



Geophysical Investigation of Groundwater at the Proposed Ibrahim Badamasi Babangida University Teaching Hospital Site, Lapai, Northcentral Nigeria

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ABSTRACT

Two-dimensional electrical resistivity imaging (ERT) as well as the vertical electrical sounding (VES) were integrated in order to investigate the groundwater prospects at the proposed Ibrahim Badamasi Babangida University Teaching Hospital Lapai, north central Nigeria. Three 2D imaging stations and nine VES points (3 points on each 2D station) were occupied in the study. The 2D imaging technique was used to determine the vertical and horizontal changes in resistivity within the layers as well as depth to basement while the VES was used to determine the fracture depth and thickness. The results revealed three subsurface layers which were interpreted as the top soil and lateritic clay, weathered basement and fresh/fractured basement rock. The groundwater prospects increase towards the northern part of the study area with apparent resistivity values of the weathered basement ranging between 4.55Ωm – 11.7Ωm along the third profile. The VES curves showed fractures between 25m and 45m with fracture occurrences more predominant in VES 6 – 9 which falls on the third 2D imaging line. Water well drilling is recommended in the northern part of the proposed teaching hospital site at depths between 60m to 80m.

Keywords: Groundwater, Electrical Resistivity Imaging, Vertical Electrical Sounding, Aquifer

INTRODUCTION

The United States Environmental protection agency (EPA) has estimated that about 783 million of the world's population has no access to potable water. About 30% of this population is from Sub-Saharan Africa made up majorly of the poor and rural dwellers. Globally, water resources are increasingly facing numerous challenges due to issues such as population expansion, development, rural-urban migration and changes in climate. Water is an essential commodity as all life on earth depends upon it. It is also a critical input to production in most economic sectors.

About 60% of Nigeria is underlain by crystalline rocks where in a large percentage of fresh water is locked up. Groundwater yield here are unpredictable as they depend on the depth of weathering as well as interconnectivity of fractures, where they may exist. Water exploration in such locations may be challenging. However, electrical resistivity methods have proven to be reliable in detecting

the presence of subsurface structures that are capable of hosting groundwater. Various authors have utilized the vertical electrical sounding (VES) method (David et al, 2018; Aliyu et al, 2016; Mohamaden et al, 2016; Venkatara et al, 2014), 2-D electrical resistivity imaging method (Ameloko and Rotimi, 2010; Ratnakumari et al, 2012; Rai et al, 2013; Ayodeji and Adeyinka, 2015) while others have employed a combination of both method (Mohamed et al, 2012; Sikah et al, 2016; Aziman et al, 2018; Jassim and Mohammed, 2014) for groundwater exploration studies. Their results recorded varying degree of success with the integrated VES and 2D method having the best results. The traditional VES method gives a 1D model of the subsurface which is insufficient for groundwater exploration in geologically complex terrains.

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The 2D electrical resistivity tomography (ERT) method presents a holistic 2D model of the subsurface, which captures the resistivity changes in both the X and Y dimension along the survey line continuously regardless of the geological and topographical complexities of the area (Loke, 2000). In this study, the VES and 2D resistivity methods are integrated to investigate the groundwater potential the proposed Ibrahim Badamasi Babangida University Teaching Hospital (IBBUTH) Site in Lapai, North Central Nigeria.

METHODOLOGY

The Study Area

The study area is the site for the proposed IBBUTH Lapai (Figure 1). It is bounded by latitude $09^{\circ} 02'21''N$ to $09^{\circ} 13'45''N$ and longitude $006^{\circ} 29'57''E$ to $006^{\circ} 36'12''E$. It falls within the tropical region of Northcentral Nigeria with a mean annual rainfall of between 1600mm and 1500mm and rain duration of 150 to 215 days.

Geologically, the area is part of the north central Nigerian Basement made up predominantly of metavolcanic and metasedimentary rocks. The major rock types underlying the area are coarse to fine grained as well as granite gneiss (Figure 2). The prominent joints and fractures are trending in the NNE – SSW (Figure). The joints have been filled with quartzofeldspatic veins, running for between 3m and 6m and displaying sharp contrast with their host rock and in some cases, show evidence of chilled margins.

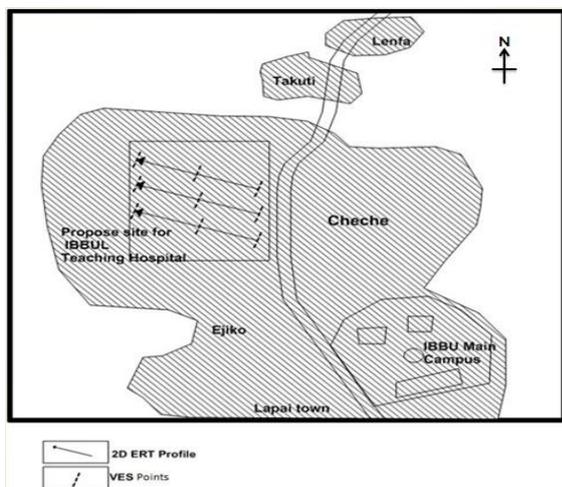


Figure 1: Sketch Map of the Study Area Showing the Survey Layout

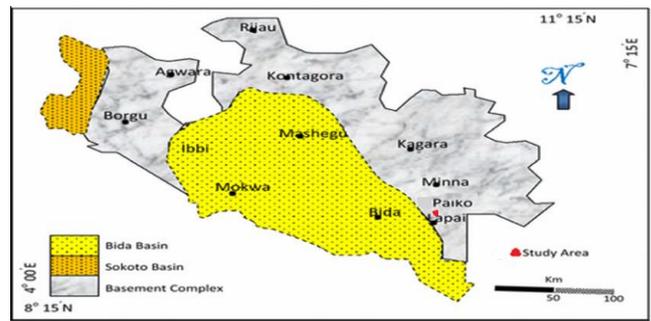


Figure 2: Geological Map of Niger State Showing the Study Area (Modified after Idris-Nda *et al.*, 2015)

Geophysical Survey

The electrical resistivity method is based on measuring the contrast in electrical conductivity of the underlying rock units. This varies according to the properties of the rock (porosity, density, shape, and pore size), water content as well as its quality and temperature (Parasmis, 1997). The water content and quality within the soil or rock matrix is controlled by the resistivity than by the soil granular resistivity value itself. Most electrical resistivity surveys are conducted by injecting electrical current into the ground using a pair of electrodes. The variation in electrical resistivity is thus determined by measuring the potential difference using another pair of electrodes.

2D ERT is conducted using a multi-electrode resistivity imaging system and processed using software inversion techniques. For the survey, multi-core cables with many electrode takeouts are connected together forming a multi-electrode setup (Figure 3) where selection of any four (two for current injection and two for potential measurement) of these electrodes is possible. The number of electrodes varies from 64 to 72 electrodes depending on the system used. Inverse modeling of the measured apparent resistivity data is done using the RES2DINV program to create a subsurface resistivity model. The model can be used for geological interpretation in order to identify aquiferous zones as well as structures such as weathered zones, fractures, joints and basement configuration (topography).

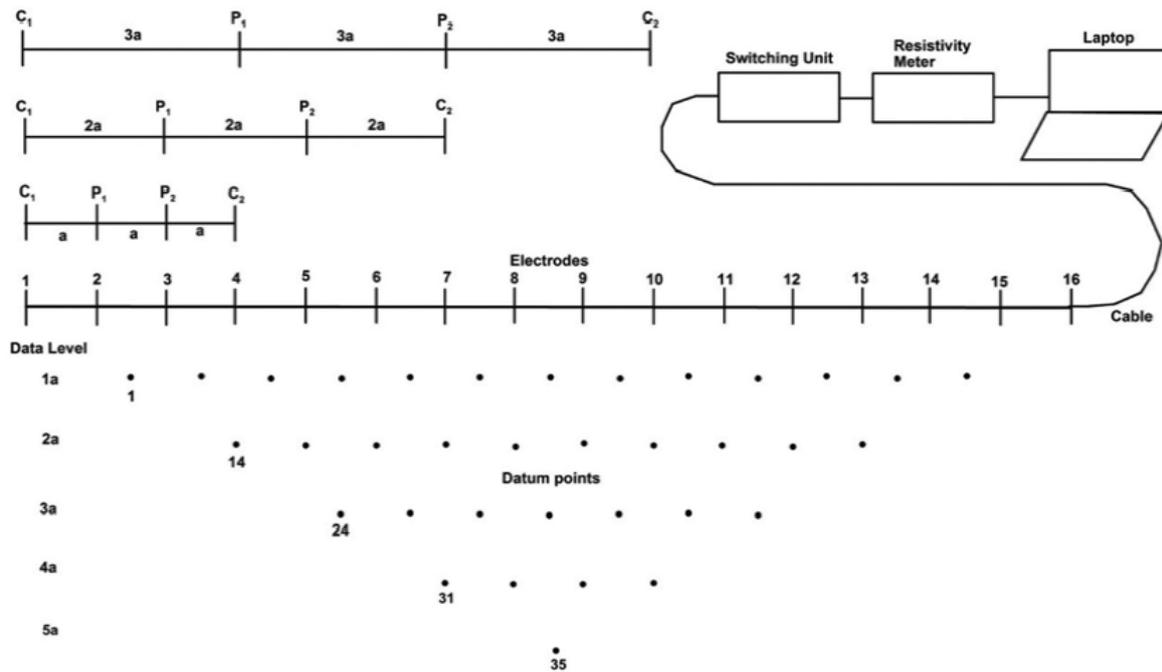


Figure 3: Sequence of Measurements for Electrical Resistivity Imaging (Source: Loke, 2000).

Generally, the VES arrangement consists of a pair of current electrodes and a pair of potential electrodes. These were driven into the earth with hammers in a straight line in order to establish a firm and good contact with the ground. The current electrode spacing was increased as the measurements progresses while the potential electrodes separations are guided accordingly as necessary.

Three 2D profiles of 100m length and inter-electrode spacing of 5 meters using the Wenner Alpha array were covered in this study. This was followed by nine VES points (3 along each ERT profile) with maximum current electrode spacing is 100m. The VES data was interpreted using the IPI2WIN software.

RESULTS

Profile 1

The resistivity imaging result for the profile covers a length of 100 meters and depth of 16 meters (Figure 4). Three major layers were identified in this profile; the top layer is at

approximately 9 meters depth with bulk apparent resistivity value of 500Ωm; the second layer is at a depth of 12.5 meters with apparent resistivity of 1279Ωm; and the third layer is at 16 meters depth with apparent resistivity value of 1500Ωm.

Profile 2

The resistivity imaging result for this profile also covers a length of 100 meters and depth of 16 meters (Figure 5). The identified layers in this profile are; a highly resistive top layer with apparent resistivity of 1553Ωm and is 3 meters deep. Below this lies a low resistivity layer of 333Ωm extending to a depth of 10 meters. The third layer has an apparent resistivity of 3360Ωm with depth of 16 meters.

Profile 3

This profile is composed of approximately 2 layers. The first layer extends from depth of 3.5 meters at 10 meters along the profile to a depth of 16 meters at 45 to 50 meters along the profile (Figure 6). The second layer is observed at the flanks of the profile with resistivity values greater than 3000Ωm.

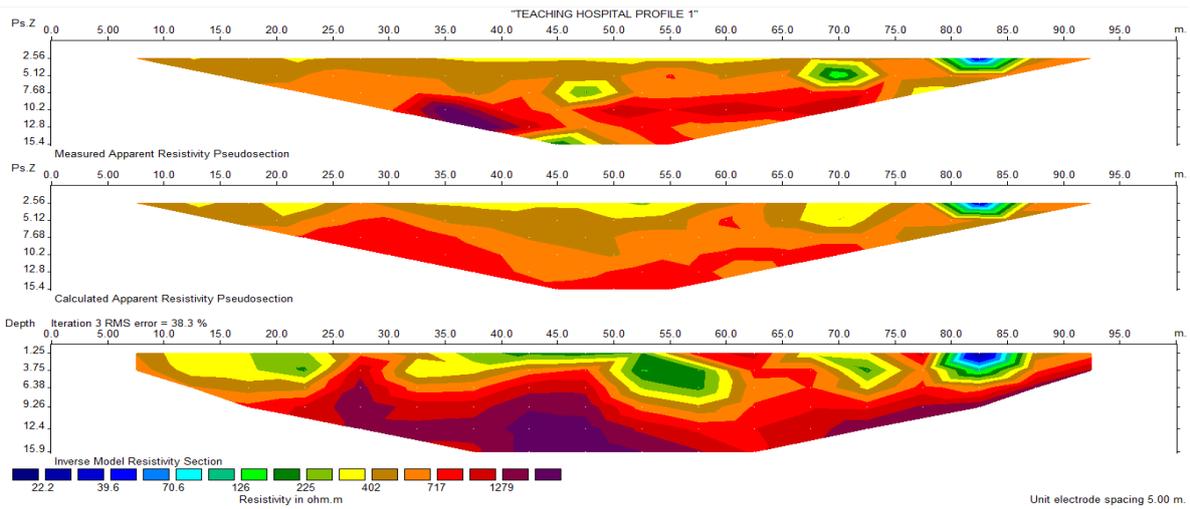


Figure 4: Measured, Calculated and Inverse Models along Profile 1

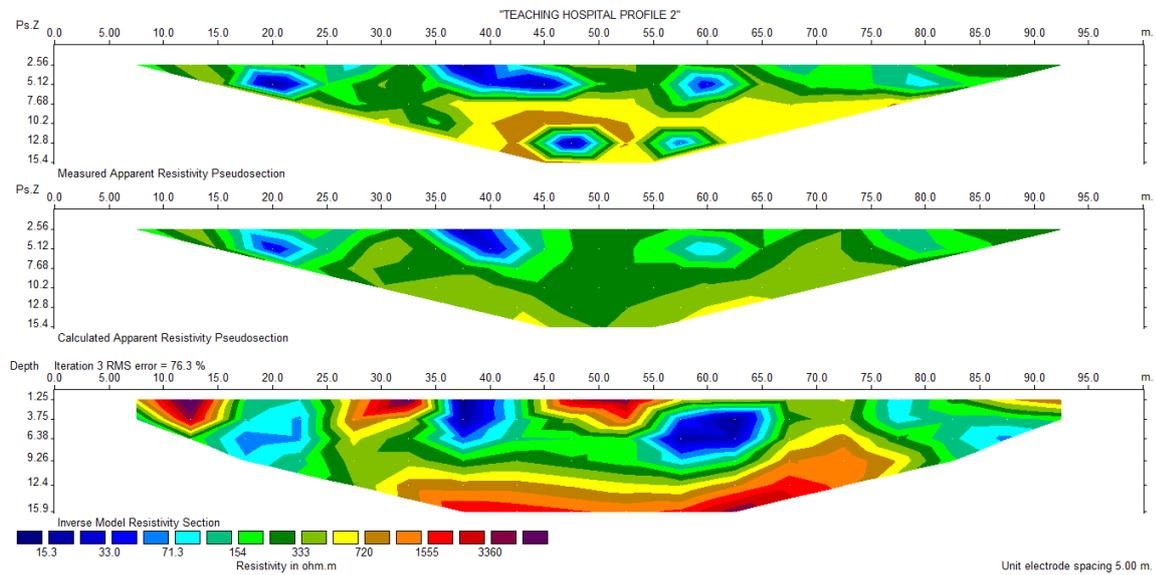


Figure 5: Measured, Calculated and Inverse Models along Profile 2

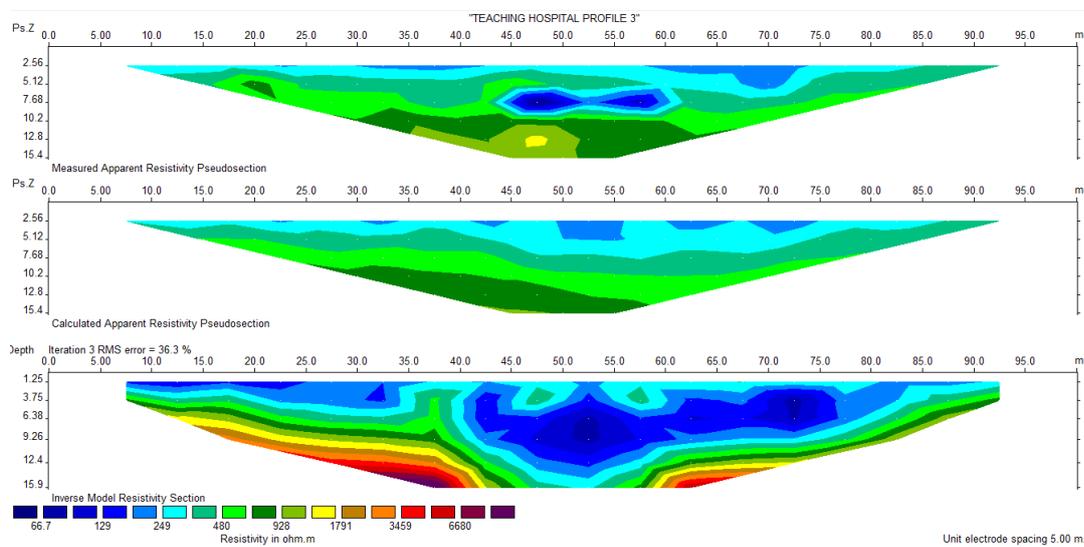


Figure 6: Measured, Calculated and Inverse Models along Profile 3

DISCUSSION

The area underlying the profile 1 and 2 has highly resistive first layer which is made up of a sandy top soil and laterites. These layers are unlikely to host reasonable quantity of groundwater. The same cannot be said of the area underlying profile three with a relatively low apparent resistivity in the first layer. This suggests saturated lateritic sand and weathered basement which is also saturated. The weathered basement, between 9 meters and 12.5 meters, in profile 1 is also not aquiferous while the prospect of this layer is higher in profile 2 and 3. The fresh/fractured basement was encountered between 12.5 meters and 16 meters along profile 1, 8 meters to 16 meters along profile 2 and 6 meters to 20 meters along profile 3. The VES method was introduced in this study in order to identify the fractured zones as the 2D method was only used to identify the weathering profile as well as the depth to basement. The fractured basement is characterized by relatively high apparent resistivity along profile 1 ($309\Omega\text{m}$ - $919\Omega\text{m}$), moderate value along profile 2 ($20.7\Omega\text{m}$ - $301\Omega\text{m}$) and low value along profile 3 ($4.55\Omega\text{m}$ - $11.7\Omega\text{m}$). The fracture thickness in the area is between 4 meters and 12 meters occurring between 25 meters and 45 meters depth. The relatively low apparent resistivity value along profile 3 is interpreted to be as a result of the presence of fresh groundwater and fresh fractured basement. This implies a pattern of increasing fracture saturation from profile 1 to 3. The basement is observed to be undulating and generally gets deeper towards the northern part of the study area.

Conclusion

The 2D and VES methods were integrated in this study to unravel the subsurface geology of the area and determine the prospects for groundwater availability. The 2D resistivity tomography was able to delineate the weathering profile overlying the basement as well as the groundwater potential. The VES was used to determine the fractures at depth as well as the fracture thickness. The study generally reveals 3 subsurface layers in the area; the top

soil and lateritic sand layer; the weathered basement and the fractured/fresh basement. The weathered profile is increasingly aquiferous towards the northern part of the study area while the southern part is considered to be non-aquiferous. Also, the depth to basement increases towards the north providing a considerable interplay of good sediment thickness and basement fracturing which are the best targets in groundwater exploration campaigns.

Conclusively, the northern part of the study area provides the best targets for groundwater availability and exploration and water well drilling activities are advised to be located in this area at depth of between 60m and 80m

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