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Application of VES and 2D – Electrical Resistivity Tomography in delineating Groundwater Potential Zones within Ganaja -Jimgbe area, North Central Nigeria

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ABSTRACT

Groundwater exploration within Basement Complexes requires integrated geophysical approaches due to its complex geological formation as aquifer are concentrated within fractured and weathered Basement zones. This study focuses on the investigation of subsurface structures and identify groundwater-bearing formations by employing Electrical Resistivity Tomography (ERT) (2D imaging) and Vertical Electrical Sounding (VES) approaches. The results from the electrical resistivity tomography (ERT), indicates that the aquifer occur at a shallow and deeper depth between the depth of 22.6m and 50-100 m. Majority of the area lacks geological structures that could serve as groundwater accumulation. This coincide with VES result in which the aquifer is primarily influenced by weathered Basement rocks. Though, few of the area are majorly of fractured basement aquifer. VES result revealed 4-5 geoelectric layers. The top soil/lateritic clay has resistivity and thickness ranging from 16.5-308.9 Ωm and 0.2-22.5 m. The confining and fairly weathered Basement have resistivity and thickness of 168.9-3848.4 Ωm and 5.9-47.4 m. The weathered/fractured basement aquifer has resistivity and thickness ranging from 9.7-1985.5 Ωm and 2.3-62.2 m. The fresh/hard Basement rocks have resistivity between 750.1-20283.4Ωm. The curve types are KH, HK, and HA curve type indicating variation in groundwater and Basement geometry. The aquifers resistivity and thickness revealed that the groundwater within the area is of poor-moderate-high groundwater potential zones which can be easily polluted. This study provides critical insights into the hydrogeological conditions of the area, offering valuable data for groundwater exploration, sustainable management, and the development of water resources in the region.

Keywords: *Aquifer Characterization, VES, 2D Imaging, Ganaja-Jimgbe, Central Nigeria*

INTRODUCTION

Groundwater is an indispensable resource which is important for the survival of living things, and its demand has increased due to the rapid population growth (Mushtaq *et al.*, 2021). Sometimes there could be the problems of quality and low yield because of the nature of the water-bearing layer within the subsurface. Hence there is need for investigations of the subsurface before drilling a borehole in an area. The yielding, storing, and transmitting capabilities of groundwater in the basement rocks are determined by the continuity, extent, and thickness of weathered/fractured zones (Hervé *et al.*, 2021; Awosika *et al.*, 2020).

Numerous techniques that have been used over the years for groundwater exploration include; electromagnetic (Bon *et al.*, 2022; Omeje *et al.*, 2021; Nazıfı and Gülen, 2019; Akpah *et al.*, 2022), electrical resistivity (Lubang *et al.*, 2023; Mohamed and Alshehri, 2023; Oladunjoye *et al.*, 2019; Kizito *et al.*, 2023a; 2023b), gravity (Mohamed and Alshehri, 2023), magnetic (Oni *et al.*, 2020; Patra *et al.*, 2016, Musa *et al.*, 2025), seismic refraction (Patra *et al.*, 2016; Grelle and Guadagno, 2009) and remote sensing imagery (Hervé *et al.*, 2021; Ahmed II *et al.*, 2022; Akudo *et al.*, 2024; Jimoh *et al.*, 2025). Geophysical investigation in groundwater development, usually involves delineation and assessment of aquifer potential, aquifer protective capacity, water quality and sometimes pollution assessment studies among others (Kinnear *et al.*, 2013; Orakwe *et al.*, 2018; Olorunfemi and Oni, 2019; Kizito *et al.*, 2023a). In areas with groundwater challenges like Basement Complex, it is better to use integrated approach for its investigation. The integration of geophysical methods, as reconnaissance geophysical methods (Hasan *et al.*, 2018), and the 2D resistivity imaging and 1D vertical electrical sounding (VES) techniques for detailed follow-up studies have become standard procedure in groundwater investigation (Olorunfemi and Oni 2019; Manu *et al.*, 2019; Ibrahim *et al.*, 2023).

Ganaja- Jimgbe area is located in Lokoja, Kogi State Nigeria, situated within the basement complex which serves as a major geological feature that influences the hydrogeology of the region (Ibrahim and Adamu, 2023). This study is particularly significant due to the region's reliance on groundwater resources for various purposes, including drinking water, agriculture, and industrial activities (Ibrahim and Adamu, 2023). Water scarcity is a significant challenge in many regions of Nigeria, especially in the North Central area, where the study area is located (Akinlalu *et al.*, 2016). Groundwater in Lokoja primarily occurs in the weathered and fractured zones of the Basement Complex and in the alluvial deposits along the Niger and Benue Rivers (Ibrahim & Adamu, 2023; Kizito *et al.*, 2023a, 2023b). Previous research has focused on various aspects such as the geological formations, aquifer characteristics, groundwater quality, and the impacts of human activities on the groundwater system using combined geophysical and hydrogeological methods (Ibrahim *et al.*, 2023; Kizito *et al.*, 2023a, 2023b). However, this work includes the integration of electrical resistivity tomography (ERT) and vertical electrical sounding (VES) method. Combination of this powerful method provides more detailed and accurate result on the study area over previous work as the combination of this method was not commonly used previous works in the study area.

Location and Accessibility of the Study Area

The study area is located within Ganaja - Jimgbe community, Ajaokuta L.G.A., Kogi State, north central Nigeria within the coordinates of, latitude 07° 41′– 07° 43′ N, and longitude 06° 43′– 06° 45′ E (Figure 1). The area covers a total of 84.545km^2 and is accessible via Ajaokuta - Ganaja-Lokoja road which cuts across the mapped area. Other minor roads are footpaths that links the settlements. The study area Ganaja and Jimgbe are neighbouring communities, with Ganaja being slightly larger and more populated. The area is approximately 5-50 kilometres west of Lokoja city centre, along the Lokoja-Ganaja-Jimgbe road. The footpaths helped in designing a suitable closed transverse method during mapping and also the dry stream channels helped in exposing the low-lying outcrops for further field studies footpaths, minor and major roads that connect the communities which were traversed during this project work. Two dry stream channels running west to east of the study area join the Niger River at an angle of 90°.

Geology of the Study Area

Ganaja and Jimgbe are located in Lokoja Kogi State, and it falls within the Southwestern Nigerian Basement Complex. The hydrogeology of Lokoja is characterized by a complex arrangement of aquifers (Akinwumiju *et al.*, 2020) within the Precambrian Basement Complex and the sedimentary rocks, which are separated by a thick layer of clay (Ekwueme *et al.*, 2019).

The area is underlain by Migmatite-gneiss complex of Precambrian age, the distinguished migmatite types found in the study area include Migmatite Gneiss, Porphyritic Granite, Granite Gneiss with major and minor veins occurring at the surface of the outcrop (see Figure 1). Most of these are estimated to be over 2.5 billion years old (Adetunji *et al.*, 2020).

As described by Omali (2014), Haruna (2017) and Omali *et al.* (2019), Lokoja Basement Complex consists of Migmatite-Gneiss, Obajana Gneiss and the Older Granites of the Southern Nigeria. Migmatite Gneiss and Obajana Gneiss cover about half of the area outcropping at the Southwest, West, Northwest and central part of the area. The Southern and the Southeastern parts are underlain by undifferentiated Older Granites mainly

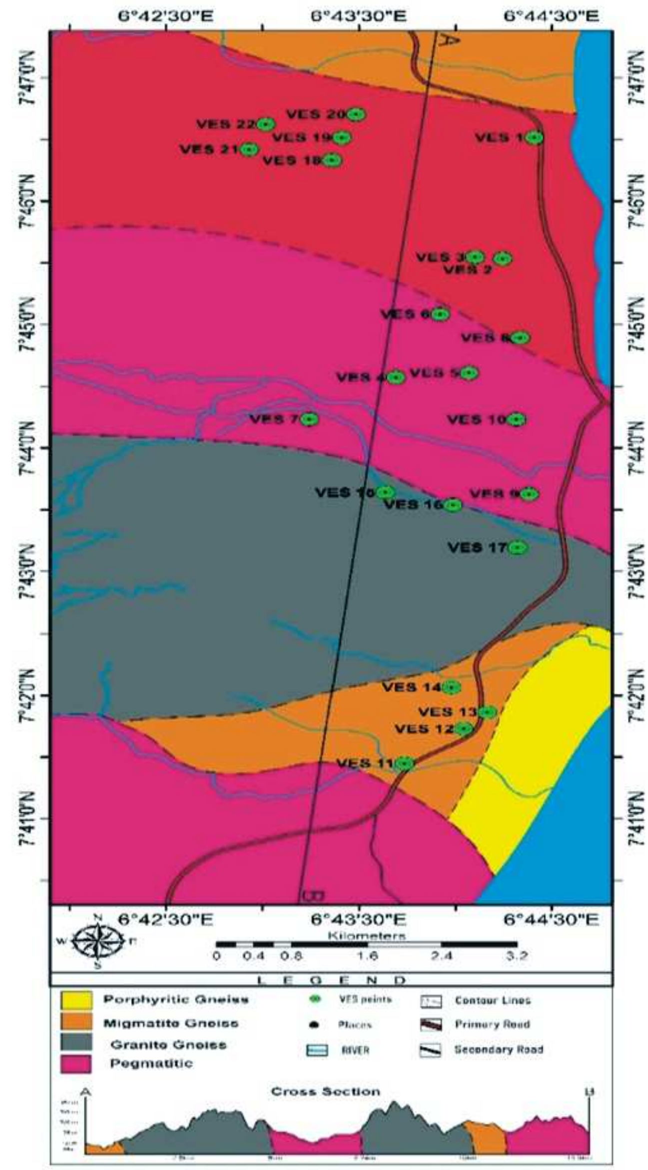

Figure 1: Geology Map indicating various rock types and Sounding Points of the Study Area

porphyritic granites, granodiorite, diorite, quartz diorite and granite gneiss (Omada *et al.*, 2015; Ozulu *et al.*, 2019). Basically, the study area is underlain by Migmatite Gneiss, Granite Gneiss, porphyritic Gneiss and Pegmatite intrusion (Figure 1).

METHODOLOGY

The geophysical survey locations were based on areas that are accessible for easy electrode spreading. DDR-3 resistivity meter was used for measuring the electrical resistivity value of the subsurface. Global positioning system (GPS) was used to take the coordinates of each sounding points on the geological map. Other materials used are electrodes, measuring tape, cable reels, and field notebook.

Electrical Resistivity Tomography (ERT) Method

Electrical Resistivity Tomography (ERT) using Werner configuration was firstly adopted with inter-electrode spacing of 5m and the 'n' factor ranging from 1-8. This process consists of a series of electrodes (two current and two potential electrodes) arranged along a straight line at equidistance, with each electrode connected to a multi-core cable. A current was injected between two outer electrodes (current electrode), and the resulting voltage differences were measured between adjacent electrode pairs (potential electrode). The resulting resistance value is then multiplied by the geometric factor to generate resistivity value as seen in equation 1. By improving the electrode array along the survey line, a 2D dataset of resistivity values was generated, representing the subsurface resistivity distribution. With this, four 2D profiles was carried out within the study area. Further processing of the data was done using RES2DIVN to generate the ERT image commonly known as 2D imaging.

$$\rho = 2\pi aR = GR \qquad (1)$$

Where; a = interelectrode spacing, R = Measured resistance, ρ = computed resistivity of the subsurface material, G = Geometric factor, and π = 22/7.

Vertical Electrical Sounding (VES) Method

Vertical electrical sounding was followed up at each area where the ERT was carried out and other surrounding area. Schlumberger electrode configuration was adopted for vertical electrical sounding field data collection. Current electrode spacing (AB/2) ranges from 1m to 160 m while potential electrode spacing (MN/2) ranged from 0.5 m to 15 m. The values of resistance (R) were obtained directly from the resistivity meter, and the product of resistance (R) obtained and geometric factor (K) gives the apparent resistivity (ρa) as show in equation 2 below. Resistivity data collected from the field, including the electrode spacing (AB/2) and the corresponding apparent resistivity values (ρa) was processed using a computer iterative software called WinRESIST which assumes a layered earth model, where the subsurface is divided into horizontal layers with distinct resistivity values.

$$\boldsymbol{\rho_a = \frac{\pi}{2}\left[\frac{\left(\frac{AB}{2}\right)^2 - \left(\frac{MN}{2}\right)^2}{MN/2}\right] R = GR} \qquad (2)$$

Where; R = Measured resistance, ρa = computed apparent resistivity of the subsurface material, G = Geometric factor, and π = 22/7.

RESULTS AND DISCUSSION

The ERT result for Profile 1 is displayed in Figure 2a below with colours ranging from blue for low resistivity and red to purple for high resistivity. The resistivity and lateral extent value of the Profile ranges from 18.1 Ωm to 989.0 Ωm and 1m to 150m. The depth of penetration by this Profile is 24.8m. This Profile showed that the area is underlain by three layers based on the contrast of resistivity value. The first layer can be interpreted as the top soil and lateritic clay with resistivity and depth value ranges from 18.1 Ωm to 56.7 Ωm and 0.0m to 3.5m. That is area with blue colour that show low resistivity layer. However, its depth increases to about 6.5m at horizontal distance of 40-50m and 107-117m. The second layer which is interpreted as weathered basement (green colour zones) has resistivity value ranges from 56.7 Ωm to 313.0 Ωm with depth of about 6.3m which further increase to 24.8m and 12.5m at horizontal distance of 30.0-70.0m and 97.0-117.0m. The third layer (brown to red to purple colour zones) is interpreted as the fresh Basement with resistivity value ranges from 313.0 Ωm to 980.0 Ωm which is seen underlying the weathered Basement except at horizontal distance of 30.0m to 70.0m where the weathered Basement extends to the depth of 24.0m and this area can be interpreted to serves as the weathered Basement aquifer that can produce groundwater. The results of vertical electrical sounding (Figure 2b) carried out at 40m along the Profile showed four geoelectric layer. However, layer 3 and 4 can be regarded as one layer interpreted to be the fresh Basement due to high resistivity in the layer. However, the VES result also revealed that the groundwater in the area is in the weather Basement at shallow depth.

The ERT result for Profile 2 is displayed in Figure 3a below with colours ranging from blue for low resistivity and red to purple for high resistivity. The values of resistivity and lateral distance ranges from 3.94 Ωm to 2259.0 Ωm and 1m to 150m. The depth of penetration by this Profile is 24.8m. This Profile revealed that the subsurface is underlain by 3 distinctive lithology due to the difference in the resistivity. The first layer (the blue to green colour zones) may be interpreted as sandy clay with a resistivity value of 3.94 Ωm to 149 and the depth ranges from 0.2 m to 1.25 m at 0-37.0 m, and extent to 6.38 m along the Profile until it reaches a horizontal distance of 120-140 m where it was 24.0 m. The second layer (light green to yellow colour) is interpreted to be weathered basement and has a resistivity value between 149.0 Ωm to 368.0 Ωm with depth value of 1.25 m at a distance of 0-20m and increase to 10.3 m along the Profile. The depth increases to 24.0 m at a distance of 117-125 m. This weathered layer which extends to 24.0 m depth at a distance of 120-125m can represent a low yeild aquifer and idicated that the area lacks fractures that could sever as aquifer zones. The third layer indicated by brown to red to purple color represented the underlying fresh basemen and has resistivity between 912.0 Ωm to 2559.0 Ωm. The vertical eletrical sounding as show in Figure 3b was carried out at 55.0 m along the profile showed that the area is dominated by four geoelectric layer with a progessive increase in the resistivity which suggest a low yelid undeground water at shallow depth. This corroborate with the ERT result

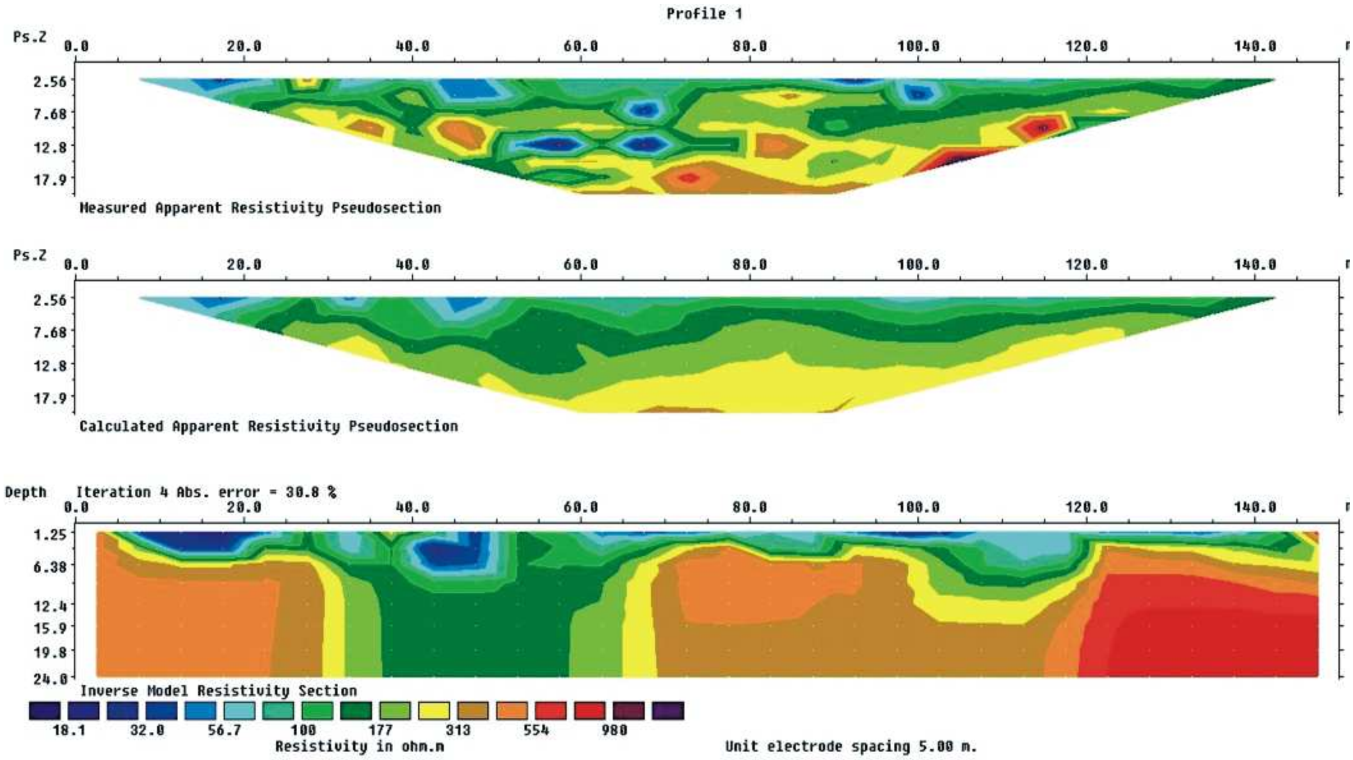

Figure 2a: ERT Image of Profile 1

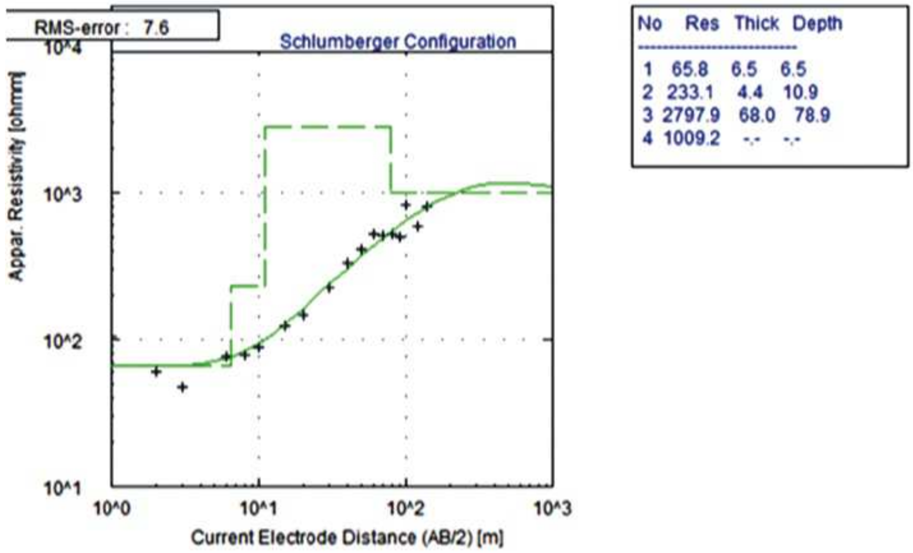

Figure 2b: VES Curve for Location 2

and showed similar groundwater and basement geometry to that of Profile 1 indicating area with poor groundwater potential zones.

The ERT result from Profile 3 is shown in Figure 4a below with colours ranging from blue for low resistivity and red to purple for high resistivity. The resistivity and lateral extent of the Profile ranges from 16.6 Ωm to 2643.0 Ωm and 1m to 150m. The depth of penetration by this Profile is 24.8m. This Profile also showed a three-model layer based on the variation in the resistivity value. The first layer indicated by light blue to blue can be interpreted as the top soil with resistivity and depth value ranges from 16.6 Ωm to 70.6 Ωm and 0.0 m to 1.5 m. The depth increases to about 2.5 m at horizontal distance of 110-125 m. This was followed by a very thin layer interpreted as weathered Basement having a resistivity value ranges from 100 to 621 m with depth of about 1.75 m which further increase to 2.55 m and 6.38m at horizontal distance of 0.0-7.5 m and 132.5-140 m. The third layer is the fresh Basement with resistivity value ranges from 621 Ωm to 2643 Ωm which extend to a depth of 24.0 and beyond. Due to its high resistivity the area does not exhibit the potential for groundwater and showed the occurrence of fresh Basement rock at shallow depth as seen from the brown-red-purple colour

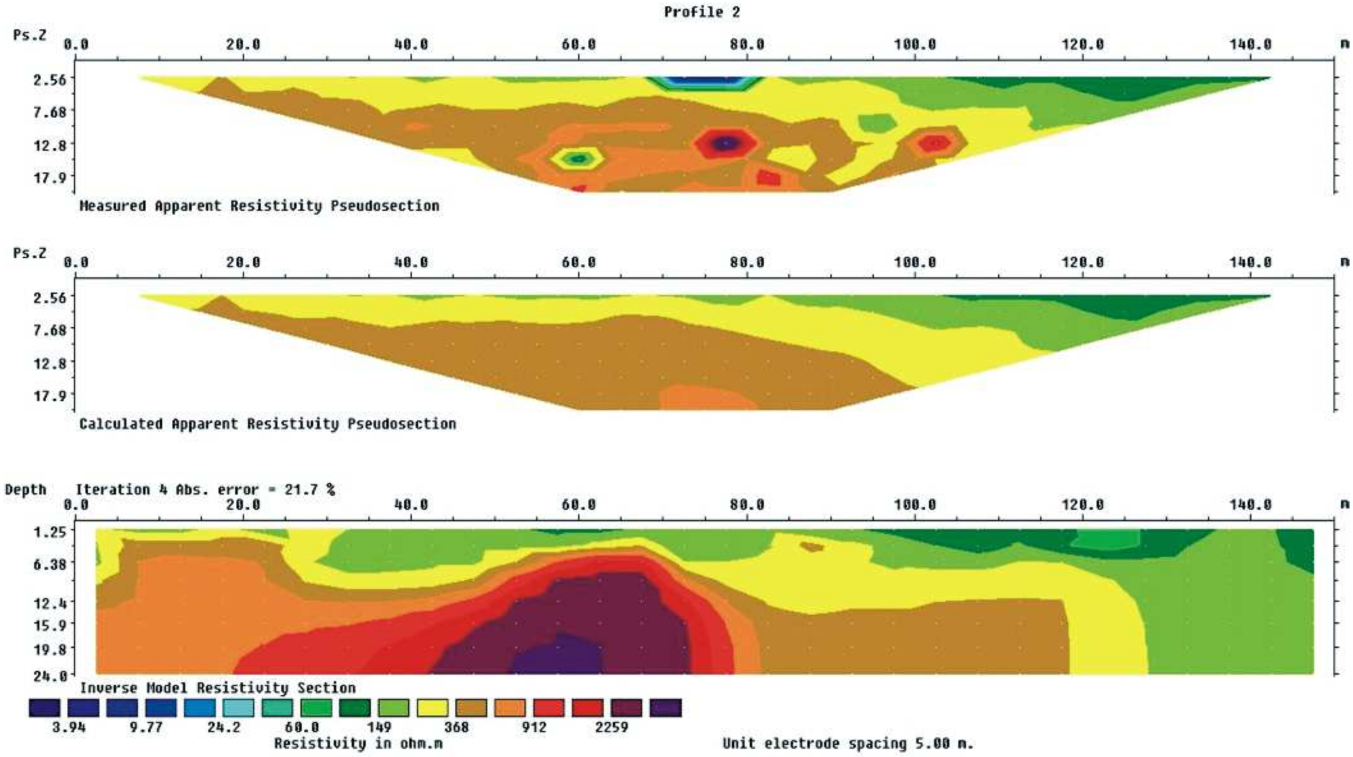

Figure 3a: ERT Image of Profile 2

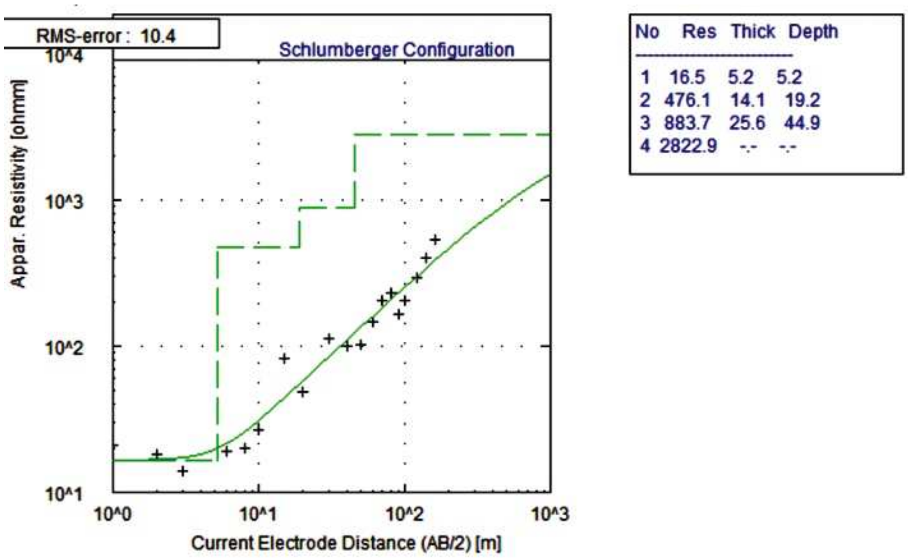

Figure 3b: VES Curve for Location 15

in Figure 4a. The results of the vertical electrical sounding (Figure 4b) carried out at 35.0 m along the profile showed four geoelectric layer. However, due to the continuous increase in the resistivity it also indicates that the area is of low yield and underlain by fresh Basement from the high resistivity value in the layer. The VES result also revealed that the groundwater in the area is in the first layer at extremely shallow depth of about 22.5 m.

The ERT result for Profile 4 is displayed in Figure 5a below with colours ranging from blue for low resistivity and red to purple for high resistivity. The resistivity and lateral extent of the profile ranges from 11.3 Ωm to 4648.0 Ωm and 1m to 150m. The depth of penetration by this Profile is 24.8m. This Profile revealed that the subsurface is underlain by four distinctive lithology due to the difference in the resistivity. In this case the first layer which referred to the top soil and lateritic clay has an intermediate resistivity value (352-582 Ωm). The second layer has resistivity value of 149 to 352 Ωm and depth ranges from 10.0 to 30.5m which is further interbedded by the third layer with at a distance of 10.0-33.0 m, 43.0-53.0 m, 60.0-90.0m, and 97.0-110.0 m.

The third layer is interpreted to be weathered/fractured

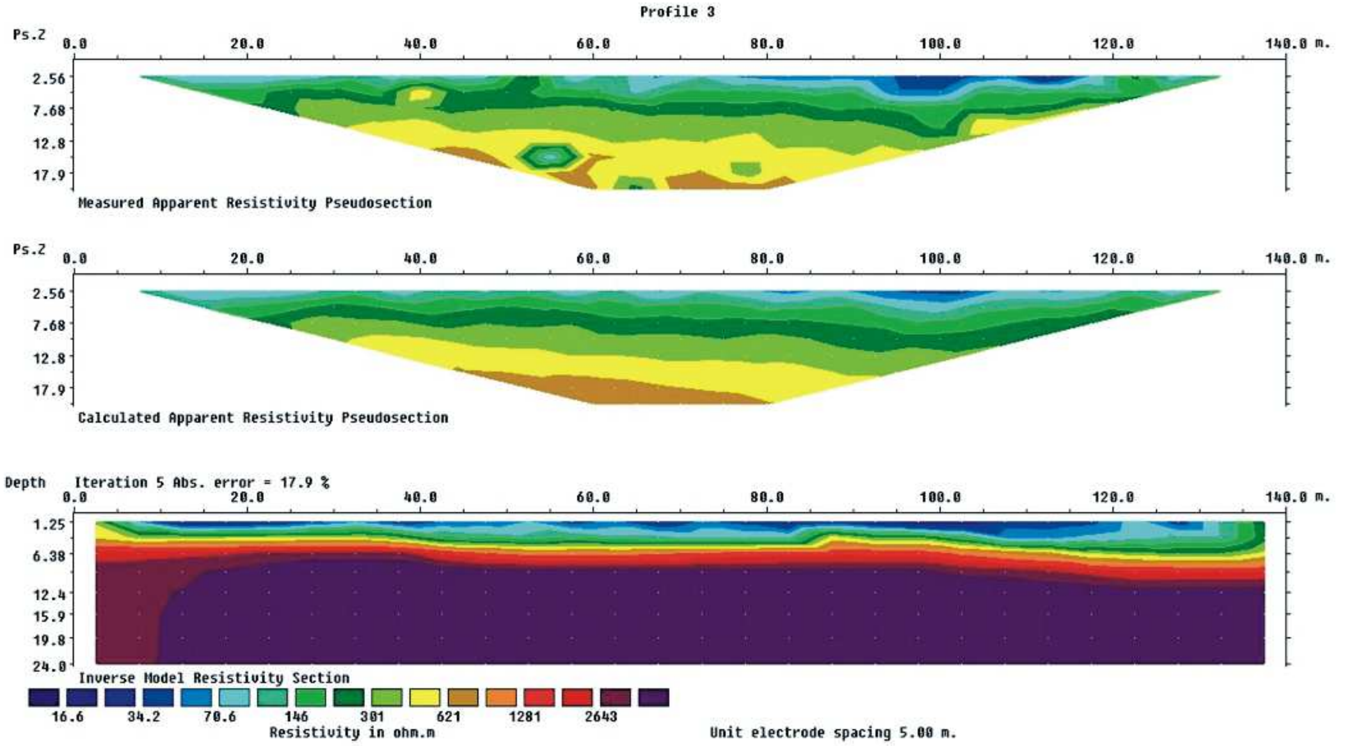

Figure 4a: ERT Image for Profile 3

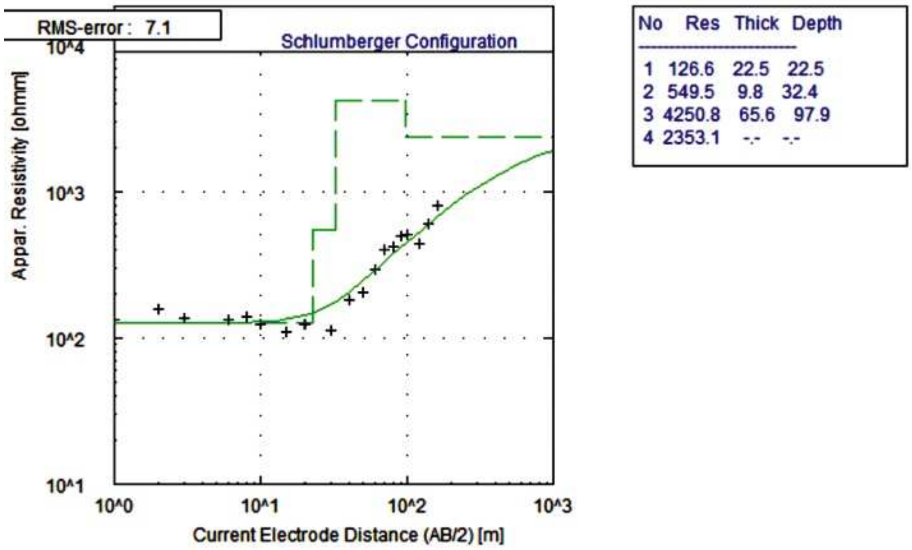

Figure 4b: VES Curve of Location 7

Basement aquifer having a resistivity value ranging from 11.3-149. Ωm occurring in patches as an indication where fault or fractured occurred. The fourth layer is assumed to be a fresh Basement with resistivity and depth of 550-4648 Ωm and 12.4-24.8 m along the Profile having brown to red to purple color. The depth is at 13.3 m along a horizontal distance of 70-125 m. However, it is noticeably that the aquifer occur at a shallow depth. The vertical eletrical sounding (Figure 5b) carried out at 50 m along the Profile has four geoelectric layers which suggest a good groundwater aquifer at shallow depth within the weathered Basement.

Furthermore, eighteen (18) VES were also carried out away from where ERT was conducted as showed in Figure 1 and Table 1. The VES curve revealed four to five (4-5) geoelectric layers in which majority of the VES has four geoelectric layers and few VES which are VES 1, 8, 9, 12, 13, 14, and 19. The layers are top soil, lateritic clay, confining weathered Basement, weathered/fractured Basement aquifer and fresh Basement. The top soil/lateritic clay has resistivity and thickness value that ranges from 16.5-308.9 Ωm and 0.2-22.5 m. The confining and fairly weathered Basement have resistivity and thickness of 168.9-3848.4 Ωm and 5.9-47.4 m. The weathered/fractured

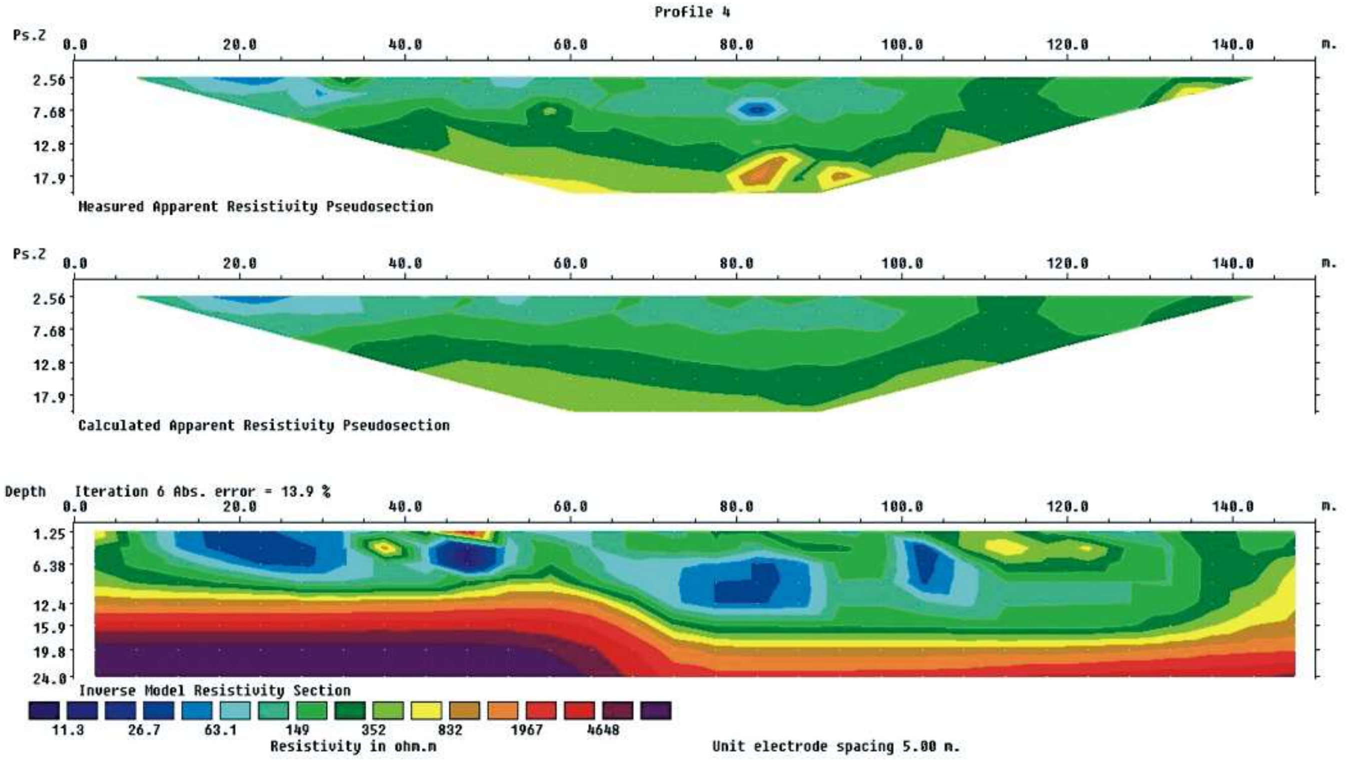

Figure 5a: ERT Image of Profile 4

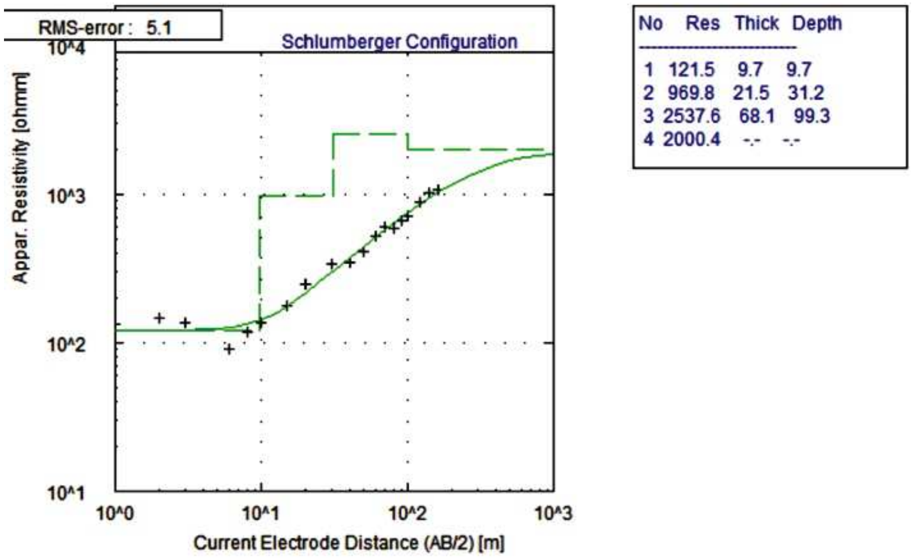

Figure 5b: VES Curve for Location 6

Basement aquifer has resistivity and thickness that ranges from 9.7-1985.5 Ωm and 2.3-62.2 m. The fresh/hard Basement rocks have resistivity between 750.1-20283.4 Ωm. The various curve types delineated within the study area are HA (VES 1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 14, 15, 16, 17, 19, 20, 21, and 22), HK (VES 9 and 18), and KH (VES 12 and 13) (Table 1).

This high resistivity value of the fresh basement exhibits by majority of the VES points corroborate with that of the ERT Profiles which further confirmed that most part of the study area is characterized by Basement rocks that lacks pronounced fractures, faults, and joints and minor occurrence of vein filled minerals. The result from the VES also revealed that the Basement is at shallow depth in most of the area except in VES 6, 7, 14, 17, and 19 which is as a result of thicker weathered Basement or overburden material.

This aquifer likely represents groundwater stored within weathered and fractures or fault zones in the Basement Complex, which is typical in crystalline terrains where primary porosity is low, and groundwater is found in secondary structures. From the aquifer resistivity it is observed that the groundwater potential can be grouped in three classes, these are high (VES 1, 2, 3, 4, 9, 12, 13, 14, and 18), moderate (VES 5, 7, 10, 16, 21, and 22), poor (VES 6, 8, 11, 15, 17, 19, and 20). This corroborate with what was delineated by previous researchers (Awosika et al, 2020; Kizito *et al.*, 2023a, 2023b; Musa *et al.*, 2025; Omali *et al.*, 2019) about the groundwater potential class in the Basement Complex. The depth of this aquifer makes it a more stable and reliable source of water, less susceptible to surface contamination and seasonal variability. However, the low resistive zones delineated in most of the ERT profiles and VES at the top layers indicated the presence of loose overburden sediments which in most cases are considered as shallow aquifers and are prone to contamination. Therefore, in most cases, it is advisable to target deeper fractured zones in order to access good aquiferous zones within the study area. Also, proper groundwater development is required during and after well construction for effective and productive yields. Routine water quality analysis should be carried out especially in areas with shallow aquifer depth and overburden materials with very low resistivity.

Table 1: Geoelectric Layers Interpretation from the VES

S/N	Number of layers	Coordinates	Resistivity	Thickness	Depth	Curve type	Lithology
1	1	N7⁰ 34` 00``	65.6	2.0	2.0	HA	Top Soil
	2	E6⁰ 36` 50``	49.8	5.3	7.3		Lateritic Clay
	3		392.3	4.9	12.2		Fractured Basement Aquifer
	4		2128.8	10.4	22.6		Fairly Weathered Basement
	5		22758.4				Fresh Basement
2	1	N7⁰ 45`31.3``	65.8	6.5	6.5	HA	Top Soil/Lateritic Clay
	2	E6⁰ 44`19.3``	233.1	4.4	10.0		Weathered Basement Aquifer
	3		2797.9	68.0	78.9		Fairly Weathered Basement
	4		10009.2				Fresh Basement
3	1	N7⁰ 45` 32``	131.7	0.4	0.4	HA	Top Soil/Lateritic Clay
	2	E6⁰ 44`10.4``	9.7	0.9	1.3		Weathered Basement Aquifer
	3		1057.0	2.7	3.9		Fairly Weathered Basement
	4		7072.9				Fresh Basement
4	1	N7⁰ 44`33.5``	188.3	1.6	1.6	HA	Top Soil/Lateritic Clay
	2	E6⁰ 43` 44.8``	293.1	17.5	19.1		Fractured Basement Aquifer
	3		2144.4	33.9	53.1		Fairly Weathered Basement
	4		5182.1				Fresh Basement
5	1	N7⁰ 44`35.7``	57.2	5.0	5.0	HA	Top Soil/Lateritic Clay
	2	E6⁰ 44` 8.4``	582.6	6.1	11.0		Fractured Basement Aquifer
	3		3848.4	47.4	58.4		Fairly Weathered Basement
	4		1777.4				Fresh Basement
6	1	N7⁰ 45` 4.2``	121.5	9.7	9.7	HA	Top soil/Lateritic
	2	E6⁰ 43` 59.1``	969.8	21.5	32.1		Confining weathered Basement
	3		2537.6	68.1	99.3		Fairly Weathered Basement
	4		2000.4				Fresh Basement
7	1	N7⁰ 45` 5.1``	126.6	22.5	22.5	HA	Top Soil/Lateritic Clay
	2	E6⁰ 44` 19.1``	549.5	9.8	32.4		Fractured Basement Aquifer
	3		4250.8	65.6	97.9		Fairly Fresh Basement
	4		2353.1				Fresh Basement
8	1	N7⁰ 44`52.8``	29.5	2.4	2.4	HA	Clay rich sediment
	2	E6⁰ 44` 25``	840.3	2.0	4.3		Fractured Basement Aquifer
	3		4231.0	6.6	11.0		Fresh Basement
	4		15376.7	77.2	88.2		Very Fresh Basement
	5		2597.0				Fairly Weathered Basement
9	1	N7⁰ 43`36.8``	180.1	0.7	0.7	HK	Top Soil
	2	E6⁰ 44` 27.9``	50.1	1.8	2.5		Lateritic Clay
	3		682.9	5.9	8.4		Confining Weathered Basement
	4		33.0	19.0	27.4		Weathered Basement Aquifer
	5		1643.6				Fresh Basement
10	1	N7⁰ 44`13.1``	29.4	3.5	3.5	HA	Top Soil/Lateritic Clay
	2	E6⁰ 44` 23.8``	183.6	7.7	11.2		Fairly Weathered Basement
	3		561.1	25.7	36.8		Weathered Basement Aquifer
	4		1133.1				Fresh Basement

S/N	Number of layers	Coordinates	Resistivity	Thickness	Depth	Curve type	Lithology
11	1	N7º 41`26.2``	97.9	7.5	7.5	HA	Top Soil/Lateritic Clay
	2	E6º 43` 47.6``	2669.2	8.3	15.9		Confining Weathered Basement
	3		3249.8	7.7	23.6		Fairly Weathered Basement
	4		30238.4				Fresh Basement
12	1	N7º 41` 43``	123.4	0.9	0.9	KH	Top Soil
	2	E6º 44` 6.8``	1401.3	2.3	3.3		Lateritic Clay
	3		64.6	9.5	12.7		Weathered Basement Aquifer
	4		2663	18.8	31.5		Fairly Weathered Basement
	5		8117.5				Fresh Basement
13	1	N7º 41`51.1``	82.6	0.5	0.5	KH	Top Soil
	2	E6º 44` 14.4``	463.6	1.8	2.3		Lateritic Clay
	3		249.7	20.0	22.3		Weathered Basement
	4		114.0	27.3	49.5		Fractured Basement Aquifer
	5		2174.8				Fresh Basement
14	1	N7º 42` 3.1``	153.9	2.5	2.5	HA	Top soil
	2	E7º 44` 2.8``	43.1	3.0	5.6		Lateritic Clay
	3		888.4	31.4	36.9		Confining Weathered Basement
	4		489.6	27.5	64.4		Fractured Basement Aquifer
	5		750.1				Fresh Basement
15	1	N7º 43`37.6``	16.5	5.2	5.2	HA	Top Soil/Lateritic Clay
	2	E6º 43` 41.4``	476.1	14.1	19.2		Fairly Weathered Basement
	3		883.7	25.6	44.9		Weathered Basement Aquifer
	4		2822.9				Fresh Basement
16	1	N7º 43`31.6``	290.1	0.7	0.7	HA	Top Soil/Lateritic Clay
	2	E6º 44`3.3``	64.3	4.2	4.9		Fairly Weathered Basement
	3		547.3	6.8	11.7		Weathered Basement Aquifer
	4		1202.5				Fresh Basement
17	1	N7º 43`10.8``	30.9	4.9	4.9	HA	Top Soil/Lateritic Clay
	2	E6º 44`24.1``	1796.1	19.8	24.8		Fairly Weathered Basement
	3		1985.5	66.8	91.6		Fractured Basement Aquifer
	4		1273.9				Fresh Basement
18	1	N7º 46`19.1``	308..9	1.0	1.0	HK	Top Soil/Lateritic Clay
	2	E6º 43`24.2``	24.2	2.6	3.6		Weathered Basement
	3		111.9	20.1	23.7		Weathered Basement Aquifer
	4		168.9				Fairly Weathered Basement
19	1	N7º 46`30.1``	130.7	2.4	2.4	HA	Top Soil
	2	E6º 43`27.3``	132.6	13.7	16.1		Lateritic Clay
	3		930.9	33.1	49.2		Confining Weathered Basement
	4		840.7	22.5	71.6		Fractured Basement Aquifer
	5		2033.9				Fresh Basement
20	1	N7º 46`41.4``	33.3	2.9	2.9	HA	Top Soil/Lateritic Clay
	2	E6º 43`31.9``	284.7	2.3	5.2		Weathered Basement Aquifer
	3		1514.7	7.7	12.9		Fairly Weathered Basement
	4		1009.6				Fresh Basement
21	1	N7º 46`24.3``	63.2	0.5	0.5	HA	Top Soil
	2	E6º 42`57.6``	5.4	2.3	2.8		Lateritic Clay
	3		606.8	62.2	65.0		Weathered Basement Aquifer
	4		282.3				Fairly Weathered Basement
22	1	N7º 46`36.6``	19.9	3.6	3.6	HA	Top Soil/Lateritic Clay
	2	E6º 43` 2.9``	289.9	11.1	11.1		Weathered Basement
	3		448.5	13.1	13.1		Weathered Basement Aquifer
	4		1754.4				Fresh Basement

CONCLUSION

This study successfully delineated both shallow and deep aquifers in the Basement Complex of Ganaja–Jimgbe area, North Central Nigeria using ERT and VES techniques. Shallow aquifers were found at depths of 30 meters, while a more reliable and extensive deeper aquifer was detected at around 50-100m. Based on the results of this study, it is recommended that groundwater exploration and development efforts in the study area are best at the deeper aquifer located at approximately 50-100 m. This aquifer is more reliable and less susceptible to contamination and seasonal fluctuations compared to the shallow aquifers. However, the shallow aquifers can still be utilized for local and short-term water needs, provided that adequate protection measures are taken to prevent contamination. Regular monitoring of water quality in the shallow aquifers is also advised. From the aquifer resistivity and thickness, groundwater potential zones were grouped into poor, moderate, and high. This highlights the importance of combining geophysical techniques for accurate groundwater exploration in basement terrains. Decrease in in rate of infiltration, increase in rural–urban population, poor housing and other infrastructural plans and arbitrary drilling of boreholes without a proper groundwater management plan, has great tendency of depleting the groundwater aquifer without compliments from the surface water recharge and improved rate of infiltration. These findings are valuable guide in groundwater prospecting and ensuring sustainable water resource management within the study area.

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