depth, has a thickness of 5.13m, and has a resistivity of 45,492 Ωm. this high resistivity is compatible with a relatively dry, coarse or cemented sandy or gravelly unit.

The fifth layer is 16.9m thick, extends to approximately 24.4m depth and has a resistivity of 146 Ωm. Rather than assigning it unambiguously to laterite or wet sand, the layer is more conservatively described as a lateritic or sandy conductive unit. Its substantial thickness makes it the most relevant interval for further hydrogeological investigation, but the resistivity value alone is insufficient to establish aquifer productivity. The sixth layer has an undefined thickness and depth in the available inversion model and has a resistivity of 0.675 Ωm. such an exceptionally low resistivity indicates a highly conductive zone, but it should not be labeled an aquifer on the basis of resistivity alone. Possible explanations include clay rich material, highly conductive or mineralized pore water or another electrically conductive lithology. This is because the thickness and depth of this layer are unresolved, its hydrogeological significance remains uncertain.

Table 2: Interpreted Geoelectric Layers at the Cattle Yard VES Station

Layer	Thickness (m)	Depth (m)	Resistivity (Ωm)	Lithology
1	0.916	0.916	126912	Cemented sandstone or gravel
2	0.106	1.02	6041	Dry sand or gravel/laterite material
3	1.31	2.34	207	Moist/saturated sandy material
4	5.13	7.47	45492	Cemented/coarse sandy or gravelly material
5	16.9	24.4	146	Lateritic/sandy conductive unit; possible groundwater bearing interval

Layer	Thickness (m)	Depth (m)	Resistivity (Ωm)	Lithology
6	Undefined	Undefined	0.675	Highly conductive zone; clay/mineralized water or other conductive lithology possible

Groundwater Potential Implications

The interpreted model indicates a vertically heterogeneous sequence characteristic of a sandy gravelly sedimentary environment. The third and fifth layers are principal intervals that merit consideration during groundwater assessment because their resistivity's are compatible with moist or potentially saturated sandy material and, in the case of the fifth layer, the intervals that appreciable thickness. However, an electrical resistivity model cannot independently determine hydraulic conductivity, transmissivity, borehole yield, or groundwater quality. The 0.675 Ωm basal response requires particular caution. Even though conductive formations may be associated with water bearing-formation zones, very low resistivity can also be generated by clay-rich sediments or water with elevated ionic content. Accordingly, the basal zone is not classified here as a confirmed aquifer. This conservative interpretation is consistent with the broader hydogeophysical literature, which emphasizes the non-uniqueness of resistivity based lithological and groundwater interpretation and the value of borehole control (Aizebeokhai et al., 2021; Oyeyemi et al., 2023; Nwozor et al., 20025a, 225b).

The very high resistivity of the upper layers is broadly compatible with dry, coarse, or cemented materials, while the intermediate resistivity's may reflect changes in porosity, moisture, grain size, and pore-water properties. These interpretations are consistent with the documented heterogeneity of the Benin Formation, where alternating sandy, gravelly, and finer-grained units occur. Nevertheless, the available dataset consists of a single vertical electrical sounding station, so the results should be considered a preliminary point based assessment rather than a spatial groundwater potential map.

Conclusion

The vertical electrical sounding (VES) investigation around the Cattle Yard in Ovia North- East Local Government Area delineated six geoelectric layers with resistivity's ranging from 0.675Ωm to 126,912 Ωm and layer boundaries extending to approximately 24.4m depth with the sixth layer unresolved in thickness and depth. The third layer has resistivity value of 207 Ωm, and particularly thick fifth layer with 146 Ωm constitute the principal intervals that warrant further hydrogeological investigation because their electrical responses and thicknesses are compatible with potentially moist or groundwater bearing sandy or lateritic materials. Nevertheless, the 0.675 Ωm sixth layer should not be regarded as a confirmed aquifer because its depth and thickness are undefined and such a low resistivity may also indicate highly mineralized water or clay rich material. The further limited by the use of a single vertical electrical sounding (VES) station and the absence of independent borehole/lithological control in the dataset supplied for interpretation. Therefore, confirmatory borehole drilling should be preceded or accompanied by lithological logging, and any developed groundwater should undergo appropriate physicochemical and microbiological quality assessment. Additional vertical electrical sounding stations and/or complementary geophysical methods would also improve spatial characterization and reduce interpretation uncertainty.

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