International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435 (Online) Volume 15, Issue 06, June 2026)

An Evaluation of Hydrogeological Properties of Aquifers in Ohimini Local Government Area, Benue State, Nigeria using Geophysical Techniques.

Terhemba Emberga[1], Opara Alexander[2], Osubor Alma[3], Epuerie Emeka[4], Anuforo Dominic[5], Abara Josiah[6]

[1]*Department of Physics, Joseph Sarwuan Tarka University, Makurdi -Nigeria*
[2]*Department of Geology, Federal University of Technology Owerri*
[3,4,6]*Department of Physics/Electronics, Federal Polytechnic Nekede, Owerri*
[5]*The Marsh Academy, Station Road New Romney, United Kingdom*

Abstract-- **Groundwater constitutes the primary source of potable water in many rural communities of Benue State, where surface water resources are often seasonal or contaminated. Its sustainability and quality are largely controlled by the hydrogeological characteristics of underlying aquifer systems. This study evaluates the hydrogeological properties of aquifers in Ohimini using electrical resistivity techniques. A total of sixteen Vertical Electrical Soundings (VES) were conducted employing the Schlumberger configuration. Apparent resistivity data were processed using WinRESIST to obtain layer resistivity, thickness, and depth parameters. The results reveal three to five geoelectric layers comprising topsoil, lateritic sand, weathered basement, fractured basement, and fresh basement rock. Aquifer units are predominantly associated with the weathered and fractured basement zones. Aquifer resistivity values range from 20 to 150 Ωm, with thicknesses between 5 and 25 m and depths varying from 5 to 30 m. Estimated hydraulic conductivity ranges from 2.5×10^{-3} to 1.2×10^{-2} m/s, while transmissivity varies between 10 and 65 m²/day. Zones characterized by moderate resistivity and significant overburden thickness exhibit high groundwater potential, whereas areas with thin overburden and high resistivity indicate low potential. Recommended borehole depths range from 15 to 30 m, with expected yields of 1.2–5.8 m³/h. The study demonstrates that VES is an effective and reliable method for delineating aquifer geometry and evaluating groundwater potential in basement complex terrains. The findings provide a scientific basis for sustainable groundwater development and improved water resource planning in the study area.**

Keywords-- **Groundwater potential; Electrical resistivity; Vertical Electrical Sounding (VES); Hydrogeological properties; Basement complex aquifers**

I. INTRODUCTION

Groundwater is an essential component of the hydrological cycle and constitutes a major source of freshwater for domestic, agricultural, and industrial use worldwide.

In many developing countries, including Nigeria, groundwater remains the most reliable source of potable water, particularly in rural and peri-urban areas where surface water resources are either seasonal or contaminated (Freeze and Cherry 1979; Todd and Mays 2005). Within Benue State, groundwater plays a dominant role in water supply due to increasing population pressure, inadequate infrastructure, and climatic variability affecting surface water availability.

The occurrence, distribution, and sustainability of groundwater resources are largely controlled by subsurface hydrogeological conditions, including lithology, aquifer geometry, porosity, permeability, and structural features such as fractures and faults (Fetter 2001). In sedimentary basins and transitional basement terrains such as the Benue Trough, aquifer systems are often heterogeneous and anisotropic, resulting in significant spatial variability in groundwater potential and yield (Offodile 2002; Olorunfemi and Fasuyi 1993). This variability necessitates detailed subsurface investigations to ensure effective groundwater exploration and sustainable management.

Ohimini Local Government Area is situated within a complex geological setting characterized by sedimentary formations interspersed with weathered and fractured basement rocks. The subsurface consists of alternating sequences of lateritic soils, clayey horizons, sandy units, and fractured bedrock, resulting in considerable heterogeneity in aquifer properties. These variations strongly influence groundwater recharge, storage, transmissivity, and flow dynamics. Despite the critical dependence of local communities on groundwater, hydrogeological information for the area remains sparse, leading to uncoordinated borehole siting, inconsistent well yields, and inefficient water resource utilization.

Geophysical methods have become indispensable in groundwater investigations due to their non-invasive nature, cost-effectiveness, and ability to provide spatially continuous subsurface information (Telford et al. 1990; Reynolds 2011).

Among these, electrical resistivity techniques—particularly Vertical Electrical Sounding (VES) and Electrical Resistivity Tomography (ERT)—are widely used for delineating subsurface stratification, identifying aquifer zones, and estimating geoelectric parameters (Koefoed 1979; Zohdy et al. 1974). These methods exploit contrasts in electrical resistivity between subsurface materials such as clay, sand, and fractured rock to infer lithological and hydrogeological characteristics. When integrated with hydrogeological models, resistivity data can be used to estimate key parameters such as transmissivity and hydraulic conductivity (Niwas and Singhal 1981; Heigold et al. 1979).

Previous studies in Nigeria and similar geological environments have demonstrated the effectiveness of resistivity methods in groundwater exploration. For example, Olorunfemi and Fasuyi (1993) successfully delineated weathered and fractured basement aquifers in southwestern Nigeria, while Offodile (2002) provided a comprehensive hydrogeological framework for groundwater occurrence in the Benue Trough. Additionally, Niwas and Singhal (1981) established a quantitative relationship between transverse resistance and aquifer transmissivity, forming the basis for estimating hydraulic properties from geoelectric data. However, many of these studies are largely qualitative, focusing primarily on lithological interpretation without rigorous estimation of hydraulic parameters or site-specific calibration.

Despite the growing application of geophysical methods in groundwater studies, several gaps remain evident in the context of Ohimini LGA: Limited site-specific hydrogeophysical studies addressing aquifer characteristics in the area ,inadequate quantitative linkage between geoelectric parameters and hydraulic properties such as transmissivity and hydraulic conductivity , poor understanding of spatial variability of groundwater potential in sedimentary basement transition zones , continued reliance on trial and error borehole drilling, leading to frequent borehole failures and suboptimal yields .

This study addresses these gaps through an integrated hydrogeophysical approach with the following key contributions: Application of Dar-Zarrouk parameters for quantitative estimation of transmissivity in a complex sedimentary basement environment , establishment of a predictive relationship between resistivity-derived parameters and hydraulic conductivity , delineation of groundwater potential zones using combined geoelectric and hydrogeological criteria , development of a localized hydrogeophysical database to support sustainable groundwater exploration and management .

In addition to addressing these gaps, the study provides a refined framework for interpreting resistivity data in heterogeneous terrains, thereby improving the reliability of groundwater potential assessment and borehole siting.

The study further incorporates an analysis of the location, physiography, geology, and hydrogeology of the study area. Ohimini LGA lies between latitudes 7°45′–7°55′N and longitudes 7°45′–8°05′E, covering approximately 1,045 km². The terrain is characterized by gently undulating plains with elevations ranging from 120 to 320 m above sea level. The drainage pattern is dendritic, consisting of seasonal streams that feed into the Benue River system. The climate is tropical with distinct wet and dry seasons, and annual rainfall ranges from 1,200 to 1,600 mm, supporting groundwater recharge.

Geologically, the area is part of the Lower Benue Trough, a Cretaceous sedimentary basin comprising alluvial deposits, sandy-clayey sediments, and localized weathered and fractured basement rocks. These formations give rise to both unconfined and semi-confined aquifers, with groundwater occurrence primarily controlled by lithological variations and structural features. Hydrogeologically, aquifers are generally shallow (5–40 m depth) and exhibit variable hydraulic properties depending on the degree of weathering, fracturing, and sediment composition.

Therefore, this study aims to evaluate the hydrogeological properties of aquifers in Ohimini LGA using Vertical Electrical Sounding (VES). The specific objectives are to delineate subsurface lithology, identify aquifer zones, estimate hydraulic parameters, and map groundwater potential zones. The outcomes of this research are expected to enhance groundwater exploration strategies and contribute to sustainable water resource management in Ohimini LGA and similar hydrogeological settings.

II. Theoretical Framework

Conceptual Basis

The theoretical framework of this study integrates principles of hydrogeology and applied geophysics to evaluate aquifer characteristics in Ohimini, Benue State. Groundwater occurrence and movement are controlled by lithology, structural features, porosity, permeability, and degree of saturation (Freeze and Cherry 1979; Fetter 2001). Direct subsurface investigation through drilling is often expensive and spatially limited; hence, indirect geophysical methods, particularly electrical resistivity techniques, provide an effective means of characterizing aquifer systems (Telford et al. 1990; Reynolds 2011).

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435 (Online) Volume 15, Issue 06, June 2026)

This study therefore adopts a hydrogeophysical approach, combining resistivity measurements with hydrogeological principles to infer aquifer geometry and estimate hydraulic properties.

III. Hydrogeological Principles

Aquifer Systems

An aquifer is defined as a geological formation capable of storing and transmitting significant quantities of groundwater (Todd and Mays 2005). Aquifers are commonly classified into: Unconfined aquifers, where the water table forms the upper boundary, Confined aquifers, overlain by impermeable layers and under pressure and Semi-confined aquifers, partially bounded by aquitards

In sedimentary and basement transition terrains such as the Benue Trough, aquifers typically occur within weathered overburden, fractured basement rocks, and unconsolidated sandy deposits (Offodile 2002; Olorunfemi and Fasuyi 1993). These formations exhibit varying hydraulic properties due to lithological heterogeneity.

Groundwater Flow Theory

Groundwater flow in porous media is governed by Darcy's Law (Darcy 1856), expressed as equation (1).

$$Q = KA\frac{dh}{dl} \quad (1)$$

Where Q = discharge (m³/s), K = hydraulic conductivity (m/s), A = cross-sectional area (m²),

$\frac{dh}{dl}$ = hydraulic gradient.

Hydraulic conductivity represents the ability of a medium to transmit water through pore spaces or fractures (Freeze and Cherry 1979).

The transmissivity T, which defines the capacity of an aquifer to transmit water, is given by equation (2).

$$T = Kb \quad (2)$$

where b is the aquifer thickness (Fetter 2001). These parameters are fundamental in assessing aquifer productivity and groundwater potential.

Electrical Resistivity Theory

Electrical resistivity methods are based on the response of subsurface materials to an applied electrical current. The resistivity of geological formations depends on mineral composition, porosity, degree of saturation, pore fluid conductivity, and clay content (Archie 1942; Keller and Frischknecht 1966).

The governing relationship is derived from Ohm's Law (Ohm 1827) as presented in equation (3).

$$V = IR \quad (3)$$

where V is potential difference, I is current, and R is resistance.

The resistivity ρ of a material is expressed as equation (4).

$$\rho = R\frac{A}{L} \quad (4)$$

where A is cross-sectional area and L is the length of the conductor (Telford et al. 1990).

Apparent Resistivity and Vertical Electrical Sounding

In geophysical field surveys, the subsurface is assumed homogeneous for the computation of apparent resistivity ρ_a, given by equation (5)

$$\rho_a = K\frac{\Delta V}{I} \quad (5)$$

where K is the geometric factor dependent on electrode configuration (Koefoed 1979).

For the Schlumberger array, the geometric factor is presented in equation (6).

$$K = \frac{\pi(AB)^2}{4MN} \quad (6)$$

where AB is the current electrode spacing and MN is the potential electrode spacing.

The Vertical Electrical Sounding (VES) technique involves progressively increasing the current electrode spacing (AB/2) to probe deeper subsurface layers (Zohdy et al. 1974). This enables the determination of layer resistivity, thickness, depth to bedrock, and aquifer geometry.

IV. Resistivity-Hydraulic Property Relationship

Archie's Law

The relationship between resistivity and porosity in clean, fully saturated formations is described by Archie's Law (Archie 1942) as presented in equation (7).

$$\rho = a\rho_w\phi^{-m} \quad (7)$$

Where ρ = bulk resistivity, ρ_w = pore water resistivity, ϕ = porosity, a and m = empirical constants.

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435 (Online) Volume 15, Issue 06, June 2026)

This relationship indicates that resistivity decreases with increasing porosity and water saturation. However, in clay-rich formations, surface conduction effects may lead to deviations from Archie's law (Keller and Frischknecht 1966), requiring careful interpretation.

Dar-Zarrouk Parameters and Aquifer Evaluation

The interpretation of layered earth resistivity data can be enhanced using Dar-Zarrouk parameters (Maillet 1947), which relate geoelectric properties to aquifer characteristics.

The longitudinal conductance (S) is given by equation (8).

$$S = \sum \frac{h_i}{\rho_i} \qquad (8)$$

The transverse resistance (TR) is expressed as equation (9).

$$TR = \sum h_i \rho_i \qquad (10)$$

where h_i and ρ_i represent the thickness and resistivity of the i-th layer.

Niwas and Singhal (1981) demonstrated that transverse resistance is directly proportional to aquifer transmissivity as shown in equation (11).

$$T \propto TR \qquad (11)$$

This relationship enables the estimation of transmissivity from geoelectric data after calibration with hydrogeological information.

Hydraulic conductivity can subsequently be derived from equation (12).

$$K = \frac{T}{b} \qquad (12)$$

where b is the aquifer thickness obtained from VES interpretation.

V. Materials And Method

Study Area Description

The study was conducted in Ohimini Local Government Area (LGA), located in Benue State, north central Nigeria. The area lies within the sedimentary terrain of the Lower Benue Trough and is characterized by alternating sequences of sandstone, shale, clay, and lateritic overburden. The climate is tropical with distinct wet and dry seasons, and groundwater constitutes a major source of domestic and agricultural water supply. Hydrogeologically, aquifers in the area are typically associated with weathered overburden, fractured bedrock, and sandy formations.

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435 (Online) Volume 15, Issue 06, June 2026)

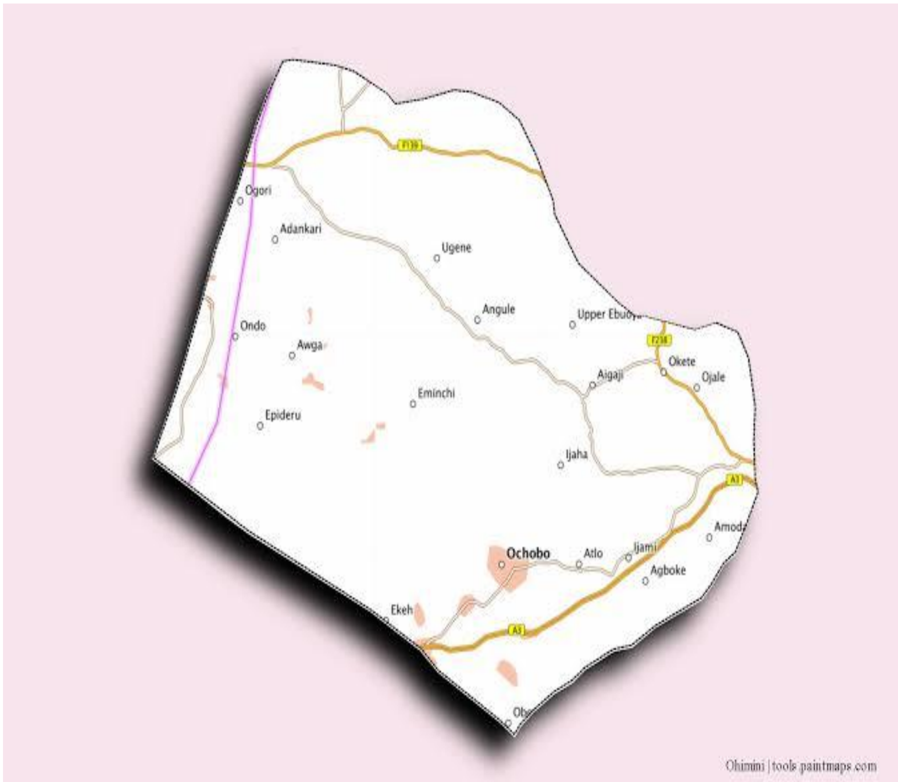

Figure 1: Location map of the study area

Research Design

The study adopted an integrated hydro-geophysical approach using the electrical resistivity method to evaluate subsurface lithology and aquifer hydraulic properties. The Vertical Electrical Sounding (VES) technique was employed to determine layer resistivity, thickness, and depth to aquiferous zones. Derived geoelectric parameters were subsequently used to estimate hydraulic conductivity and transmissivity.

VI. FIELD DATA ACQUISITION

Equipment

Field measurements were carried out using: A digital resistivity meter, Stainless steel electrodes, Insulated connecting cables, Measuring tapes, GPS receiver for coordinate recording

Electrode Configuration

The Schlumberger array was adopted due to its depth penetration capability and sensitivity to vertical resistivity variations. Four electrodes were arranged collinearly: Two outer current electrodes (A and B), Two inner potential electrodes (M and N)

The current electrode spacing (AB/2) was progressively increased to probe deeper subsurface layers, while the potential electrode spacing (MN/2) was kept relatively small and expanded only when necessary to maintain measurable potential differences.

Data Collection Procedure

A known current (I) was injected into the ground through electrodes A and B while the resulting potential difference (ΔV) was measured between electrodes M and N and apparent resistivity (ρa) was computed using equation (13)

$$\rho_a = K\frac{\Delta V}{I} \qquad (13)$$

Where the geometric factor K for the Schlumberger configuration is shown in equation (14)

$$K = \frac{\pi(AB)^2}{4MN} \qquad (14)$$

The process was repeated for increasing values of AB/2 until the maximum desired depth of investigation was achieved.

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435 (Online) Volume 15, Issue 06, June 2026)

VES stations were strategically distributed across the study area to ensure adequate spatial coverage and representation of different lithologic settings.

VII. Data Processing And Interpretation

Curve Matching and Inversion

Field apparent resistivity data were plotted on log-log graphs of apparent resistivity (ρa) versus electrode spacing (AB/2). Preliminary interpretation was conducted through manual curve matching using standard master curves to determine curve types (A, H, K, HA, KH, etc.).

Quantitative interpretation was performed using computer-based iterative inversion software to obtain: True layer resistivity (ρ_i), layer thickness (hi) and depth to aquifer and bedrock.

Lithologic Interpretation

Layer resistivity values were correlated with typical resistivity ranges for earth materials: Low resistivity i,e clay and shale, Moderate resistivity i.e saturated sand and high resistivity i.e dry sand, laterite, or consolidated bedrock.

Hydrogeological interpretations were made by integrating resistivity values with known regional geology of Benue State.

Estimation of Hydraulic Parameters

Hydraulic properties were derived from geoelectric parameters using established empirical relationships.

Dar-Zarrouk Parameters

Longitudinal conductance (S) and transverse resistance (TR) were computed as seen in equation (15) and (16)

$$S = \sum \frac{h_i}{\rho_i} \quad (15)$$

$$TR = \sum h_i \rho_i \quad (16)$$

Where h_i = thickness of the ith layer, ρ_i = resistivity of the ith layer

Transmissivity Estimation

Aquifer transmissivity (T) was estimated using the empirical relationship as shown in equation (17)

$$T = C \times TR \quad (17)$$

Where C is a calibration constant obtained from regional hydrogeological studies and literature correlations for similar sedimentary environment.

Hydraulic Conductivity

Hydraulic conductivity (K) was determined from equation (18)

$$K = \frac{T}{b} \quad (18)$$

Where b = aquifer thickness interpreted from VES results

VIII. Results And Discussion

Geoelectrical Characterization of the Subsurface

The Vertical Electrical Sounding (VES) results across Ohimini Local Government Area of Benue state Nigeria reveal a heterogeneous subsurface framework typical of basement complex terrains within the place. The interpreted models (Table 1) indicate between four and ten geoelectric layers, corresponding to topsoil, lateritic/clayey horizons, weathered basement, fractured basement, and fresh crystalline bedrock.

The wide resistivity range (9.8 Ω·m to >15,000 Ω·m) reflects strong lithological variability both laterally and vertically. Very low resistivity values (<20 Ω·m), recorded at stations such as OHM 11, OHM 12, and OHM 16, are indicative of clay-rich or highly conductive formations that typically function as aquitards due to low permeability. Conversely, very high resistivity values (>600 Ω·m), observed at OHM 08 and OHM 13, suggest compacted or fresh basement rocks with limited groundwater storage potential.

Moderate resistivity values (100-500 Ω·m), recorded at stations including OHM 02, OHM 06, OHM 07, OHM 14, and OHM 15, correspond to weathered or sandy basement materials. These units represent the principal aquifer horizons in the study area. The resistivity distribution map (Figure 3) shows that these moderately resistive zones form discrete belts, reflecting localized weathering and fracture development.

Aquifer thickness (Figure 2) further supports this interpretation. Productive zones are characterized by weathered/fractured layers exceeding 20-40 m thickness, while low-yield areas are associated with thin overburden (<10 m). This confirms that groundwater occurrence in the area is primarily controlled by the depth and intensity of weathering and fracturing, consistent with hydrogeological models for basement terrains.

Table:1 Geoelectrical Layer Resistivity and Thickness Obtained in the Study Area from Vertical Electrical Sounding Computer Iteration

Resistivity (Ω.m)

Ves No.	Layer No	ρ_1	ρ_2	ρ_3	ρ_4	ρ_5	ρ_6	ρ_7	ρ_8	ρ_9
OHM 1	10	134.00	8300.00	578.00	129 00	1030.00	107.00	285.	669.	1010. 00 00 00
OHM 2	10	386.00	3330.00	54.80	5580.80	2080.00	409 00	104.00	39.50	30.70
OHM 3	10	260.00	1110 00	23.00	2.80	25.80	57.70	39.40	17.00	11.90
OHM 4	10	311.00	980.00	488.00	1590.00	1270.00	1640.00	548.00	325.00	249.00
OHM 5	9	161.00	1210.00	5440.00	268.00	121.00	86.00	22.90	232.90	87.00
OHM 6	10	94.00	723.00	268.00	1830.00	528.00	149.00	280.00	406.00	668.00
OHM 7	10	158.00	10.40	475.00	137.00	99.00	154.00	84.00	128.00	111.00
OHM 8	10	54.70	196.00	474.00	50.20	860.00	30.00	182.00	2440.00	552.00
OHM 9	10	1170.00	251.00	15200.00	10200.00	668.00	686.00	226.00	1270.00	1000.00
OHM 10	8	55.80	3.70	650.00	1250.00	2114.00	1897.00	1354.00	1021.00	587.00
OHM 11	9	270.00	3310.00	910.00	4560 00	378.00	670.00	1510.00	1980.00	2810.00
OHM 12	10	399.00	44.00	104.00	9.00	3.00	35.00	10.00	2.00	
OHM13	8	82.00	830.00	405.00	79.00	14.70	5.00	12.70	13.50	14.00
OHM 14	9	356.00	681.00	28.70	8.20	12.20	124 00	255.00	850.00	
OHM 15	10	176.00	270.00	354.00	9800 00	2200 00	860.00	738.00	707.00	218.00
OHM 16	10	177.00	12.00	171.00	1300 00	10400.00	950.00	95.00	464.00	2210.00

Thickness (m)

Ves No.	h_1	h_2	h_3	h_4	h_5	h_6	h_7	h_8	h_9
OHM 1	0.30	1.10	1.20	5.10	17.20	31.60 10	25.40 00	28.	33.
OHM 2	0.90	0.90	2.80	8.40	8.70	6.40	19.00	34.80	121 00
OHM 3	0.60	2.00	13.10	12.20	17.70	28.10	36.30	42.00	46.00
OHM 4	0.90	13.80	15.70	19.20	8.80	27.70	25 90	29 00	34.00
OHM 5	0.9	0.70	3.50	2.80	3.60	3.70	22.20	52.10	40.40
OHM 6	1.00	4.20	7.30	16.20	14.10	48.90	16.30	31.00	32.00
OHM 7	1.30	1.70	8.90	20.70	18.80	36.60	48.00	41.00	43.00
OHM 8	0.70	0.50	1.90	4.50	10.80	32.50	23.00	69.10	61 00
OHM 9	1.60	2.40	6.40	8.50	12.80	8.90	46.00	39 40	41.00
OHM 10	1.10	1.90	7.60	33.30	24.00	26.10	22.00	7. 00	
OHM 11	0.30	1.60	6.70	21.80	37.60	28.00	28.00	29.00	36.00
OHM 12	0.60	1.60	3.00	4.70	16.60	321.00	31.10		
OHM13	0.80	2.70	6.30	11.30	12.40	40.10	47.40	48 00	48 00
OHM 14	0.90	1.80	6.50	11.10	9.70	16.50	26.40		
OHM 15	0.90	9.10	11.40	31.10	27.10	31.60	33.00	35.00	
OHM 16	0.50	1.20	2.40	2.10	11.10	11.70	59.50	62.00	

Depth (m)

Ves No.	d_1	d_2	d_3	d_4	d_5	d_6	d_7	d_8	d_9
OHM 1	0.30	1.40	2.60	7.70	24.90	56.50	81.90	110.00	143.00
OHM 2	0.90	1.80	4.60	13.00	21.70	28.10	47.10	81.90	203.00
OHM 3	0.60	2.60	15.70	27.90	45.60	73.70	110.00	152.00	198.00
OHM 4	0.90	14.70	30.40	49.60	58.40	86.10	112.00	141.00	175.00
OHM 5	0.90	1.60	5.10	7.90	11.50	15.20	37.50	89.60	130.00
OHM 6	1.00	5.20	12.50	28.70	42.80	91.70	108 00	139 00	171 00
OHM 7	1.30	3.00	11.90	32.60	51.40	88.00	136 00	177 00	220 00
OHM 8	0.70	1.20	3.10	7.60	18.40	50.90	73.90	143.00	204.00
OHM 9	1.60	4.00	10.40	18.90	31.70	40.60	86.60	126 00	167 00
OHM 10	1.10	3.00	10.60	43.90	67.90	94.00	116.00	123.00	
OHM 11	0.30	1.90	8.60	30.40	68.00	96.00	124.00	153 00	189 00
OHM 12	0.60	2.20	5.20	9.90	26.60	57.50	88.60		
OHM13	0.80	3.50	9.80	21.10	33.50	73.60	121.00	169.	217.
OHM 14	0.90	2.70	9.20	20.30	30.00	46.50	72.90		
OHM 15	0.90	10.00	21.40	52.50	80.40	112.00	145.00	180.00	
OHM 16	0.50	1.70	4.10	6.20	17.30	29.00	88.50	151.00	

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435 (Online) Volume 15, Issue 06, June 2026)

Table:2 Study Area and Survey Location (Summary)

SITE ID	TOWN/VILLAGE	LGA WARD	LATITUDE (°N)	LONGITUDE (°E)	ELEVATION (m)	LAND USED
OHM 01	Agadagba, Ohimini LGA	Agadagba, Ward	7°23.2425	7°90.1892	546	Agricultural land
OHM 02	Emichi Health Center	Onyagede -Icho Ward	7°25.358	7°90.331	500	Residential Area
OHM 03	Awga, Ohimini LGA	Awume-Icho, Ward	7°25.733	7°87.104	565	Residential Area
OHM 04	Epideru, Ohimini LGA	Onyagede Ehaje Ward	7°24.336	7°84.485	619	Agricultural land
OHM 05	Ochobo, Ohimini LGA	Ochobo Ward	7°18.8016	7°93.2494	356	Agricultural land
OHM 06	Otobi, Ohimini LGA	Ehatokpe Ward	7°13.3513	8°02.9997	600	Agricultural land
OHM 07	Ejeh, Olengbeche	Oglewu Ward	7°14.986	7°90.5023	640	Residential Area
OHM 08	Onyagede, Ehaje	Onyagede Ehaje Ward	7°31.1986	7°81.1644	584	Residential Area
OHM 09	Ehatokpe, Ohimini LGA	Ehatokpe Ward	7°26.5671	7°96.1333	543	Agricultural land
OHM 10	Oglewu-Icho, Ohimini LGA	Oglewu-Icho Ward	7°27.5207	8°01.4891	579	Agricultural land
OHM 11	Idekpa, Ohimini LGA	Idekpa Ward	7°33.2417	7°88.5802	311	Residential Area
OHM 12	Amejo, Ohimini LGA	Idekpa Ward	7°21.9352	783.2243	545	Agricultural land
OHM 13	Okonobo, Ohimini LGA	Agadagba Ward	7°11.4435	7°87.3442	632	Agricultural land
OHM 14	Oglewu-Ehaje, Ohimini LGA	Oglewu-Ehaje Ward	7°22.7526	8°04.7850	574	Residential Area
OHM 15	Idekpa-Okpiko Ohimini LGA	Idekpa Ward	7°23.060	7°91.882	541	Agricultural land
OHM 16	Ajide, Ohimini LGA	Onyagede Ward	7°13.369	7°90.475	563	Residential Area

Table :3 Inversion/ Model Summary

VES NO	LAYER NO	RESISTIVITY VALUE (Ω.m)	THICKNESS PER LAYER (m)	RMS ERROR (%)	NOTES ON RELIABILITY
OHM 01	10	129.00	5.10	4.8	Excellent curve fit, very reliable.
OHM 02	10	104.00	19.00	5.3	Good fit, reliable interpretation.
OHM 03	10	39.40	36.30	6.2	Good, Minor Variable at depth.
OHM 04	10	548.00	25.90	4.1	Excellent model correlation
OHM 05	10	121.00	3.60	7.0	Good fit, consistent layer response.
OHM 06	10	528.00	14.10	6.5	Good agreement, reliable data.
OHM 07	10	154.00	36.60	5.7	Good curve alignment.
OHM 08	10	182.00	23.00	4.5	Excellent fit, very reliable
OHM 09	10	668.00	12.80	8.3	Moderate fit, slightly scattered data.
OHM 10	9	650.00	7.60	6.8	Good fit, reliable result.
OHM 11	10	670.00	28.00	5.5	Acceptable fit, shallow data reliable.
OHM 12	8	9.80	4.70	4.9	Excellent fit, highly reliability.
OHM 13	10	12.70	47.40	6.1	Good fit, consistent model.
OHM 14	8	12.20	9.70	5.4	Reliable, slight noise at depth.
OHM 15	9	860.00	31.60	7.2	Moderate reliability, recheck deeper layer.
OHM 16	9	950.00	11.70	5.0	Good fit, shallow section re

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435 (Online) Volume 15, Issue 06, June 2026)

Table:4 Geophysical survey summary

Site ID	Aquifer Unit **ƒ (Ω.m)**	Estimated Hydrualic Conductivity K	Transmissivity (m/day) T	Method/empirical relation	Uncertainty
OHM 01	129.0.	3.0	15.30	Archie's law, K from Porosity class	Low
OHM 02	104.0.	3.0	57.00	Archie's law, empirical K	Low
OHM 03	344.0.	0.3	10.89	Archie's	Moderate
OHM 04	548.0.	0.03	0.78	Archie's law	High
OHM 05	128.0.	3.0	10.80	Archie's law	Low
OHM 06	154.0.	3.0	42.30	Archie's law	Low
OHM 07	182.0.	3.0	109.80	Archie's law	Low
OHM 08	668.0.	0.03	0.71	Archie's law	High
OHM 09	650.0.	0.03	0.384	Archie's law	High
OHM 10	640.0.	0.03	1.43	Archie's law	High
OHM 11	9.80.	0.24	1.44	Archie's law (Invalid φ)	Very Low
OHM 12	12.70.	0.27	2.65	Archie's law (Invalid φ)	Very Low
OHM 13	860.2.	1.45	1.34	Archie's law	Very Low
OHM 14	86.20.	0.03	0.471	Archie's law	Low
OHM 15	150.0.	3.0	46.80	Archie's law	Very High
OHM 16	9.00.	3.0	45.30	Archie's law (Invalid φ)	Very Hihg

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435 (Online) Volume 15, Issue 06, June 2026)

Table:5 Estimated Safe yield/expected well yield

Site ID	Aquifer unit.	Estimated sustainable yield (m/day)	Recommended well depth(m)	Confidence
OHM 01.	129.0	0.08.	35	High
OHM 02.	104.0	0.29.	55.	High
OHM 03	344.0	0.05.	60.	Moderate
OHM 04	548.0	0.004	45	Low
OHM 05.	128.0	0.05.	30.	High
OHM 06.	154.0	0.21.	45.	High
OHM 07.	182.0	0.55.	70.	High
OHM 08	668.0	0.004.	40.	poor aquifer
OHM 09	650.0	0.002.	35.	Low
OHM10	640.0	0.007	65	Low
OHM 11	9.80	0.005	54	Very Low
OHM 12	12.70	0.0045	57	Very Low
OHM 13	860.2	0.002.	40.	Low
OHM 14.	86.0	0.23.	50.	High
OHM 15	150.0	0.23	50.	High
OHM 16	9.00	0.34	56	Very Low

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435 (Online) Volume 15, Issue 06, June 2026)

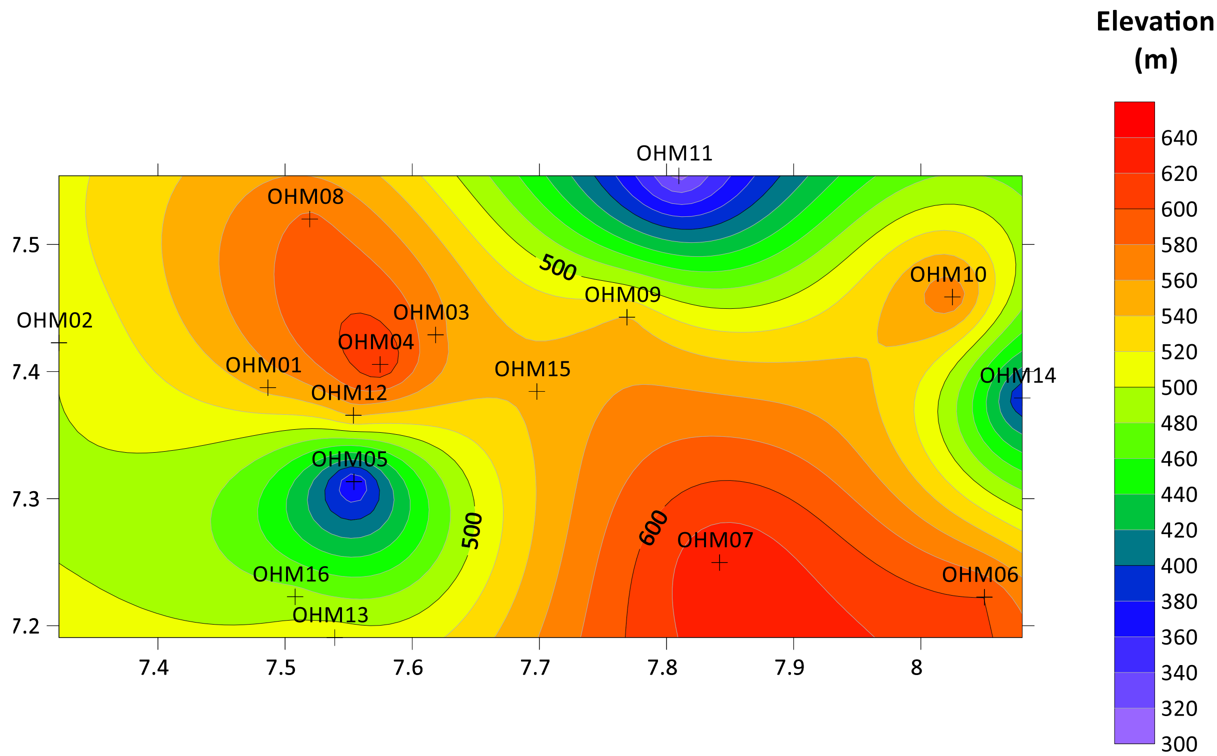

Figure 1: Elevation map of the study area

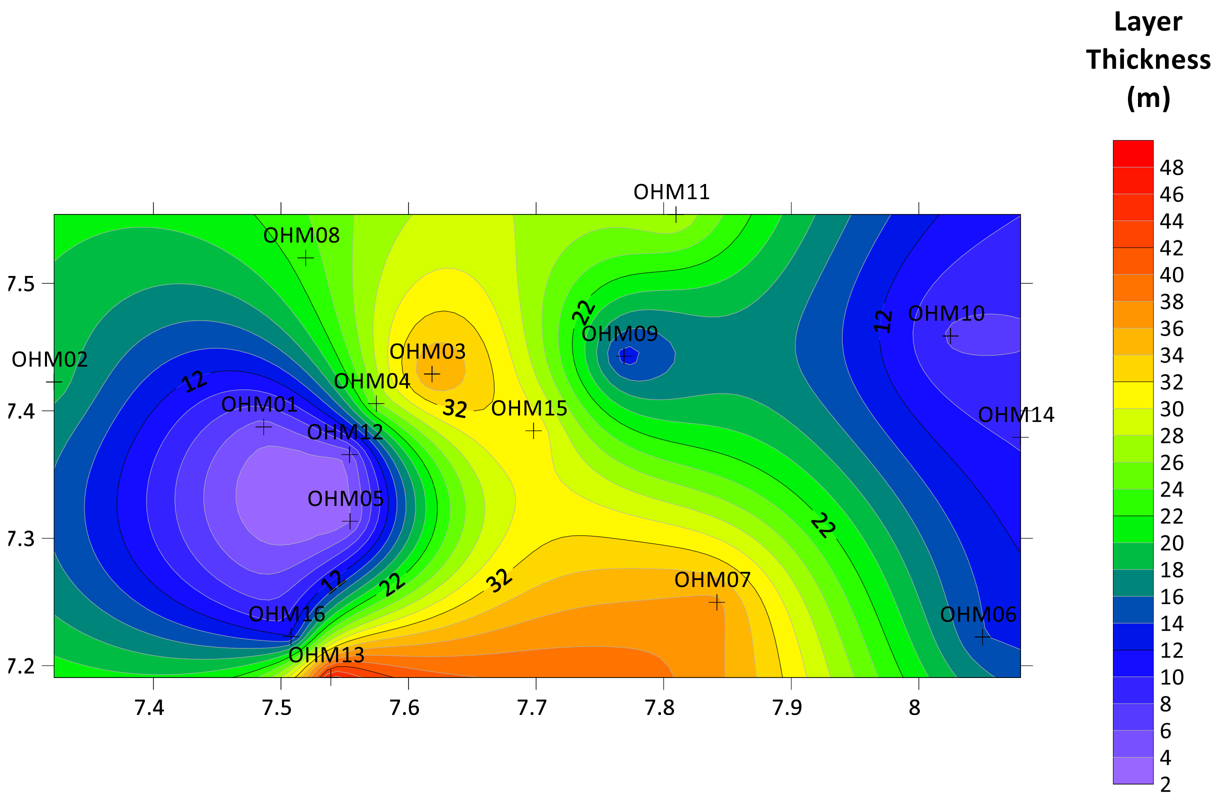

Figure 2: Aquifer Layer thickness

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435 (Online) Volume 15, Issue 06, June 2026)

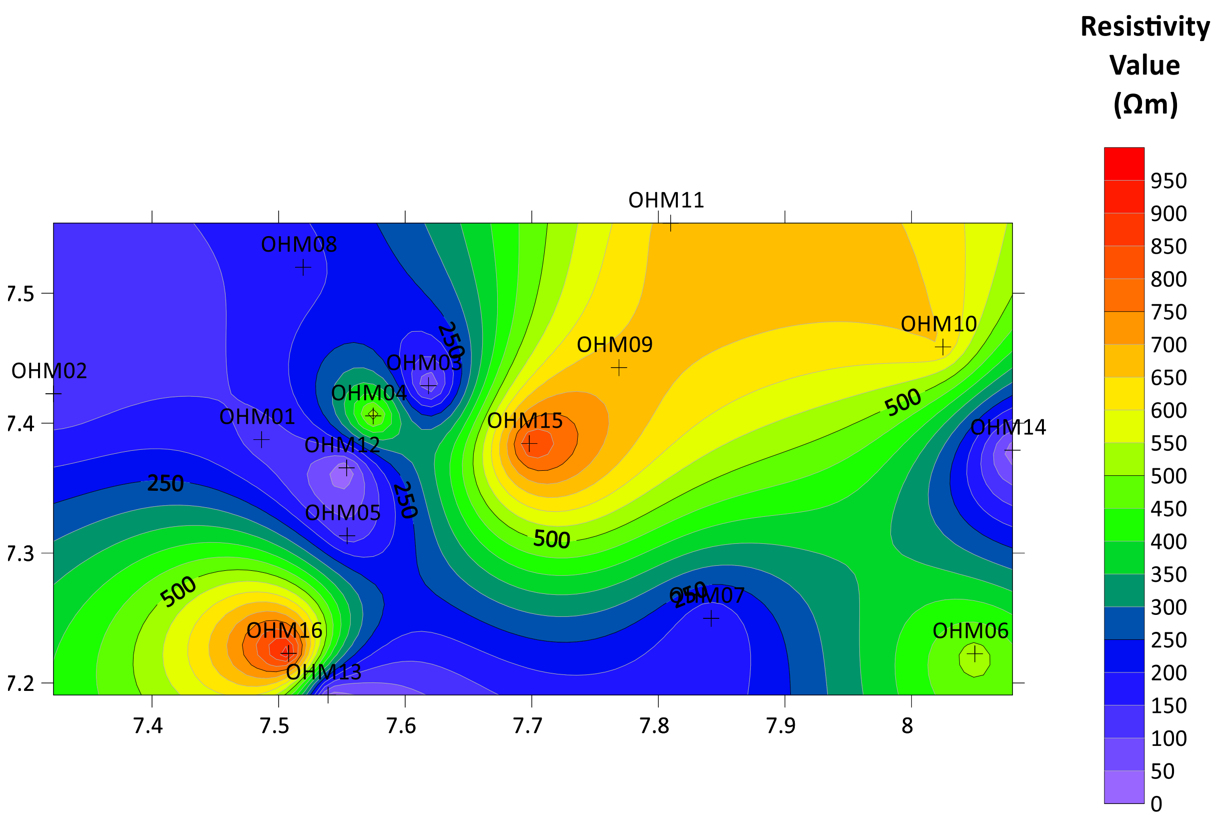

Figure 3: Aquifer Resistivity map of the study area

Spatial Variability of Aquifer Properties

The spatial distribution of VES stations (Table 2) indicates that aquifer properties vary with elevation and land-use patterns. Lower elevation zones and predominantly agricultural areas-such as Agadagba, Epideru, and Ochobo-tend to exhibit enhanced recharge potential due to higher infiltration capacity. In contrast, residential and compacted areas show relatively reduced recharge conditions.

Depth to aquifer, derived from layer thickness and depth columns in Table 1, generally ranges between 30 m and 70 m. This corresponds to the transition from the weathered layer to the fractured basement zone. The recommended drilling depths presented in Table 4.5 fall within this range, demonstrating consistency between geophysical interpretation and practical borehole development planning.

The elevation map (Figure 1) suggests that recharge is influenced by local topography, with relatively lower terrains facilitating infiltration and groundwater accumulation. However, lithological control appears to be the dominant factor governing aquifer productivity.

Reliability of the Geophysical Interpretation

The inversion results (Table 3) show RMS errors between 4.1% and 8.3%, indicating good to excellent curve fitting. Stations such as OHM 01, OHM 04, OHM 08, and OHM 12 exhibit excellent model correlation, while a few stations (e.g., OHM 09 and OHM 15) show slightly higher RMS values due to deeper-layer noise-an expected limitation in resistivity surveys at larger electrode spacings.

Overall, the low RMS errors enhance confidence in the derived resistivity and thickness parameters. The consistency between resistivity, aquifer thickness, transmissivity, and sustainable yield further validates the robustness of the interpretation.

Hydrogeophysical Parameters and Aquifer Productivity

Hydraulic conductivity (K) and transmissivity (T), estimated using Archie's empirical relationship (Table 4), display pronounced spatial variability. Hydraulic conductivity values range from 0.03 to 3.0 m/day, reflecting differences in porosity, grain size distribution, and degree of saturation.

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347-6435 (Online) Volume 15, Issue 06, June 2026)

Higher K values are associated with moderately resistive and thicker weathered layers, while low K values correspond to clay-dominated or compact formations.

Transmissivity values range from 0.384 to 109.8 m²/day, clearly differentiating high-, moderate-, and low-productivity aquifers. Stations OHM 06, OHM 07, and OHM 15 exhibit transmissivity values exceeding 40 m²/day, indicating aquifers capable of sustaining continuous abstraction for domestic and small-scale agricultural use. In contrast, stations with transmissivity below 1 m²/day represent marginal aquifers unsuitable for high-demand applications.

The strong correlation between aquifer thickness (Figure 2) and transmissivity (Table 4) demonstrates that groundwater productivity is primarily controlled by the thickness and permeability of the weathered/fractured zone.

Groundwater Potential Zonation

Integration of resistivity, aquifer thickness, hydraulic conductivity, transmissivity, and estimated sustainable yield (Table 5) enabled classification of the study area into three groundwater potential zones:

i) **High-potential zones** are characterized by thick (>20 m), moderately resistive (100-300 Ω·m) aquifer units with transmissivity >40 m²/day. These include OHM 02, OHM 06, OHM 07, OHM 14, and OHM 15.

ii) **Moderate-potential zones** display intermediate resistivity and moderate aquifer thickness, indicating partially developed or discontinuous aquifers.

iii) **Low-potential zones**, such as OHM 11, OHM 12, and OHM 16, are dominated by clay-rich layers or fresh basement rocks with low transmissivity and minimal sustainable yield.

This zonation aligns with established hydrogeological understanding of crystalline basement terrains, where groundwater storage depends predominantly on secondary porosity created by weathering and fracturing.

Implications for Groundwater Development and Management

Estimated sustainable yields range from 0.002 to 0.55 m/day. High yield locations are suitable for community water supply and small-scale irrigation, whereas low yield zones require cautious development or supplementary investigation.

Recommended borehole depths of 30-70 m ensure penetration into saturated weathered and fractured zones. Drilling beyond this interval into fresh basement rock is unlikely to significantly enhance yield and may increase development costs.

The results provide a scientific basis for groundwater planning in Ohimini LGA, supporting optimized borehole siting, reduced drilling failure rates, and sustainable aquifer management. The integration of geoelectrical interpretation with hydrogeological indices demonstrates the effectiveness of VES as a reliable tool for groundwater exploration in basement complex terrains.

IX. Conclusion

This study successfully evaluated the hydrogeological properties of aquifers in Ohimini Local Government Area, Benue State, using Vertical Electrical Sounding (VES) techniques. The geoelectrical investigation revealed a heterogeneous subsurface comprising topsoil, lateritic/clayey horizons, weathered basement, fractured basement, and fresh bedrock, with aquifer occurrence primarily controlled by the thickness and degree of weathering and fracturing of the basement rocks.

Resistivity values ranging from 9.8 Ω·m to over 15,000 Ω·m reflect significant lithological variability across the study area. Productive aquifers are mainly associated with moderately resistive (100–500 Ω·m), thick weathered and fractured basement zones occurring at depths of approximately 30–70 m. Derived hydraulic conductivity and transmissivity values indicate wide spatial variation in aquifer productivity, with transmissivity values reaching up to 109.8 m²/day in high-potential zones.

Groundwater potential zoning delineated the area into high, moderate, and low potential zones. High groundwater potential zones, identified at OHM 02, OHM 06, OHM 07, OHM 14, and OHM 15, are characterized by thick, permeable aquifer units capable of sustaining domestic and small-scale agricultural water supply. In contrast, low-potential zones are dominated by clay-rich layers or unfractured basement rocks, resulting in poor groundwater yield. Overall, the reliability of the VES interpretation is supported by low RMS errors, confirming the suitability of electrical resistivity methods for groundwater exploration in Ohimini LGA.

Recommendations

Based on the findings of this study, the following recommendations are made:

i) Borehole Siting and Development**:** Borehole drilling should be prioritized in high groundwater potential zones characterized by thick weathered and fractured basement layers. Optimal borehole depths of 30–70 m are recommended to maximize sustainable yield.

ii) Groundwater Management and Protection: Shallow and productive aquifers, particularly in agricultural and residential areas, should be protected from surface contamination through proper land-use regulation and the establishment of groundwater protection zones.

iii) Supplementary Investigations: Integration of geophysical surveys with borehole logging, pumping tests, and hydrochemical analysis is recommended to further refine aquifer characterization and improve groundwater resource evaluation.

iv) Sustainable Water Use: Groundwater abstraction should be regulated to align with estimated sustainable yields, especially in moderate and low potential zones, to prevent aquifer depletion and well failure.

v) Future Research: Further studies employing advanced techniques such as 2D/3D electrical resistivity tomography and remote sensing are recommended to enhance understanding of fracture networks and groundwater flow systems in the area.

REFERENCES

[1] Archie, G. E. (1942). The electrical resistivity log as an aid in determining some reservoir characteristics. Transactions of the AIME, 146(1), 54–62.

[2] Adanu, E. A., & Schneider, W. J. (1983). Groundwater resources of the Benue State, Nigeria: Occurrence and potential for development. Journal of Mining and Geology, 20(1), 43–52.

[3] Adanu, J. K., & Schneider, W. (1983). Hydrogeology of the Benue Trough, Nigeria. Journal of African Earth Sciences, 1(2), 45–58. https://doi.org/10.1016/0899-5362(83)90005-2

[4] Ako, B. D., Olorunfemi, M. O., & Ajayi, T. R. (2005). Groundwater prospecting and aquifer delineation using electrical resistivity methods in parts of southwestern Nigeria. Journal of Mining and Geology, 41(2), 215–227.

[5] Ako, B. D., Olorunfemi, M. O., & Ajayi, T. R. (2005). Groundwater potential evaluation using vertical electrical sounding in southwestern Nigeria. Environmental Geology, 47(3), 329–336. https://doi.org/10.1007/s00254-004-1166-3

[6] Anomohanran, O. (2015). Determination of groundwater potential in Asaba, Nigeria using surface geoelectric sounding. International Journal of Geosciences, 6(2), 233–241. https://doi.org/10.4236/ijg.2015.62017

[7] Bala, A. E., & Ike, E. C. (2001). The aquifer of the crystalline basement rocks in parts of Kaduna State, Nigeria. Journal of Mining and Geology, 37(2), 177–184.

[8] Batayneh, A. T. (2011). Use of electrical resistivity methods for detecting subsurface fresh and saline water in the eastern Dead Sea area, Jordan. Hydrogeology Journal, 19(2), 387–399. https://doi.org/10.1007/s10040-010-0684-0.

[9] Egbai, J. C., & Iserhien-Emekeme, R. E. (2015). Application of vertical electrical sounding (VES) for groundwater exploration in parts of Delta State, Nigeria. Journal of Applied Sciences and Environmental Management, 19(4), 695–703.

[10] Egbai, J. E., & Iserhien-Emekeme, O. (2015). Hydrogeophysical investigation of groundwater potential zones in Delta State, Nigeria. International Journal of Water Resources, 5(2), 85–98.

[11] Ekine, A. S., & Osobonye, G. (1996). Surface geoelectric sounding for the determination of aquifer characteristics in parts of Bonny Local Government Area, Rivers State, Nigeria. Nigerian Journal of Physics, 8, 82–87.

[12] Emberga, T. T., Opara, A. I., Onyekuru, S. O., Omenikola, A. I., Bilar, A. A., Unegbu, C. C., & Epuerie, T. E. (2023). Estimates of aquifer hydraulic conductivity based on grain-size data and multiple regression techniques in Imo River Basin. International Journal of Energy and Water Resources, 1–19.

[13] Etu-Efeotor, J. O., & Akpokodje, E. G. (1990). Aquifer systems of the Niger Delta. Journal of Mining and Geology, 26(2), 279–284.

[14] Freeze, R. A., & Cherry, J. A. (1979). Groundwater. Prentice-Hall.

[15] Henriet, J. P. (1976). Direct applications of the Dar Zarrouk parameters in groundwater surveys. Geophysical Prospecting, 24(2), 344–353.

[16] Offodile, M. E. (2002). Groundwater study and development in Nigeria (2nd ed.). Mecon Geology and Engineering Services Ltd.

[17] Olayinka, A. I., & Olorunfemi, M. O. (1992). Determination of geoelectrical characteristics in Okene area and implications for borehole siting. Journal of Mining and Geology, 28(2), 403–412.

[18] Olayinka, A. I., & Olorunfemi, M. O. (1992). Groundwater exploration using vertical electrical sounding in basement complex areas of Nigeria. Journal of African Earth Sciences, 14(3), 289–297. https://doi.org/10.1016/0899-5362(92)90022-R

[19] Olorunfemi, M. O., & Fasuyi, S. A. (1993). Aquifer types and the geoelectric/hydrogeologic characteristics of part of the central basement terrain of Nigeria (around Akure). Journal of African Earth Sciences, 16(3), 309–317. https://doi.org/10.1016/0899-5362(93)90051-O

[20] Olorunfemi, M. O., & Fasuyi, S. A. (1993). A geoelectric evaluation of groundwater potential in basement complex terrain. Water Resources, 27(5), 635–644.

[21] Okogbue, C. O., & Omonona, O. V. (2013). Groundwater potential evaluation using geoelectrical resistivity method in parts of Anambra State, southeastern Nigeria. Environmental Earth Sciences, 70(3), 1219–1233. https://doi.org/10.1007/s12665-012-2185-8

[22] Orellana, E., & Mooney, H. M. (1966). Master tables and curves for vertical electrical sounding over layered structures. Madrid: Interciencia.

[23] Oseji, J. O., Atakpo, E. A., & Okolie, E. C. (2005). Geoelectric investigation of the aquifer characteristics and groundwater potential in Kwale, Delta State, Nigeria. Journal of Applied Sciences and Environmental Management, 9(1), 157–160.

[24] Reynolds, J. M. (2011). An introduction to applied and environmental geophysics (2nd ed.). Wiley-Blackwell.

[25] Telford, W. M., Geldart, L. P., & Sheriff, R. E. (1990). Applied geophysics (2nd ed.). Cambridge University Press.

[26] Todd, D. K., & Mays, L. W. (2005). Groundwater hydrology (3rd ed.). John Wiley & Sons.

[27] Uma, K. O. (1989). An appraisal of the groundwater resources of the Benue River Basin, Nigeria. Journal of Mining and Geology, 25(1–2), 57–63.

[28] Zohdy, A. A. R., Eaton, G. P., & Mabey, D. R. (1974). Application of surface geophysics to groundwater investigations. U.S. Geological Survey Techniques of Water-Resources Investigations, Book 2, Chapter D1.