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Evaluation of Aquifer Characteristics within Birnin Kebbi Metropolis, Northwestern Nigeria Using Geoelectric Survey

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Abstract

Birnin Kebbi metropolis is located in northwestern Nigeria, characterized by extensive Gwandu Formation of the Sokoto Basin. There are few or no published records of subsurface information. The study is geared towards characterizing different aquifers that inhabit groundwater in the area. The geophysical method employed is Schlumberger soundings at 51 points with half-current electrode separation (AB/2) varying from 1m to 100m.

The interpreted resistivity data reveals four lithologic units across the study area: the topsoil, fine-medium sandstone, coarse sandstone and the bedrock. The fine-medium sandstone and coarse sandstone layers serve as the major aquifer units within the area of study. The fine-medium sandstone layer is the best aquifer because of its textural and associated structural features. The aquifer unit has an average resistivity value of 220Ω-m and thickness ranges from <5m to 15 m. In this study, the aquifer layers tend to decrease in thickness westward, thereby making the coarse sandstone layer as alternative aquifer unit within the area. The resistivity data has provided information on the hydrogeologic framework and subsurface geological characteristics of major aquifer units in the study area. This will assist borehole abstraction in the area with a view towards drilling productive boreholes.

Keywords: Schlumberger Sounding, Aquifer Units, Delineation, Sokoto Basin

1. Introduction

It is a known fact that water is essential for the survival of life and the need for water is constantly increasing due to growth in population and urbanization (Ola-Burimo et al, 2018). The increase in demands for drinking water, agriculture and industrial purposes are not commensurate with availability (Ola-Buraimo et al, 2018), this prompted the need to investigate the geological properties responsible for the aquifers in the study area. The search for better living made it very difficult to control the influx of both skilled and unskilled people in and out of Birnin Kebbi metropolis. This has brought about stress on the groundwater resources in the capital city coupled with the fact that the Kebbi State Water Board no long produce water for the populace. Geoelectric method was adopted for this research in order to avoid drilling of dry boreholes which is commonly experienced in the area. It should be noted that the present study is a continuation of earlier part carried out by Ologe et al, (2018) using the same methodology in the same study area but dealt with assessment of groundwater distribution while this present study is considering the characteristics of aquifers in same study area. This approach is important in order to evaluate the aquifers geoelectrical characteristic in terms of their similarities or differences in their geological properties.

1.1 Study Location and Geology

The study area, Birnin Kebbi has coordinates of Longitude 12˚ 16' and 12˚ 42' N and Latitude 4˚ 00' and 4˚ 34' E Figure 1. The geology of the study area is well articulated in the work of Ola-Buraimo et al, (2018). The outcrop at different parts of the study area were described to be massive claystone characterized by the alternation of reddish and purple coloured clays of various thicknesses(Ola-Buraimo et al, 2018). The top of the intercalated clays is capped by ironstone which forms screes and boulders at the foot of the hills as a result of weathering while the topmost head of the hill is flat and extensive with steep sides Ola-Buraimo et al, 2018). The outcrops are said to be intensively fractured and associated with other structures such as loadcasts within the claystone (Ola-Buraimo et al, 2018). Birnin Kebbi is predominantly a gentle undulating plain with an average elevation varying from 250m to 400m above sea level; the plain is occasionally interrupted by low mesas and other escarpment feature (Kogbe, 1979, Obaje 2009). the sedimentary structures present in the study area was described to be two types, sedimentary and tectonic types. Sedimentary structures are contemporaneously formed structures that were formed during deposition of a sedimentary rock and these structures result from combined factors of environment of deposition and nature of the transporting medium (Ola-Buraimo et al, 2018). Tectonic structures were described to have formed after deposition of the rock and indurations of the facies due to stress and strain from earth movements. Tectonic structures could be in micro and mega scale, formed as a result of tectonic impact on the deposits (Ola-Buraimo et al, 2018; Ologe et al, 2018). Sedimentary structures identified in the field were described to be bedding, cross lamination, channel fill, clinoform,

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loadcast, bioturbation and ichnofossil (organic structure), while types of tectonic structures encountered are faults, fracture and joints in the study area (Ola-Buraimo et al, 2018).

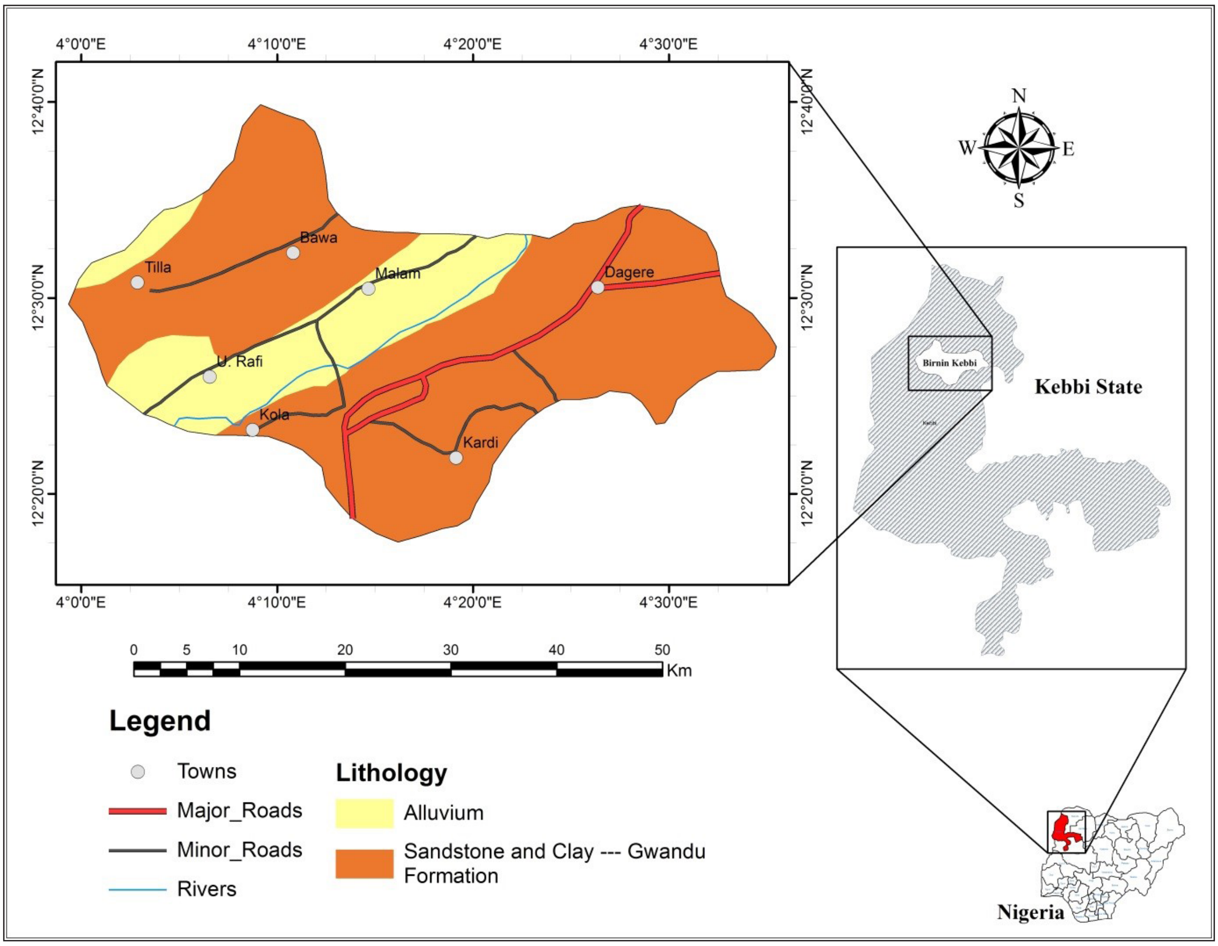


Figure 1. Location and Geological map of Birnin Kebbi area Northwestern Nigeria.

2. Materials and Methods

The R50 d. c. resistivity meter equipment was used for the VES survey. The vertical electrical resistivity sounding utilized schlumbeger configurations. In Schlumbeger array Figure 2, the separation between the current electrodes (AB) is successively expanded while the two potential electrodes (MN) have a short separation and remain partially stationary at the depth sounding position (Ologe et al, 2018). The geoelectric survey is such that the minimum electrode spacing "AB/2" = 1 m and gradually increase to a maximum spread length "AB/2" of 100 m (Ako and Osondu, 1986; Olorunfemi and Fashuyi, 1993). A total of 51 VES points were occupied to cover the study area (Ologe et al, 2018). The measured unit is the apparent resistivity, ρa, which is the product of a geometrical factor, K, and the quotient of the measured potential, ΔU, and the source current, I. The apparent resistivity is plotted versus AB/2 in meters on bilogarithmic paper resulting in a VES curve. The VES curve showed the change of resistivity with depth, since the effective penetration increases with increasing electrode spacing.

From the resistance values (R) obtained from the resistivity meter, apparent resistivity values were calculated by multiplying the corresponding geometric factors, K with the resistance values. The apparent resistivity values were plotted against the electrode spread (AB/2). This was subsequently interpreted. The interpretation of VES curves (DCINV software program by Markku Pirttijärvi, 2005) involves segment-by-segment of sounding curves with rms values not >0.1. This exercise yields geo-electric parameters and layer resistivity; thickness values were calculated.

The field data and the obtained data were input into the system for computer iteration as a starting model in an iterative forward modelling technique 1-D inversion pro- gram (Pirttijarvi, 2005) which in turn displayed the resultant theoretical curves. Therefore, the parameters were subsequently varied until what was considered the best possible fit between the field and the theoretical curve was obtained for each VES station. The parameters for the final model give the layer resistivity and thickness for the VES points. The resultant geo- electric parameters obtained from the iteration were used to establish the geoelectric sections. The quantitatively interpreted sounding curves gave interpreted results as geoelectric parameters in layer resistivity and layer thickness (see Figures 3a to d).

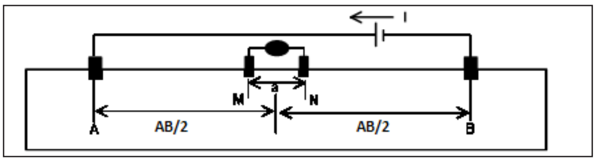
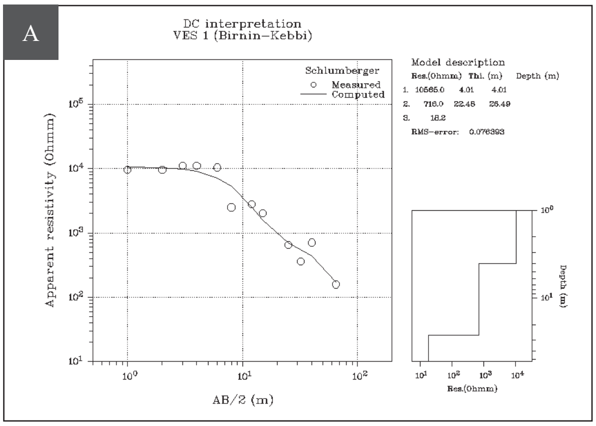
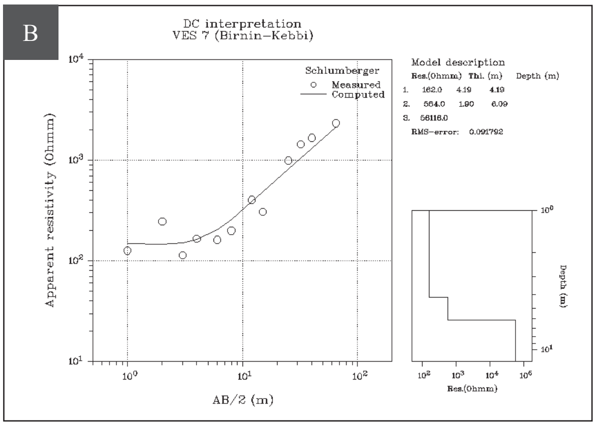


Figure 2. Schlumbeger Configurations Array

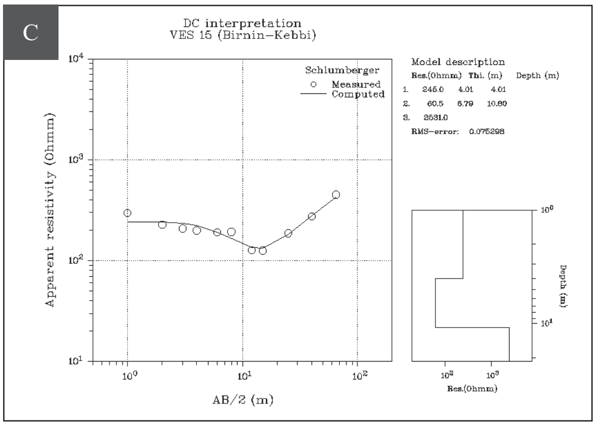
Q –Curve Type



A –Curve Type



H–Curve Type



QH-Curve Type

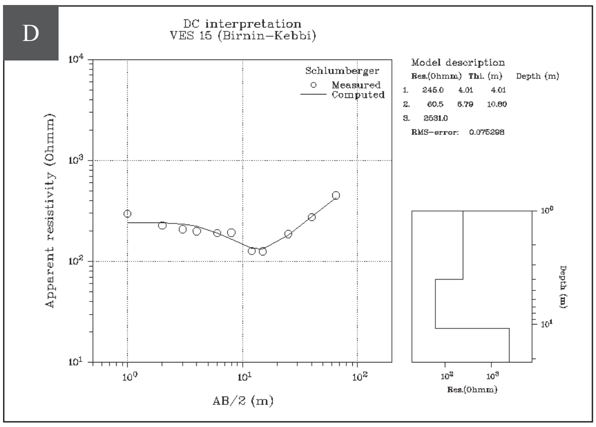


Figure 3a-d: Typical Sounding Curves from the Study Area

3. Results and Discussion

3.1 Aquifer types

The curves obtained from the sedimentary terrain of the study area vary from simple curve A, H, K, Q, KH, HA, HK types to complex curve KHA and KHK types. They are similar to those obtained by Omosuyi et al., (2008); Faleye and Olorunfemi (2015) and Ologe et al., (2018) on aquifer characterization and groundwater potential assessment of the sedimentary basin of Ondo State and Kebbi State respectively. The resistivity data interpretation reveals four lithologic units across the study area vis-à-vis topsoil, fine-medium sandstone, coarse sand and the bedrock. The predominant curve type is the K curve type having percentage frequency of 17.7%, the pictorial statistical analysis of the result is presented in Figure 4. The high percentage recorded by the K curve type within this study area has relationship to predominantly high groundwater potential and rock type associated with it. The least percentage of (5.9%) corresponds to KHA curve type. The curve types were grouped on the basis of the aquifer types. The curve types were grouped into

i) Group One: H, Q, K, A

ii) Group Two: HA, KH, HK, KHK, KHA

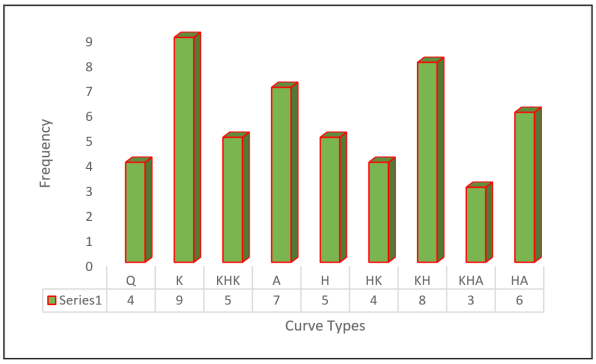


Figure 4. Frequency of Curve Types across the Study Area

Group One: Aquifers in this group correspond to layer 2 in A, H, Q, K curve types. The aquifer type is that of fine-medium sand layer.

Group Two: The aquifer in this group consist of layer 3 of HA, KH, HK, and layer 4 of KHK and KHA which correspond to coarse sandstone. Thus, from the study area, two major aquifer types were mapped which were coarse sandstone and fine-medium sandstone. However, areas underlain by the fine-medium sandstone aquifer are more promising in terms of groundwater development than the coarse sandstone aquifer.

3.2 Aquifers Identification

The resistivity parameter of a geoelectric layer is an important factor to adjudge an aquifer or otherwise (Omosuyi, 2010). To delineate or identify aquiferous or non-aquiferous layers, resistivity contrasts must exist across the subsurface lithologies (Ologe and Abdulsalam, 2018, Omosuyi, 2010). Figures 5 and 6 show four interpretive geoelectric sections taken in the W-E and SW-NE directions. These sections show variation in the subsurface lithofacies and electrical resistivity contrasts both vertically depicting the thickness of the aquifer and laterally showing lateral decrease in lithofacies thickness and pinchout structure of the subsurface lithologies.

Figure 5 is a geoelectric section which shows an interpreted resistivity data of four lithologic units; topsoil, fine-medium sandstone, coarse sandstone and the bedrock. The topsoil which is relatively thin is characterized by resistivity values which vary between 39.3 to 2050 Ohm-m and thickness values between 1.1m to 2.1m. The high resistivity anomaly in VES 41 may be due to textural characteristics in terms of grain size, grain roundness and sorting which are controlling factors of porosity and permeability. This may also be related to structures such as fractures, joints and faults associated with the study area (Ola-Buraimo et al., 2018 and Ologe et al., 2018). Underlying the overburden layer is the identified aquifer unit of different locations characterized by sand unit of 8.1m thickness towards the east and thin layer in the western part.

Figure 6 also shows the geoelectric section drawn in the southwest – northeast direction across vertical sounding points 31, 13, 49 and 44. The top soil along the section has resistivity values ranging from 397 Ohm-m to 781 Ohm-m characteristic of lateritic soil. Beneath the top soil layer there is a relatively high resistivity value of 723 Ohm-m to 2389 Ohm-m, characterized by fine-medium sandstone unit which does not extend to VES 44 location, suggestive of pinchout structure. In some other cases, areas associated with relatively thin fine-medium sandstone compared to relatively thick (15m) underlying coarse sandstone is associated with resistivity values between 107 Ohm-m to 212 Ohm-m; characterizing prolific coarse sandstone aquifer units.

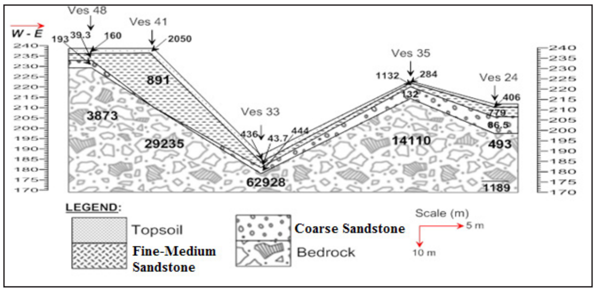


Figure 5. A W-E Geoelectric Section Embracing VES 48, 41, 33, 35 and 24

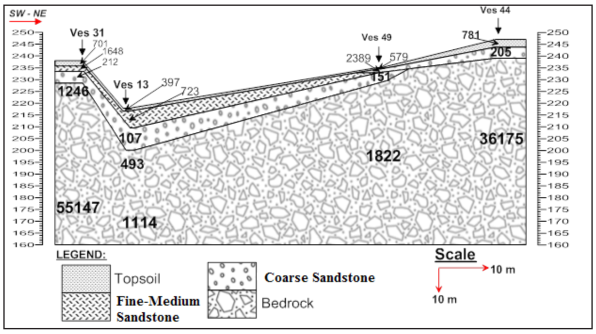


Figure 6. An SW-NE Geoelectric Section Embracing VES 31, 13, 49 and 44

4. Conclusion

The application of surface geophysics using VES technique has greatly helped in delineating the area of study aquifers characteristics with good prospect for groundwater development programme. The aquifer in the area comprises of coarse sand-sandstone layer. The aquifer thickness is variable and ranges from <5m to 15 m. In this study, the resistivity data has provided information on the hydrogeologic framework and subsurface characteristics of major aquifer units in the study area. This will no doubt guide borehole abstraction in the area with a view to drilling productive boreholes.

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