Characterization of Groundwater System Using Geology, Hydrogeology and Geophysical Methods in Federal University of Technology, Minna, Bosso Campus, North-Central, Nigeria

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Abstract
The studies aimed at characterising the groundwater system of the Bosso campus of Federal University of Technology, Minna was carried out. Geology of the area was studied using a topographical map on a scale of 1:10,000. Hydrogeological studies were conducted on existing boreholes within the campus and new areas. 1D geophysical study was conducted using a Terrameter employing the Schlumberger array for the Vertical Electrical Sounding (VES). The geological mapping revealed presence of granitic rock with intrusion of quartz vein and joints, major jointing/fracturing is in the NE–SW direction. Geophysical data interpretation was done using computer aided iteration method which enabled the delineation of various geophysical layers in order to reveal the structural control of groundwater and aquifer system. The results show three predominant geoelectric layers: the topsoil, weathered/fractured granite and fresh granite. Apparent resistivity values of the first layer ranges from 14.1Ωm-571.9Ωm with thickness of 0.5m-4.6m, second layer has apparent resistivity values of 10.0Ωm–406.9Ωm with thickness of 2.0m-13.1m and the third layer having apparent resistivity values ranges from 1467.6Ωm–19031.2Ωm with an infinite thickness. Isopach map with the resistivity maps at 10m and 30m respectively shows very low to low apparent resistivity values with thick overburden which can constitute zones of high groundwater potential at north-eastern and south-eastern parts of the study area. Hydraulic conductivity results range from.7.00×10^{-5} m/s to 4.31×10^{-4} m/s. The result falls within standard range for fine grain to coarse grain sand of 2.00×10^{-7} m/s to 6.00×10^{-3} m/s. It is concluded that the north central parts of the study area have poor to marginal groundwater potential while the north-eastern and south-eastern part is supported by the occurrences and concentration of fractures which can constitute weathered/fractured aquifers around these regions.

Keywords: Geological mapping, VES, Hydrogeological studies, fractures and groundwater

INTRODUCTION

Studies aimed at characterising the groundwater system of the Bosso Campus of the Federal University of Technology, Minna was carried out because water is life and without water there can be no life. Every aspect of human endeavour requires quality, adequate and timely supply of water to succeed. Water is what makes life possible and it must be adequately supplied.

The occurrence of groundwater is greatly influenced by the local geological conditions which also control well yields. Recharge to aquifer influences the safe yields of wells. Hence the availability of groundwater will depend on hydrogeological setting characterized by hydraulic parameters and also, its distribution and management require reliable aquifer characterization.

Federal University of Technology, Minna is one out of many institutions present in Niger State which is also among academic communities (institutions) facing water supply problem. Accessibility to water is the right of all staff and students, but unfortunately this remains unrealized for a larger number of people within the study area.

This work will employ the use of Electrical Resistivity Survey to find areas of high groundwater potential within the Campus, Sieve analysis to access grain size distribution of granular material (gradation) and Infiltration rate experiment to know the velocity at which water can seep into the soil. These will help to characterise the groundwater system to find areas of high groundwater potential within the Campus which will help for future groundwater exploration and exploitation in the area.

Location, Drainage Pattern and Accessibility of the Area

The study area lies between longitudes $6^{0}31'20.01"$E and $6^{0}31'45.05"$Eof the Greenwich meridian and latitudes $9^{0}38'56.7"$N to $9^{0}39'30.02"$N of the equator. The study area is part of Minna Sheet 164SW North Central, Nigeria covering a total area of about 1.45km^2 and located in Minna the capital city of Niger State (Figure 1).

Most tributaries in the study area are channel into a concrete-wall canal that passes through the north-eastern side of the school to the southern down to Minna City. The study area possesses a good drainage pattern. The area is accessible through the following express-ways: Lambata, Bida, Zungeru and Kuta.

Climate and Physiography of the area

The study area is characterized by two sessions which are dry and rainy season with temperature ranges from about 21^{0}C at the climax of rainy season (December and January) to about 35^{0}C at the peak of dry season (March and June) (Federal Meteorological Agency, Minna, 2011).The study area vegetation belongs to the central portion of savannah which is a transitional type between the forest zone of Southern Nigeria and the Guinea Savannah types of the Northern Nigeria that is characterize by tall grasses with sparsely distributed trees. During dry season, the trees are sparsely distributed and evenly distributed in the rainy (wet) session.

Geology and Hydrogeology

The study area lies within the north-central portion of the Nigerian Basement Complex, which is characterized by three lithofacies: the migmatite gneiss complex, the lowgrade schist belt and the older granites (Olarewaju, et al., 1996; Olasehinde, 1999; Oyawoye, 1972) (Figure 2).

The aquifer in the area is recharged by precipitation and as a result, the discharges of the boreholes tapping from the regolith aquifers are higher during the rainy season than during the dry season (Amadi, et al., 2013). The general trend of groundwater flow in the study area is northeast-southwest direction, which conforms to the regional structural trend in the area. The capacity of these crystalline rocks to store and allow movement and yield water largely depends on the extent, pattern, size, openness and continuity of the fracture, and the degree to which these fractures are hydraulically connected (Todd, 1980).

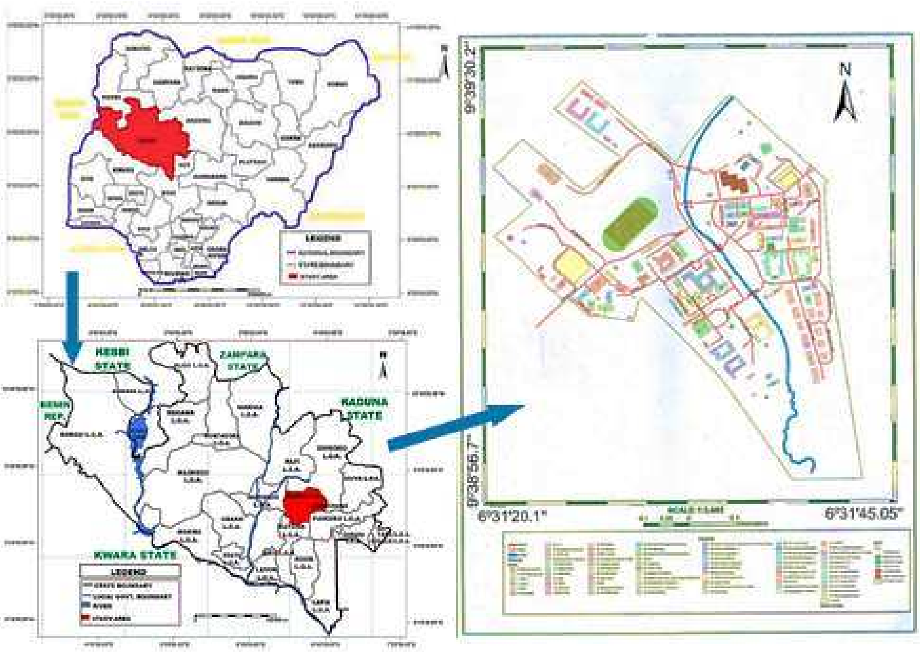

Figure 1: Map of the study Area.

METHODOLOGY

Both the surface and subsurface materials was investigated using multiple studies of geology, geophysical and hydrogeological studies by conducting field mapping, vertical electrical sounding (VES), infiltration rate field experiment and sieve analysis. This was achieved by using both systematic method (gridding of map) and study along existing borehole site in the study area. The map was carefully gridded into cells at regular intervals (Figure 3). GPS values for each point on the map were obtained so as to be able to locate the actual point on land surface. All studies were done using a systematic method except for vertical electrical sounding that was conducted using systematic method and by sounding across existing boreholes. Soil Samples for sieve analysis were collected at six different locations (0 meters, 0.5 metres, 1 metre and 1.5 meters) at regular intervals from each other. The soil surface was also dug for infiltration rate experiment. Likewise, the geological mapping was conducted to know the rock type present in the area and their geological features.

The blue colour points (L5, L6, L8, L9, L11 and L12) in figure 4 indicate locations where soil samples were collected for sieve analysis and where infiltration rate experiment was performed, while the red and black coloured locations are where VES survey was performed

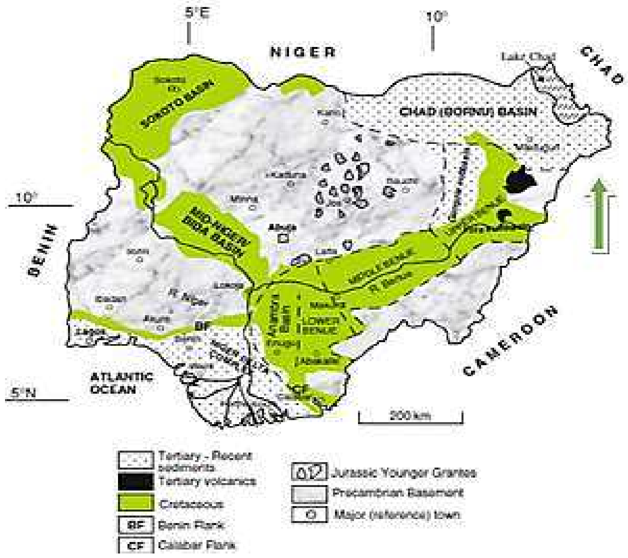

Figure 2: General Geology of Nigeria (Obaje, 2009).

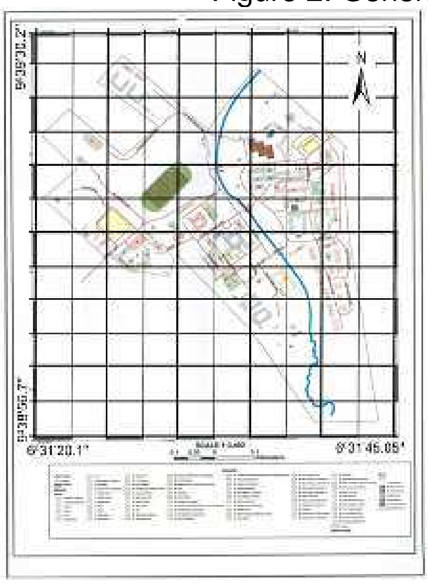

Figure 3: Grid Map of the Study Area.

Figure 4: Map of the Study Area: VES and Sampling Points.

Field and Laboratory Experiment

The soil sample test was done at the Laboratory of Civil Engineering, Federal University of Technology, Minna. The purpose of the index geotechnical test of sieve analysis is to classify the soil sample based on their physical characteristics. All analysis was carried out using American Standard Testing Method (ASTM).

The GeoSensor of high-impedance voltmeter with high precision and accuracy was used in the investigation. It has been used over the years for several geophysical surveys – environmental, engineering, structural mapping, and hydrogeology. Electrical Resistivity of geophysical survey was employed for acquisition of data through schlumberger array configuration. Data interpretation was done using computer aided iteration method which enabled the delineation of various geophysical materials into subsurface aquiferous units. Geoelectric Section was generated by computing each VES stations on profiles. Profile 1 geoelectric section consists of location 1, 4, 7, 10, and 13, Profile 2 consists of location 2, 5, 8, 11, 14, Profile 3 consists of location 6, 9, 12, and 15, Profile 4 consists of Location A11, A9, A3, A2 and A4, Profile 5 consist of location 16, A8, A6, and 17. Figure 7 shows only for Profile 2.

Infiltration rate field experiment was performed where sieve analysis sample was taken. A cylindrical container with volume of 446.16cm^3 was driven into the ground after which water was poured to the brim of the container, followed by taking record of how long it takes the water to infiltrate through the soil until there is only a glistening sheen on the soil after waiting patiently (Plate III).

313.99gram of soil sample taken from the field was obtained and then air dried for 5-7 day sand then pulverized using a rubber-tipped pestle and a ceramic mortar. Pulverized sample was transferred into a pan and weighed using a weighing machine. Weigh of pan with sample was obtained. Other normal steps for grain size analysis were followed.

RESULTS AND INTERPRETATION

Geological Mapping

The rock found within the study area is granite which occurs mostly at the northern part of the location with occurrence of joints with length ranges from3.5m - 8.0m with width of about 0.01- 0.15metres (Figure 5). The fractures are in NE-SW direction as indicated by the rose diagram in Figure 6. In the area mapped, quartz vein ranges in size of 5mm, 20mm, 30mm was observed (Plate I).

Fractured granitic rocks were observed all over the exposed outcrop in the area which suggest suitable site for borehole and gives evidence of thin regolith (Plate II). From the geological field mapping, it can be said that fractured basement aquifer suggests the only possible means for groundwater supply. This now shows presence of fractured bedrock in the subsurface which serves as conduits for the infiltration and migration of groundwater system. Hence, it hydrogeology lies mainly on location of fractures and/or weathering. Groundwater seeps into well through the fractures and fissures of these rocks causing it to weathered rapidly. Weathering weakens the strength of the rock fabrics and increases the structural weaknesses of the rock mass (Bell, 2007). The presence of fractures in the rock increases intensity of weathering in the rock mass by creating opening in the rock for the agents of weathering to penetrate.

Plate I: Quartz Vein on the Granitic Rock.

Plate II: Highly Jointed Granitic Outcrop.

Figure 5 Geology map of the study area.

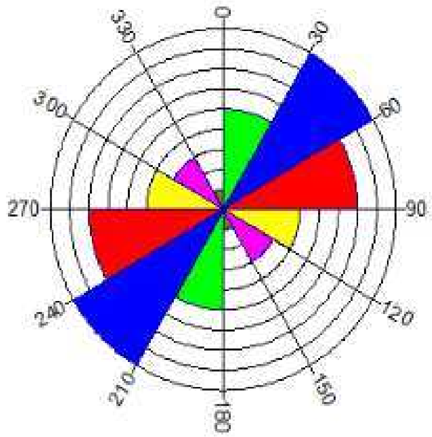

Figure 6: Rose Diagram

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Geophysical Survey

27 VES stations were established and their geoelectic sections were generated. Geoelectric Sections was generated by computing each VES stations into groups of profiles as shown in Figure 7. Isopach map with the resistivity at 10m and 30m are represented in Figure 8 and 9 respectively. Groundwater Potential Map in figure 10 shows area having high groundwater, moderate and low to be at the south-eastern, southwestern and extreme northern. The Apparent Resistivity values of the first layer ranges from 14.1Ωm-571.9Ωm with thickness of 0.5m-4.6m, second layer has apparent resistivity values of 10.0Ωm–406.9Ωm with thickness of 2.0m-13.1m and the third layer having apparent resistivity values ranges from 1467.6Ωm–19031.2Ωm with an infinite thickness. 1D electrical

method using Vertical Electrical Sounding has been employed over the years to characterize aquifer in different geologic environments and to map fractures in basement areas (Koefoed, 1979, McDowell, 1979, Ayolabi *et al.,* 2003).

All Interpreted Vertical Electrical Sounding Curve generated from the resistivity in the study areas show a three (3) layers curve consisting of Top Soil, Weathered/ Fractured layer and Fresh Basement. The resistivity curve types are A and H- type curve.

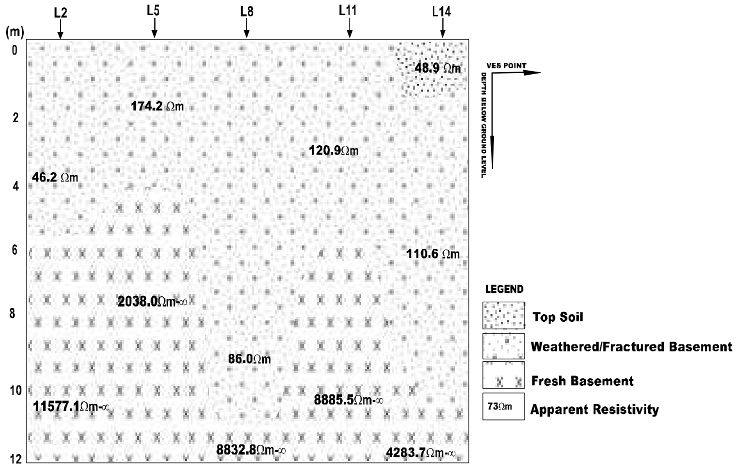

Figure 7: Geoelectric Section for Profile 1.

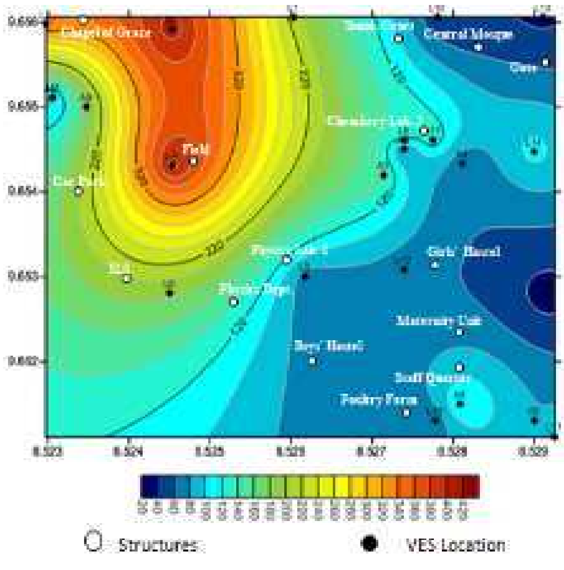

Figure 8: Iso – Resistivity at 10m.

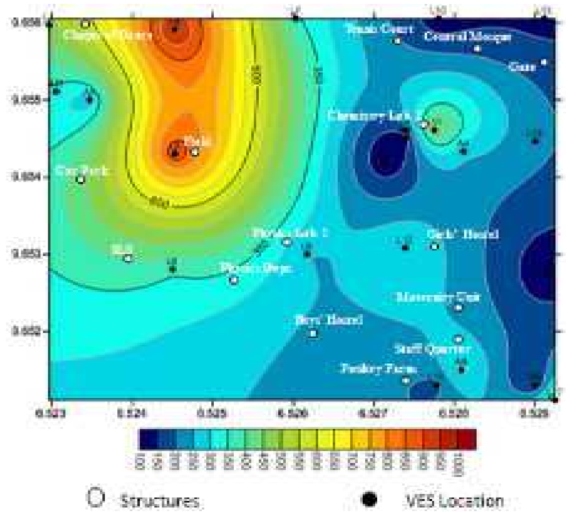

Figure 9: Iso – Resistivity at 30m.

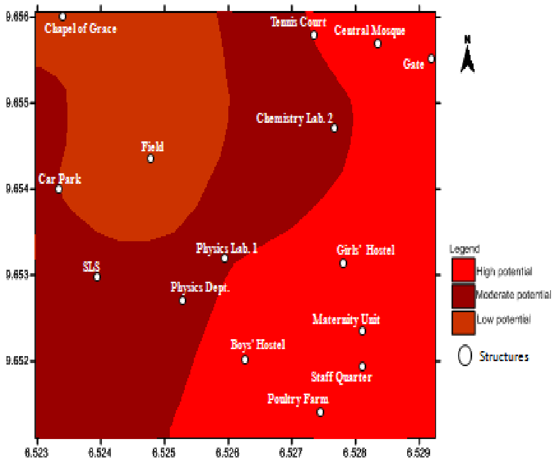

Figure 10: Groundwater Potential Map.

Infiltration Rate

The result generated from the Infiltration rate experiment performed ranges from 1.259 $\times 10^{-5}$ l/s to 2.974$\times 10^{-4}$l/s in location 5 and 11 respectively (Table 1). This shows the rate at which water infiltrate vertically into the subsurface. The geological materials in location 11 have the highest infiltration rate (fastest) than other locations while the geological materials in location 5 infiltrate very lowly when compared with others locations.

Plate III: Some of the Procedure involved in Infiltration Rate Experiment

Table 1: Infiltration Rate Parameter Table.

LOCATION	Infiltration Rate (L/S)
5	1.259 $\times 10^{-5}$
6	2.399$\times 10^{-5}$
8	1.062$\times 10^{-4}$
9	3.38$\times 10^{-5}$
11	2.974$\times 10^{-4}$
12	2.675$\times 10^{-4}$

Sieve Analysis

From result obtained in the particle size distribution characteristics of the sand size fraction, soil retained on the ASTM sieve for all the locations ranges from 63.7% to 88.0% at 0-meter depth, 53.2% to 84.0% for 0.5 meter, 68.6% to 88.3% and 31.5% to 88.0% at 1.5 meters. Figure 11 shows the grading curve for location 5.

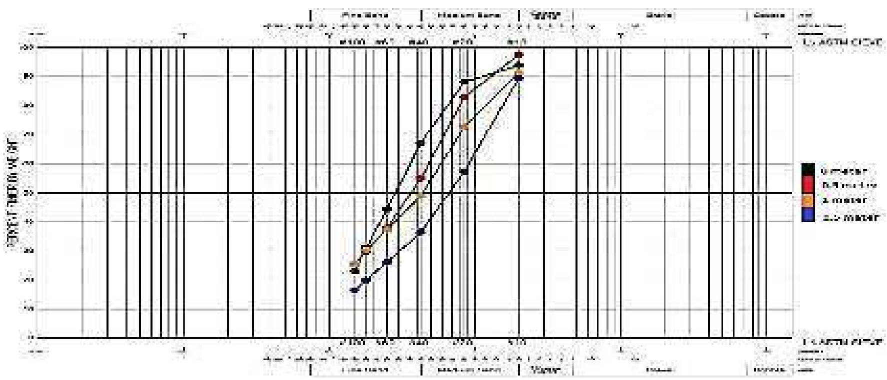

Figure 11: Grading Curve for location 5.

The result shows that 63.7%, 84.0%, 88.3% and 88.0% of soil samples taken at 0meter, 0.5meter, 1 meter and 1.5 meter respectively ranges in grain size from coarse sand to fine sand. The sieve analysis data was used to get the rate at which water moves through geological materials in the area by calculating the hydraulic conductivity.

DISCUSSION

Geological, hydrogeological and geophysical methods were employed to characterized groundwater system within Bosso Campus of the Federal University of Technology Minna. From the geological field research, fractures were observed in the exposed outcrop and the result of the resistivity value revealed the presence of fracture which suggest suitable site for borehole and gives evidence of thin regolith because fractured basement aquifer suggest the only possible means for groundwater supply. Presence of fractured bedrock in the subsurface serves as conduits for the infiltration and migration of groundwater system.

Isopach map shows very low to low apparent resistivity values with thick overburden, this is capable of constituting high groundwater potential at northeastern and southeastern parts of the study area which indicate fracture basement, while those with high resistivity value might be due to non-existence or absence of fracture. From sieve analysis result, we have reasonable percentage of sand than any other types of materials. Water moves easily in sand because is permeable and also porous and to region of lower hydraulic head. Particle Size for sand (fine, medium and coarse) ranges from 0.06mm – 2mm which is higher than clay and silt and lower than boulders, gravel and pebble which means that it transmits water easily.

The lowest and highest transmissivity rate (hydraulic conductivity) result ranges from 7.00×10^{-5} m/s to 4.31×10^{-4} m/s in location 5 to location 12. The result falls within standard range of fine grain to coarse grain sand (2.00×10^{-7} m/s to 6.00×10^{-3} m/s) of Structx (2019) and Domenico *et al.* (1990). The result of the sieve analysis experiment was used together with infiltration rate result of the area for extensive result to achieve the objectives of this study. From the result of the infiltration rate experiment, it shows that there is possibility of impermeable layer in location 5 which contributed to the very low infiltration rate in the area.

CONCLUSION

It is concluded that the north central parts of the study area have poor to marginal groundwater potential while the north-eastern and south-eastern part is supported by the occurrences and concentration of fractures which can constitute weathered/fractured aquifers around these regions.

RECOMMENDATION

It is recommended that water wells should be drilled within northeastern and southeastern part to an effective depth for optimum groundwater yields, and that hydraulic conductivity should be determined on drilled wells in order to also determine the aquifer efficiency and production in the area.

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