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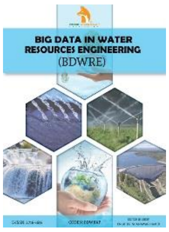

RESEARCH ARTICLE

USING ELECTRICAL RESISTIVITY AS A HYDROGEOLOGICAL TOOL TO DETERMINE THE AQUIFER CONTINUITY AND LATERAL EXTENT WITHIN DUTSIN-MA BASEMENT COMPLEX

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ABSTRACT

This research investigates the aquifer continuity and lateral extent in the Dutsinma Basement Complex using the electrical resistivity method, particularly Vertical Electrical Sounding (VES). The study aims to delineate aquifer characteristics critical for sustainable groundwater management. Aquifers are vital for water supply, especially in arid regions. Understanding their continuity and extent is essential for effective resource management. This study focuses on the Dutsinma Basement Complex, characterized by geological complexities that affect groundwater. The demand for clean and portable water increases exponentially with increase population and industrialization. Water is therefore a vital resource without which life will become impossible. The methodology adopted used and interpreted 20 Vertical Electrical Sounding (VES) images obtained using ADMT 300S. The aquifer parameters information estimated from the (VES) were used to produce maps. For effective use of these parameters, iso-thickness and iso -resistivity maps were compared with contour maps of transverse resistance. The agreement between these parameters provided the basis for identification of auriferous zones. The Dutsinma Basement Complex is part of Nigeria's extensive Basement Complex, characterized by ancient crystalline rocks such as migmatites, gneisses, and schists. These rocks have undergone significant geological processes, including multiple folding and metamorphism, mainly during the Eburnean and Pan-African orogenies. The complex serves as a crucial area for understanding the region's geological history and structural evolution, providing insights into groundwater flow dynamics. Aquifers within the Dutsinma Basement Complex are vital for local water supply, supporting agriculture and domestic needs. They play a significant role in maintaining ecosystem health by providing water to rivers and wetlands. Understanding aquifer continuity and lateral extent is essential for sustainable management of these resources, especially in areas where groundwater is the primary source of water.

KEYWORDS

Groundwater, VES, Resistivity, Aquifer, Lateral extent, Basement complex, Delineate, Dutsinma.

1. INTRODUCTION

Water is an essential resource for humanity, with the largest reserves of fresh water located underground. It plays a critical role in supporting human consumption and driving economic development. As agricultural, industrial, and domestic activities continue to grow, the demand for high-quality water is increasing. Groundwater is often the preferred source to meet these demands due to its generally lower levels of contamination and widespread availability.

Moreover, water significantly influences the formation of various landforms. The occurrence and movement of groundwater in any given area are shaped by a range of interconnected factors, including topography, lithology, geological structures, depth of weathering, extent of fractures, secondary porosity, slope, drainage patterns, landforms, land use and cover, and climatic conditions. Understanding these relationships is vital for effective water management. In hard rock regions, groundwater primarily resides in weathered zones, fractures, faults, and joints, underscoring the importance of careful exploration and sustainable use of this invaluable resource.

The electrical resistivity method stands out as the most suitable geophysical technique for delineating groundwater resources, primarily due to the significant contrast in resistivity between water-saturated formations and those devoid of water. Numerous researchers have successfully employed electrical resistivity surveys to delineate aquifers across various geological settings. Geophysical methods provide a more effective alternative to many conventional techniques in groundwater exploration. While well drilling represents a direct method for investigating subsurface groundwater systems, it is often prohibitively expensive. A substantial number of boreholes must be drilled to accurately characterize the depth and composition of different geological formations. Initially developed for oil and mineral exploration, geophysical techniques have gained traction in groundwater studies as water becomes increasingly valuable and scarce, significantly enhancing our understanding of these vital resources. The electrical resistivity method (ERM) has proven to be exceptionally effective in mapping groundwater resources, as groundwater flow and distribution are highly localized and

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challenging to ascertain.

By integrating borehole data with interpretations obtained from resistivity imaging, reliable information regarding groundwater can be generated. The demand for clean and potable water grows exponentially with increasing population and industrialization. Water is an essential resource, crucial for sustaining life. It exists as surface water in streams and lakes, as well as groundwater accumulating beneath the earth's surface. In and around the study area, the water necessary to meet domestic, agricultural, and industrial needs is predominantly supplied by basement aquifers. These aquifers are typically found within weathered and fractured rocks where sufficient porosity and permeability exist to facilitate water storage and movement allow appreciable amount of water storage (Dike, 1994). Recent hydrological surveys have shown that careful studies backed up by improved drilling techniques can yield very favourable results even in problematic areas of Basement Complex (Dike, 1994).

Although, various geophysical methods have been applied successfully to explore for ground water in basement terrains. Some of these methods include electrical, magnetic, electromagnetic etc. Of all these methods, electrical resistivity method has been the most widely used for groundwater exploration (Alile et al., 2008). It is used to evaluate the vertical variation of electrical resistivity below the earth surface since the electrical resistivity of most rocks is dependent on the amount of water in the pore spaces within the rocks, the distribution of these pores and the salinity of the water in the pore spaces.

The Dutsinma Basement Complex is part of Nigeria's extensive Basement Complex, characterized by ancient crystalline rocks such as migmatites, gneisses, and schists. These rocks have undergone significant geological processes, including multiple folding and metamorphism, mainly during the Eburnean and Pan-African orogenies. The complex serves as a crucial area for understanding the region's geological history and structural evolution, providing insights into groundwater flow dynamics. Aquifers within the Dutsinma Basement Complex are vital for local water supply, supporting agriculture and domestic needs. They play a significant role in maintaining ecosystem health by providing water to rivers and wetlands. Understanding aquifer continuity and lateral extent is essential for sustainable management of these resources, especially in areas where groundwater is the primary source of water.

1.1 Exploration in the Basement Complex

Groundwater exploration in Nigeria, particularly within the intricate geological framework of the Basement Complex rocks, commonly employs the method of Vertical Electrical Sounding (VES). The Basement Complex consists predominantly of granite, which has undergone various stages of metamorphic transformation, resulting in a diverse array of rock types, including gneisses and migmatites. These rocks typically exhibit low permeability and are generally considered non-water bearing, posing challenges for groundwater accessibility.

In many regions underlain by the Basement Complex, there exists only a thin, often discontinuous layer of weathered rock, which can limit groundwater potential. However, in areas where the Basement Complex rocks exhibit significant fracturing and weathering, these geological formations can attain a porous and permeable state. This alteration allows them to effectively store and transmit groundwater. In contrast to sedimentary basins, where aquifers may extend vast distances, water occurrences within Basement Complex rocks tend to be localized, found primarily in pockets that are confined to fractured and weathered zones.

Successful groundwater development schemes in these basement regions necessitate a thorough, quantitative understanding of various hydro-geophysical parameters pertaining to the hydro-geologic units. This encompasses the investigation of superficial materials that lie above the crystalline bedrock, as well as the inherent structures and relief of the geological environment.

In this study, a comprehensive hydro-geophysical exploration was conducted in the vicinity of Dutsinma, aiming to ascertain the geoelectrical properties of the overburden materials situated above the bedrock. This includes determining key parameters such as layer composition, resistivity, and thickness, as well as elucidating the subsurface structural arrangement of the bedrock and their associated hydrogeological characteristics. The exploration was driven by a detailed analysis of both geoelectrical and hydrogeological parameters relevant to the unique Basement Complex setting.

According to the findings presented by the presence of groundwater is closely linked to the geological history of the rocks, specifically when they undergo deformation through processes such as deep fracturing, weathering, and faulting (Nur and Kujir, 2006). The availability of groundwater in any particular region is significantly influenced by the thickness and lateral extent of the weathered rock material. When both features are present, the conditions for groundwater are typically favorable (Arabi et al., 2010).

1.2 Occurrence of Basement Aquifers

Basement aquifers are primarily found within the weathered residual overburden, often referred to as the regolith, as well as within the fractures of the bedrock itself. The development of the aquifer system associated with the regolith is frequently facilitated through the installation of wells and shallow boreholes, which can utilize lightweight percussion drilling rigs for efficiency. These drilling methods are particularly suitable for penetrating the relatively less consolidated materials that make up the regolith layer, enhancing access to potential groundwater reserves. Boreholes which are designed to penetrate the fractured bedrock to a significant extent require more powerful drilling rigs, preferably air hammer. Viable aquifers wholly within the fractured bedrock are of rare occurrence because of the typically low storability of fracture systems (< 1%, Clark 1985). To be effective, development of the bedrock component requires interaction with storage available in overlying or adjacent saturated regolith, or other suitable formations such as alluvium.

Basement aquifers are essentially phreatic in character but may respond to localized abstraction in semi-confined fashion if the rest water level occurs in a low- permeability horizon, such as clayey regolith. Although the aquifers have a regional occurrence, they respond to abstraction in 'discontinuous' fashion, due either to discontinuities or barrier boundaries within the fracture system being tapped or to the constraints of the low-permeability regolith. These features are commonly reflected in a significant borehole failure rate and a wide range of yields, despite the apparent regional uniformity of the basic controls of climate, morphology and geology. Recent studies in Europe and America in association with radioactive waste disposal have increased knowledge of the detailed hydraulics of bedrock fracture systems (Black, 1987).

Most other information on basement aquifer occurrence is derived from groundwater development projects. The high failure rate of boreholes testifies to the difficulties of predictive exploration in this environment. The cause must lie in the limited sensitivity of current exploration techniques and an incomplete understanding of the controls on basement aquifer occurrence.

1.3 Classification of Aquifers

Aquifers are generally classified into two main categories: confined aquifers and unconfined aquifers.

1.3.1 Confined Aquifers

Confined aquifers are bodies of water that accumulate in permeable rock and are enclosed by two impermeable layers of rock. These aquifers are overlain by confining rock layers, often composed of clay, which provide some protection from surface contamination. The non-permeable geological barriers between the aquifer and the surface result in water being under pressure, which is greater than atmospheric pressure.

In some cases, fractures or cracks in the bedrock can allow water to accumulate in larger openings, leading to high yields of wells in karst areas, such as Augusta and Bath in Virginia. Groundwater flow through aquifers occurs both vertically and horizontally, at rates influenced by gravity and geological formations in the area.

Confined aquifers are sometimes referred to as “artesian aquifers.” These aquifers are typically found above the base of the confining rock layers. Punctured wells that draw water from artesian aquifers experience fluctuations in water levels mainly due to changes in pressure rather than the quantity of stored water. These wells act more as conduits for transmitting water from replenishing areas to natural or artificial discharge points.

1.3.1.1 Groundwater Quality

Natural groundwater quality in most basement environments is generally good, with low salinities and neutral to slightly acid pH values being common (Clark, 1985; Chilton and Foster, 1995). However, salinities are elevated in areas of low recharge and/or prolonged residence times in the subsurface. Natural water quality in basement can occasionally be detrimental to human health through high levels of trace elements such as fluoride (Marais, 1999). Metals such as aluminium are also mobile in low pH groundwater. High iron concentrations associated with lateritic soils, whilst not harmful to human health, can stain appliances and clothes and make water unpalatable (Clark, 1985).

Crystalline basement aquifers are very vulnerable to pollution of the groundwater, particularly where the regolith is thin, since groundwater movement through fractures is rapid and the fractured rock matrix provides little attenuation of contaminants. It is therefore necessary to test groundwater for natural quality, and groundwater development in a new area should always take water quality into account. Numerous village water supply boreholes in basement areas have been sited close to pit latrines, and microbial contamination has occurred, since both latrine and borehole penetrate to below the zone of lower permeability regolith. Poor water quality can be as great a constraint on the development of a resource, as low quantities.

1.3.1.2 Groundwater Hydraulics.

Crystalline basement aquifers can be considered to fall on a continuum between porous media and conduit systems (Cook, 2003). The unconsolidated weathered mantle can be represented by a porous medium, while the consolidated fractured Bedrock can be regarded as a fractured porous media with groundwater flows in the conduit network and water stored in the aquifer matrix between the conduits. The analysis of pumping test data studies the behaviour of an aquifer inversely and suffers from non-uniqueness, where the observed response of an aquifer can be fitted with two or more sets of aquifer parameters, boundary and initial conditions that differ completely from one another (Van Tonder et al., 2001). Usually this is solved by assuming a simple model based on a set of hydraulic parameters, boundary and initial conditions of a known conceptual model. However, the difficulty is to identify the model that best represents reality.

1.3.1.3 The Study Area

Dutsin-Ma is located at the central part of Katsina State and lies between Latitudes 12027 ′10′′ N and 12027 ′16′′ N and longitude and 07029′ 56′′ E 07030′ 04′′ E (Idris, 2011). It is bounded to the north by Kurfi, some part of Charanchi and Kankia LGA's, Matazu in the south-east, Safana and Dan-musa from west. With an estimated area of 552,323 km2 the area comprises of Safana, Batsari, Kurfi and Dan-musa LGAs respectively, the relief consists of low land plains that are undulated. These plains are dotted with granitic rock out-crops known as Inselbergs. There are also low valleys and channels which are wide and full of sand materials. Generally, the soil of the area is the tropical ferruginous red and brown soil of the basement complex (Kankara, 2019).

In the study of structure of Dutsin-Ma region, it lies in the heart of Nigerian Basement rocks, that generally lie in the vast region east of west African Craton that was affected by the Pan African Orogenic event about 650 Ma ago (Ibrahim, 2003; Kankara, 2014). Evidence from the Cratonic margin in Hoggar and Pharussian, Ghana and Togo indicate that the west African region that was affected by Pan-African, east of the Craton has evolved through plate tectonics involving continents to continent collision and subduction, an incomplete anatexis of the oceanic crust and formation of an acidic magma, leading to the emplacement of Older granites at the late Precambrian to early Paleozoic period. The older granites have yielded almost uniformly Pan African (Oyawoye, 1972). The field occurrence of these granites however shows that they are not of the same age

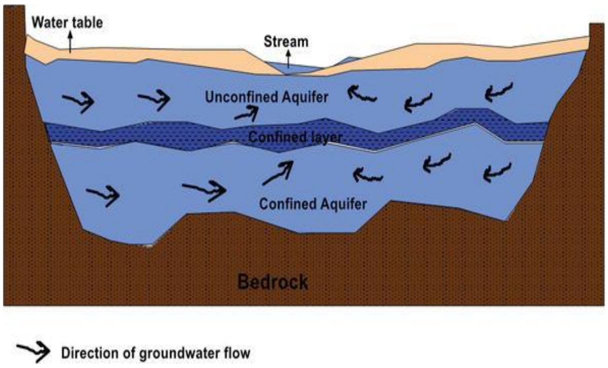

Figure 1: Schematic cross-section of aquifer types (source: http://en.m.wikipedia.org>wiki>Aquifer)

1.3.2 Unconfined Aquifer

Unconfined aquifers play a crucial role in our water resources, as they are typically situated close to the land surface and lack the protective layers of clay or other impermeable materials found in confined aquifers. Instead, they sit above impermeable clay rock layers, allowing for a direct connection to the water table, which serves as the upper boundary of groundwater. One significant characteristic of unconfined aquifers is their susceptibility to contamination from surface pollutants. Since groundwater can easily infiltrate these areas, it is essential to manage surface activities carefully to protect this vital resource. The water levels within unconfined aquifers can fluctuate based on the stored groundwater volume, influencing the availability of water in wells that draw from these aquifers. Generally, unconfined aquifers have a storative value greater than 0.01, indicating their capacity to hold water.

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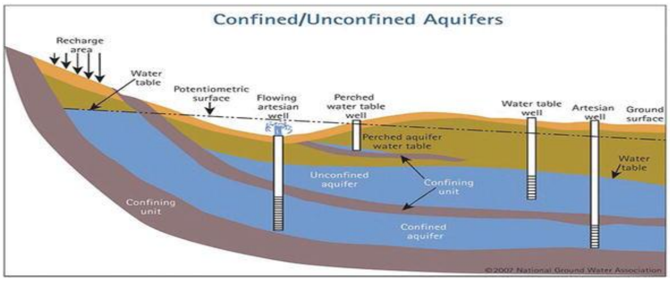

Figure 2: Schematic cross-section of aquifer types (Source: coloradogeologicalsurvey.org>wateratlas).

1.3.2.4 Groundwater Quality

The natural quality of groundwater in most basement environments is generally good, characterized by low salinity and a neutral to slightly acidic pH (Clark, 1985; Chilton and Foster, 1995). However, salinity levels can increase in areas with low recharge or extended residence times within the subsurface. In some cases, natural groundwater quality in the basement may pose health risks due to high concentrations of trace elements, such as fluoride (Marais, 1999). Additionally, metals like aluminum can become mobile in acidic groundwater. While high iron concentrations, often found in lateritic soils, are not harmful to human health, they can stain appliances and clothing, making the water unpalatable (Clark, 1985).

Crystalline basement aquifers are particularly vulnerable to groundwater pollution, especially where the regolith is thin. In these areas, groundwater moves rapidly through fractures, and the fractured rock matrix does not effectively attenuate contaminants. Therefore, it is essential to assess groundwater quality, and any development of groundwater resources in a new area should prioritize water quality considerations. Many village water supply boreholes in basement areas have been placed too close to pit latrines, leading to microbial contamination, as both latrines and boreholes penetrate below the low-permeability regolith. Poor water quality can significantly hinder the development of groundwater resources, just as much as low quantities can.

1.3.2.5 Groundwater Hydraulics

Crystalline basement aquifers can be viewed as existing on a spectrum between porous media and conduit systems (Cook, 2003). The unconsolidated weathered mantle functions as a porous medium, while the consolidated fractured bedrock behaves as fractured porous media, where groundwater flows through conduit networks and is stored in the aquifer matrix surrounding these conduits. Analyzing data from pumping tests examines the behavior of an aquifer in an inverse manner and is often subjected to non-uniqueness; this means that a given response from an aquifer can be matched by multiple sets of parameters, boundary conditions, and initial conditions that can differ significantly (Van Tonder et al., 2001). Generally, this complexity is addressed by assuming a straightforward model based on a specific set of hydraulic parameters and conditions from an established conceptual model. However, the challenge lies in identifying the model that most accurately reflects reality.

1.3.2.6 The Study Area

Dutsin-Ma is located in the central part of Katsina State, lying between latitudes 12027′10″ N and 12027′16″ N, and longitudes 07029′56″ E and 07030′04″ E (Idris, 2011). It is bordered to the north by Kurfi, parts of Charanchi, and Kankia local government areas (LGAs), Matazu to the southeast, and Safana and Dan-Musa to the west. Covering an estimated area of 552,323 km², the region includes Safana, Batsari, Kurfi, and Dan-Musa LGAs. The landscape features low-lying plains that are undulated and dotted with granitic rock outcrops known as inselbergs. Furthermore, there are wide valleys and channels filled with sandy materials. The soil in this area predominantly consists of tropical ferruginous red and brown soil from the basement complex (Kankara, 2019).

In terms of geological structure, the Dutsin-Ma region is situated within the heart of Nigerian basement rocks, which generally extend across the vast area east of the West African Craton. This region was affected by the Pan-African Orogenic event approximately 650 million years ago (Ibrahim, 2003; Kankara, 2014). Evidence from the cratonic margin in Hoggar and Pharussian, Ghana, and Togo suggests that the West African region, influenced by the Pan-African event, has undergone changes through plate tectonics, including continental collisions and subduction, as well as incomplete anatexis of the oceanic crust. This led to the formation of acidic magma, resulting in the emplacement of older granites during the late Precambrian to early Paleozoic era. The older granites from this period have yielded nearly uniform results in terms of their Pan-African age (Oyawoye, 1972). However, field observations indicate that these granites do not share the same age.

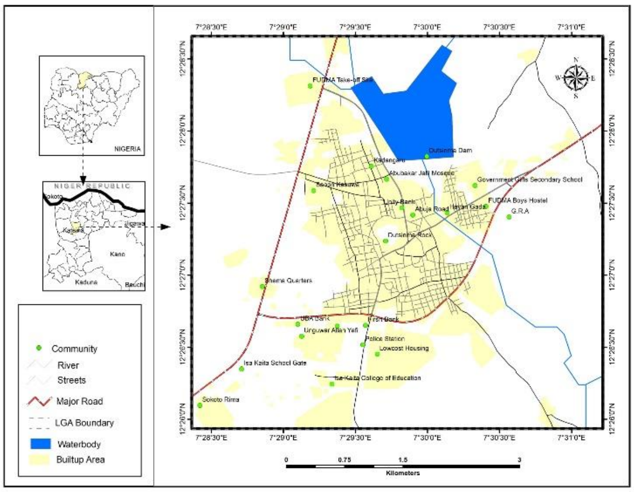

Figure 3: Map of the study Area (Source: Umar Ashaka 2024)

1.3.2.7 The Geology of the Area

The most notable tectonic-igneous reactivation in this region is attributed to the Pan-African episode, which occurred about 650 ± 150 million years ago. This Pre-Cambrian crystalline complex of rocks extends throughout the area and into neighboring regions (Figure 4) (Ajibade et al., 1987). The undifferentiated migmatite-gneiss was intruded by older granitic rocks during the Pan-African Orogeny.

In the study area, it was observed that geology serves as the foundation for soil, with clay, sand, and silt all resulting from rock weathering. In some parts of the area, the cycle of erosion has been completed, while larger regions are still experiencing ongoing weathering. From the collected data, a geological map was created, inferring the boundaries between different lithologies. The angle of dips and strikes in the lithological units reveals the orientations of the rock emplacements. Vein directions predominantly run north-south (NS) and west-southwest to east-northeast (WWS-NEE). The rocks are primarily characterized by the development of veins on their surfaces.

Approximately nine orogenic movements have occurred in the Dutsin-Ma sub-sector of the Basement Complex, including significant fracturing of the earth (Bowden et al., 1976). Intensive folding transpired during the Pre-Cambrian, with the three most recent orogenic cycles being Caledonian, Hercynian, and Alpine. The Alpine cycle was the last major orogenic movement, occurring nearly 30 million years ago, resulting in the uplifting and extensive deformation of mountain ranges.

The geological history of this area is part of the broader geological history of the Nigerian Basement, situated east of the West African craton, which was affected by the Pan-African Orogeny around 650 ± 150 Ma ago. Evidence from the cratonic margins of Hoggar and the Pharusian regions, as well as Ghana and Togo, suggests that the Pan-African belt in the western part of Africa evolved through plate tectonics involving continent-to-continent collisions and subduction, leading to the incomplete melting of the crust and the formation of magma. This process resulted in the emplacement of older granites during the late Precambrian to early Paleozoic periods.

A subsequent regional folding phase, likely in the late Eburnean period (approximately 2000 Ma), resulted in the formation of a local anticlinal dome affecting both the migmatites and the metasedimentary sequences. In the late Pan-African period, deep weathering processes caused significant erosion of the upper portions of this anticlinal structure, exposing the eastern and western limbs of truncated bands of carbonate and schist intermixed with the basement migmatite.

The region is characterized by igneous inselbergs and low-lying migmatite rocks of the Basement Complex, contributing to a prominent relief that appears as massive ridges and isolated dome-shaped structures. The average elevation of the area ranges from 305 to 630 meters above sea level. The dissected peneplained landscape forms the drainage divides for streams flowing north and south toward the Atlantic Ocean, which are major features of northern Nigeria.

It is believed that the denudation history of the Dutsin-Ma region began with marine transgression from the Tethys Sea, which extended southward from North Africa during the late Maastrichtian period, resulting in sediment deposition. This region is composed of various rocks formed during different geological periods. The higher plains feature a dissected plateau of complex crystalline rocks characterized by numerous ranges of hills. These hilly formations are part of an extensive inselberg region stretching across northern Nigeria, from eastern Sokoto to as far as Bauchi and Abuja (Holt, 1982). They represent a stage in the geomorphic history known as the African planation surface, formed through erosional processes.

The Pre-Cambrian rocks of this region are intersected by numerous shallow valleys that create drainage channels or streams. Since the Miocene period (23 to 5.3 million years ago), continental conditions have prevailed along with some crustal uplift. Sediment deposition has mainly been restricted to superficial deposits of sands during arid phases of the Pleistocene and Holocene, alongside alluvial deposits resulting from river sedimentation during wetter phases.

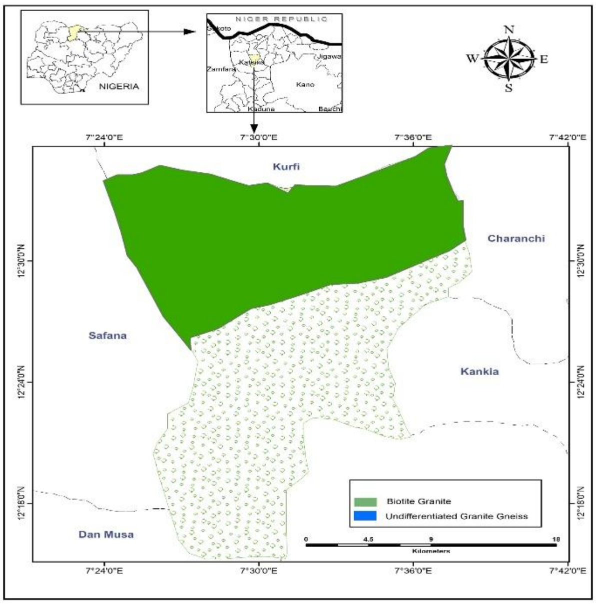

Figure 4: The Geologic Map of the study Area (Source: Umar Ashaka 2024)

1.3.2.8 The Hydrogeology of the Area

Sub-surface data obtained from wells indicates three types of aquifer zones which are made up of medium to fine grained sand (Ruwasa, 2014). The thickness of aquifer zones and the depth at which groundwater for dug well is encountered is 10m- 20m. The thickness of aquifer zones and the depth at which groundwater for borehole is encountered is 45 to 60m. Aquifer zones found within 50m depths have much higher discharge than the deeper aquifers. The discharge of these deep tube wells ranges from 1500 to 3500lp/h and their minimum drawdown is between 6-30m in Dutsin-Ma town. Water table varies between 1.5- 9.17m bgl and is shallow towards SE and SW of Dutsin-Ma town (Ruwasa, 2014). In the area, ground water occurs in unconfined shallow aquifer and semi-confined to confined aquifer conditions in deeper aquifers. The porosity and permeability of the sedimentary rocks in the hilly areas are partly due to coarser grain size of some rocks, weathering, fracturing and faulting. Ground water occurs in both unconfined and confined conditions; in some places within Dutsin-Ma town ground water occurs at shallow depths both under unconfined and confined conditions (Ruwasa, 2014)

2. METHODOLOGY

Conducting an electrical survey to detect aquifer zones using the Aidu ADMT 300S is an effective and constructive approach to identifying groundwater resources. This involved the use of ADMT 300S and its accessories. Distance of 100m and 50m each is measured in straight line on the surface of the earth at each VES point at an interval of 10m to determine the resistivity variations.

2.1 Preparation

2.1.1 Assemble Essential Equipment: In

Addition to the Aidu ADMT 300S, gather complementary tools such as

mustimeters and data loggers. This comprehensive setup will enhance the accuracy and efficiency of your survey.

2.1.2 Review Safety Protocols

Prioritize safety by thoroughly understanding and adhering to guidelines that ensure a safe working environment throughout the survey process.

2.1.3 Familiarize with the Survey Area

Take time to understand the geographical and geological characteristics of the region. Knowing the soil composition and existing features will inform your strategy and improve anticipation of the expected results.

2.2 Steps for Conducting the Survey

2.2.1 Site Selection

Strategically choose locations for testing where aquifers are most likely to be located, based on existing geological data. This thoughtful approach maximizes the chances of successfully identifying groundwater zones. - Ensure that these locations are easily accessible to facilitate smooth setup and data collection.

2.2.2 Setting up the ADMT 300S

Position the Aidu ADMT 300S at predetermined intervals across the survey area, ensuring thorough coverage. - Carefully configure the device for the specific electrical measurements required, such as resistivity, which can indicate the presence of water. The system integrates global geological data and big data analytics to automatically analyze the collected geological information, thereby accurately determining the location, depth, and yield of underground water.

2.3 Conduct Electrical Measurements

Utilize the Aidu ADMT 300S to perform resistivity testing, as areas with high moisture content generally exhibit lower resistivity. This step is crucial for the identification of potential aquifer zones. - Consistently log readings at each location to ensure reliable data collection, maintaining uniformity in measurement techniques.

2.4 Data Collection and Analysis

Systematically document the readings, paying close attention to variations that may suggest the presence of groundwater. - Analyse the collected data to identify potential aquifer zones, looking for resistivity patterns that indicate geological formations capable of storing groundwater.

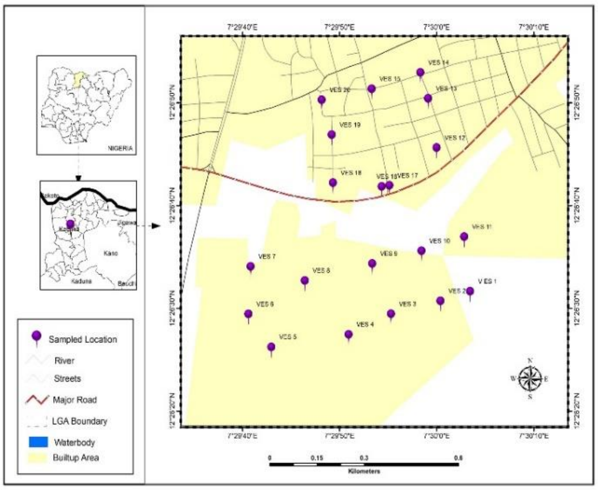

Figure 5: Map of the study Area Showing Sounding Points (Source, Umar Ashaka 2024

3. Results and Discussion

Table 1: Resistivity Survey Data around the study area

VES POINTS	VES 1	VES 2	VES 3	VES 4	VES 5	VES 6	VES 7	VES 8	VES 9	VES 10	DISTANCE (M)
RESISTIVITY (Ωm)	0.1	0.04	0.3	0.1	0.02	0.3	0.3	0.08	0.13	0.2	10
	0.2	0.08	0.9	0.2	0.10	0.4	0.4	0.17	0.21	0.3	20
	0.3	0.12	1.5	0.3	0.18	0.5	0.5	0.26	0.26	0.4	30
	0.4	0.16	2.1	0.4	0.26	0.6	0.6	0.35	0.37	0.5	40
	0.5	0.20	2.7	0.5	0.34	0.7	0.7	0.44	0.45	0.6	50
	0.6	0.24	3.3	0.6	0.42	0.8	0.8	0.53	0.53	0.7	60
	0.7	0.28	3.9	0.7	0.50	0.9	0.9	0.62	0.61	0.8	70
	0.8	0.32	4.5	0.8	0.58	1.0	1.0	0.71	0.69	0.9	80
	0.9	0.36	5.1	0.9	0.66	1.1	1.1	0.80	0.77	1.0	90
	1.0	0.40	5.8	1.0	0.74	1.2	1.2	0.89	0.87	1.1	100

VES POINTS	VES 11	VES 12	VES 13	VES 14	VES 15	VES 16	VES 17	VES 18	VES 19	VES 20	DISTANCE (M)
RESISTIVITIES	0.08	01	0.11	0.15	0.03	0.02	0.1	0.49	1.83	0.12	10
	0.12	02	0.15	0.21	0.11	0.06	0.2	0.58	1.92	0.14	20
	0.16	03	0.19	0.27	0.19	0.10	0.3	0.67	2.03	0.16	30
	0.20	04	0.23	0.33	0.27	0.14	0.4	0.76	2.13	0.18	40
	0.24	05	0.27	0.39	0.35	0.18	0.5	0.85	2.23	0.20	50
	0.28	06	0.31	0.45	0.43	0.22	0.6	0.94	2.33	0.22	60
	0.32	07	0.35	0.51	0.51	0.26	0.7	1.03	2.43	0.24	70
	0.36	08	0.39	0.57	0.59	0.30	0.8	1.12	2.53	0.26	80
	0.40	09	0.43	0.63	0.67	0.34	0.9	1.21	2.63	0.28	90
	0.45	10	0.47	0.69	0.75	0.38	1.0	1.31	2.75	0.30	100

Table 2: Summary of resistivity, lateral extents and depth from ADMT profile 1-20

ADMT PROFILE	DEPTH	LATERAL EXTENT	RESISTIVITY RANGES
1	150-160M	40M	0.1-0.3 Ωm
2	0-200M	80M	0.04-0.28 Ωm
3	110-145M	25M	0.3-1.5 Ωm
4	80-200M	25M	0.0-0.03 Ωm
5	5-200M	25M	0.02-0.26 Ωm
6	-	-	-
7	80-200M	15-50M	0.3-0.6 Ωm
8	110-125M	20M	0.17-0.44 Ωm
9	90-200M	-	0.21-0.37 Ωm
10	60-180M	-	0.2-0.6 Ωm
11	50-160M	95M	0.08-0.20 Ωm
12	5-200M	20M	1.0-6.0 Ωm
13	140-160M	100M	0.11-0.27 Ωm
14	160-185M	50M	0.15-0.33 Ωm
15	85-140M	15M	0.11-0.27 Ωm
16	25-200M	40M	0.02-0.22 Ωm
17	25-190M	70M	0.1-0.6 Ωm
18	50-70M	20M	0.49-0.76 Ωm
19	-	-	-
20	100-110M	10M	0.12-0.20

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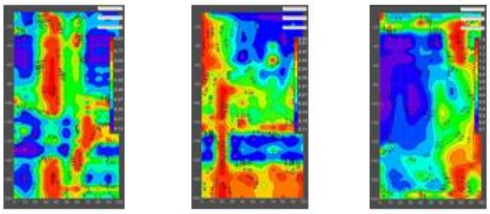

Fig 6 Resistivity image for VES 9 Fig 7 Resistivity image for VES 13 Fig 8 Resistivity image for VES 17

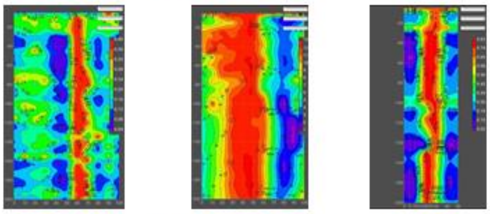

Fig 9 Resistivity image for VES 2 Fig 10 Resistivity image for VES 12 Fig 11 Resistivity image for VES 5

Figures 6-11: (Selected Images from ADMT VES survey points)

ADMT profile 1 revealed aquifer at the depth from 40-60 meters marked by bluish color with resistivity of 0.3Ωm indicating weathered zone with lateral extend of 25 meters, another aquifer occur at the depth of 150-160 meters with resistivity of 0.3Ωm indicating weathered zone marked by bluish color with lateral extend of 40 meters. Another aquifer occur at the depth of 180-200 meters with resistivity of 0.1- 0.2Ωm indicating weathered zone marked by bluish to purple color with lateral extend of 40 meters.

ADMT Profile 2 revealed weathered zone from 0-200 meters marked by greenish to bluish color with resistivity ranging from 0.04-0.28Ωm with lateral extend of about 80 meters. A fresh basement possibly a dyke occur at the lateral extend of 58-72 meters and height of 200 meters marked by red color with resistivity ranging from 0.32-0.4Ωm.

ADMT Profile 3 revealed fresh basement from 0-110 meters marked by red color with resistivity ranging from 4.5-5.8Ωm. Aquifer occurs at the depth from 110-120 meters with resistivity 1.5Ωm indicating weathered zone. Another aquifer occur at the depth of 135-145 meters with resistivity ranging from 0.3-1.5Ωm indicating weathered zone marked by bluish to purple color.

ADMT Profile 4 revealed aquifer at the depth from 80-200 meters with resistivity of 0.0-0.3Ωm indicating weathered zone marked by bluish to purple color with lateral extend of 25 meters

ADMT Profile 5 revealed aquifer at the depth from 5-200 meters with lateral extend of 25 meters marked by bluish to purple color indicating weathered zone with resistivity ranging from 0.02-0.26Ωm, fresh basement possibly a dyke occur from lateral extend of 25-40 meters marked by redish color with height of 200 meters with resistivity ranging from 0.66-0.82Ωm. another aquifer occur at the lateral extend from 40-50 meters marked by bluish to purple color indicating weathered zone with resistivity ranging from 0.02-0.26Ωm.

ADMT Profile 6 revealed groundwater throughout the profile marked by greenish to bluish color indicating weathered zone with resistivity ranging from 0.3 to 1.6Ωm and lateral extend of 50 meters.

ADMT Profile 7 revealed aquifer at the depth from 80-200 meters with lateral extend from 15-50 meters marked by bluish to purple color with resistivity ranging from 0.3-0.6Ωm indicating weathered zone.

ADMT Profile 8 revealed groundwater at the depth from 0-80 meters marked by bluish to purple color with resistivity ranging from 0.08-0.35Ωm indicating weathered zone. An aquifer occur at the depth of 110-125 meters marked by bluish color with resistivity ranging from 0.17-0.44Ωm indicating weathered zone with lateral extend of 20 meters from 30-50 meters. Another aquifer occur at the depth from 140-180 meters marked by bluish to purple color with resistivity ranging from 0.08-0.26Ωm indicating weathered zone with lateral extend of 25 meters from 25-50 meters.

ADMT Profile 9 revealed groundwater at the depth from 0-90 meters marked by bluish to purple color with resistivity ranging from 0.21-0.37Ωm indicating weathered zone. Aquifer occur at the depth from110-200 meters marked by bluish to purple color with resistivity ranging from 0.13-0.37Ωm indicating weathered zone.

ADMT Profile 10 revealed aquifer at the depth from 60-90 meters marked by bluish to purple color with resistivity ranging from 0.2-0.6Ωm indicating weathered zone. Another aquifer occur 110-180 meters with resistivity of 0.2-0.6Ωm indicating weathered zone.

ADMT Profile 11 revealed aquifer at the depth from 50-160 meters marked by bluish to purple color with resistivity ranging from 0.08-0.20Ωm indicating weathered zone with lateral extend of 95 meters.

ADMT Profile 12 revealed a fracture which host the groundwater at the depth from 5-200 meters marked by bluish to purple color with resistivity 1-6Ωm with lateral extend of 20 meters from 70-90 meters.

ADMT Profile 13 revealed groundwater at the depth from 0-80 meters marked by bluish to purple color with resistivity ranging 0.11-0.27Ωm indicating weathered basement with lateral extend of 60 meters from 40-100 meters. An aquifer occur at the depth from 140-160 meters marked by bluish to purple color with resistivity ranging from 0.11-0.27Ωm indicating weathered zone with lateral extend of about 100 meters.

ADMT Profile 14 revealed groundwater at the depth from 0-60 meters marked by bluish to purple color with resistivity ranging from 0.15-0.33Ωm indicating weathered zone with lateral extend of about 50 meters. An aquifer occur at the depth of 160-185 meter marked by bluish to purple color with resistivity ranging from0.21-0.33Ωm indicating weathered zone with lateral extend of 20 meters from 30-50 meters.

ADMT Profile 15 revealed groundwater at the depth from 05-60 meters marked by bluish to purple color with resistivity ranging from 0.03-0.27Ωm indicating weathered zone with lateral extend of 40 meters. An aquifer occur at the depth from 85-140 meters marked by bluish to purple color with resistivity ranging from0.11-0.27Ωm indicating weathered zone with lateral extend of 15 meters.

ADMT Profile 16 revealed groundwater at the depth from 25-200 meters marked by bluish to purple color with resistivity ranging from 0.02-0.22Ωm indicating weathered zone with lateral extend of 40 meters.

ADMT Profile 17 revealed an aquifer at the depth from 25-190 meters marked by bluish to purple color with resistivity ranging from 0.1-0.6Ωm indicating weathered zone with lateral extend of 70 meters.

ADMT Profile 18 revealed an aquifer at the depth from 50-70 meters marked by bluish to purple color with resistivity ranging from 0.49-0.76Ωm indicating weathered zone and lateral extend of 20 meters.

ADMT Profile 19 revealed basement throughout the profile because of high resistivity values

ADMT Profile 20 revealed an aquifer at the depth from 20-30 meters marked by bluish color with resistivity ranging from 0.14-0.18Ωm indicating weathered zone and lateral extend of 30 meters. Another aquifer occur at the depth from 100-110 meters marked by bluish to purple color with resistivity ranging from 0.12-0.20Ωm indicating weathered zone and lateral extend of 10 meters.

4. CONCLUSION

The importance and application of the Electrical resistivity method for ground water evaluation in a basement area has been demonstrated in this study carried out within Basement terrain of Dutsinma. The twenty (20) VES point data interpreted revealed that most of the aquifers occur within the depth of 25m to 200m and a resistivity ranges from 0.0Ωm to 6.0Ωm having a lateral extend of minimum of 10m and a maximum of 100m.

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