GEOPHYSICAL INVESTIGATION OF GROUNDWATER POTENTIAL IN MILLENNIUM CITY HOUSING ESTATE KADUNA, NIGERIA USING ELECTRICAL RESISTIVITY METHOD

[1]Shaibu, I., [2]Udensi, E. E., [2]Chinwuko, A.I., [2]Usman, D. A., and [2]Adetona, A. A.Omale M.E.

[1]Department of Geology, Federal University Gusau, Zamfara State

[2]Department of Physics, Federal University of Technology, Minna, Niger State

Email: isahshaibu1982@gmail.com

ABSTRACT

Lack of potable drinking water supply remains one of the main challenges of residents of Millennium City Housing Estate, Kaduna, Nigeria. The groundwater potential of the area was investigated using vertical electrical sounding (VES) method. A total number of 36 vertical electrical sounding VES points were used for the entire investigation using Schlumberger array and the data obtained were analyzed using curve matching and computer iteration techniques. The data revealed both a 3-layer (KH and H Curve types) and 4-layer (H-curve type) only for the area. In the 3-layer system, the apparent resistivity of the first layer ranged from 31.0 Ωm to 57.5 Ωm with a corresponding thickness of 0.8 m to 1.6 m. The second layer has apparent resistivity value ranged from 13.6 Ωm to 907.9 Ωm with a corresponding thickness range of 4.4 m to 22.8 m while the third layer has resistivity values ranging from 1087.1 Ωm to 1477.2 Ωm with an infinite depth. For the four (4) layered model curves, first layers resistivity ranged from 131.7 Ωm to 208.5 Ωm, with a corresponding thickness ranged from 0.8 m to 1.0 m. The resistivity of the second layers ranged between 28.8 Ωm to 29.9 Ωm with a corresponding thickness ranged from 5.1 m to 16.3 m. The third layer resistivity ranged from 111.4 Ωm to 287.2 Ωm with a corresponding thickness ranged from 8.2 m to 22.6 m. The forth layer has a resistivity value ranging from 1044.3 Ωm to 1833.6 Ωm with an infinite depth. An integration of both isopach and iso-resistivity maps for both the 3- layer model curves and 4- layer model curves indicates that most of the north/west parts of the study area have low apparent resistivity values and thick overburden which implies good groundwater potential while the southern portion has a little higher resistivity values and shallow overburden, an indication of poor groundwater potential. Future boreholes in the area should reached an effective depth of 40 m to 55 m depth and the borehole be supervised by a certified hydrogeologist or geophysicist for optimum groundwater yields. Pumping test should be carried out in order to ascertain the size and type or quality of submersible pump to be installed for optimum yield.

Keywords: *Investigation, Groundwater Potentials, Millennium City Housing Estate, Kaduna, Nigeria.*

Introduction

The growth of any locality depends on availability of basic infrastructural needs such as roads, water, electricity and industries among others. A general case of northern Nigeria where the amount of rainfall is limited to very few months of the year with annual rainfall of about 1000-1500mm Eduvie, (1998). Surface water sources are often inadequate or non-existent.(Baimba,1978,Perez and Barber,1965).

There is need for scientific identification of parameters governing ground water resources, investigation of groundwater potential and management, particularly, if satisfactory living conditions of the inhabitants are to be catered for. This is paramount, due to the presence increase in groundwater demand for various human activities has placed great importance on water science and management. The Millennium City Housing Estate Kaduna, Nigeria was designed originally for 25,000 inhabitants but currently has population of over 50,000 people and basic amenities are over-stretched. This population and the daily influx of people into Kaduna, Nigerian's in search of greener pastures have resulted in acute water shortage in the area and the inhabitants now rely on water vendors for their daily water needs. Groundwater accounts for greater percentage of the world's fresh water and it is fairly distributed throughout the world. It is the world's greatest essential factor for sustainable development and the need to delineate the areas that would be suitable for groundwater potential and need to conduct hydrological and geophysical survey of the area in order to provide useful information on the possible sites for ground water exploration. Since the object of sound is to determine the variation of electric conductivity with depth, vertical electrical sounding (VES) has been the most important geophysical method of water prospecting in area of deep in situ weathering of fresh bedrock. The geo-electric resistivity method, particularly the (VES) method has been chosen for this particular work basically, because it has proven to be an economic, quick and effective means of solving most ground water problems in different parts of the world (Breusse,1963, Zohdy and Jackson, 1969 and Frohlich, 1974).

Materials and Methods

Materials

The equipment that will be used for the resistivity method is reasonably cheap and easy to use. The resistivity field data will be acquired with the aid of the following equipment:-

Terrameter (Geopulse campus Tiger)- This is the major power source of the whole set-up. It measures the resistance of the subsurface layers and can also measure the voltage of the power source. The equipment has an in-built system of reducing the effect of noise. The instrument is portable and fixed with a rechargeable battery. it has a maximum power of 18 watts, manual selection of current in steps up to 100mA, a choice of sample time/ signal length averaged three frequency settings.

Electrodes- These are steel rods of about 30cm with a base and a pointed end. The pointed end is use to penetrate the ground. The material makes it a good conductor. Four electrodes will be used; the first pair is the potential electrode while the second pair is the current electrode. Their basic function is to pass current into the ground and measure potential between two points. Two-third of the length of the electrodes will be driven below the earth surface.

Cables- They are made of conducting material (copper). There will be four reels of cables used during the geophysical survey. The cables will be connected to the terrameter on one end and the other is connected to the electrodes.

Clips- These are objects used for passing the currents from the cables to the electrodes by clipping the electrodes after wounding the cable on it. The mouth is made of conducting materials while the base (handle) is made of insulating material to prevent electrocution. The clips ensure good electrical contact

Hammer and Cutlass-These will be used to drive the electrodes into the ground. It consists of a relatively slim wooden cylindrical handle embedded into a metallic head. While the cutlass will be used to clear the path along which measurement are to be taken.

Tapes- These are used for making measurements of length on the field as they have been calibrated in metric units. The tapes used will be of 100m in length. They will be used in measuring electrode spacing on the field.

Global Positioning System and Compass-Clinometer- this equipment will be used for taking coordinates and bearing. GPS will be used for taking the longitudes, latitudes and elevation of various locations. It is portable and handy. The compass-clinometer will be used to take direction of the profiles.

Field Stationery- These are writing materials that will be used to record all observation and field data. The stationery consists of pencils, pens, recording sheets, rulers and so on.

Study Area Description

Kaduna state millennium city, was created in 1999, following the decision to expand the city in other to build more house for both federal and Kaduna state civil servants. The millennium city lies in the north-west part of Nigeria with latitude of $10^{o}31^{'}$ N and longitude 07^{o} $30^{'}$ E, with elevation of 619 m. (Fig. 1). The study area and it is accessibility through major and minor roads, while Fig .2 shows geological maps of Nigeria showing the study area and Fig .3 shows geological map of Kaduna State (NGSA 2007).

Fig. 1: Map of Kaduna showing the accessibility of the study areas

Fig. 2: Geologic map of Nigeria showing the Study Area (NGSA., 2000)

Fig. 3: Kaduna State showing the Geology of the study area (NGSA 2007).

Geology of the Area

The study area lies within the Basement Complex of Northern Nigeria (Figure 3). The Basement Complex includes all rocks older than the late Proterozoic (McCurry., 1976) and is composed mainly of gneisses, migmatite, granites, and some extensive areas of schist, phyllites and Quartzites (Bennéis.,1978), (Perez and Barber.,1965) according to (McMCurry.,1976).The whole Basement has been through at least two tectonic–metamorphic cycles and consequent metamorphism, magnetization and granitization have extensively modified the original rocks so that they generally occur as relict rafts and xenoliths in migmatite and granites. Two groups of granites are present and these are the Older Granites and the Younger Granites. The Older Granites are Widespread and often give rise to smoothly domed hills which typically rise to about 170 m above the surrounding plains (Russ.,1957).The Younger granites which include granites, syenites and rhyolites cover extensive areas in the plateau.

The area lies entirely within the Basement Complex of Northern Nigeria (Figure 3). The rocks consist of series of granites, gneisses, migmatite, low-grade schist, quartzite and amphibolites that have been grouped by the British authors as "Basement Complex of the Precambrian age" (Olugboye., 1975). The topsoil varies in composition, colour and texture at most places. They are predominantly laterite and quartz grains (deep browns or reddish brown soils). Geophysical investigation reports of (Eduvie., 2005) and (Dan –Hassan., 1999) showed that Kaduna is underlain by 3 to 5 geologic layers; the top lateritic soil, clayey sand sandy clay, weathered transition zone, the fractured bed rock and the fresh bedrock. Geophysical investigation and borehole drilling reports have clearly established two major aquifers. These are the overburden weathered aquifer and the fractured crystalline aquifer (Dan-Hassan and Olarufemi.,1999) at some locations these aquifers are interconnected and form a hydrogeological unit of water table surface.

Pre-drilling Geophysical Investigation

A total spread of 100 m was covered with maximum current electrode separation (AB/2) of 50 m. An *ABEM SAS 1000 Terrameter*was used for the electrical resistivity survey. Schlumberger electrode configuration was used for the pre-drilling geophysical survey. The array consists of 2 current (C_1 and C_2) and 2 potential (P_1 and P_2) electrodes (Fig 4). It works under the principles of the wider the current electrodes, the deeper the current penetration (Olasehinde and Awojobi, 2004). The interpretation of the field data using WinResist Computer softwares were used to obtain of the apparent resistivity values (Annor et al., 1990; Edet and Okereke, 1997).

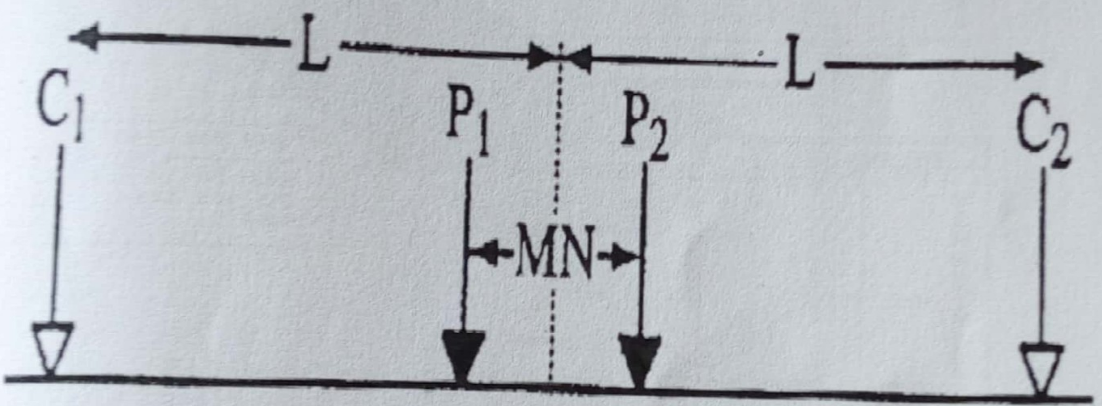
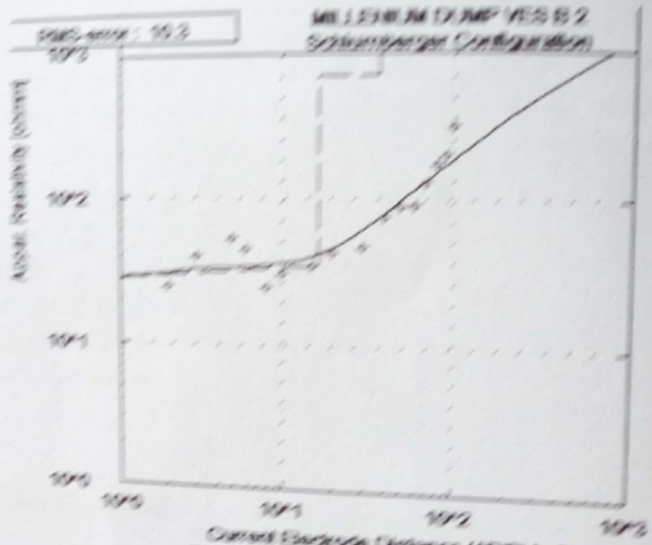


Fig. 4: Schematic Diagram of Schlumberger Array

Results and Discussion

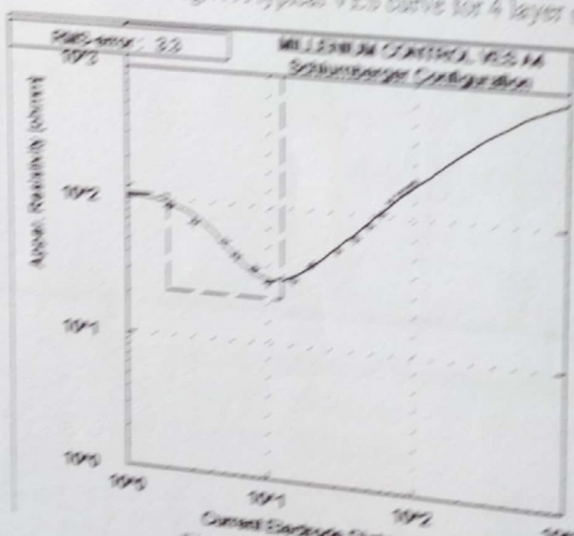
Two different categories of model curve types were identified in the study area. The first category is those with four layers which represent about 60% of VES curves (Fig. 5) while the second category consists of three layers, which representing about 40% of the sounded points within the study area (Fig. 6). The geo-electric sections with the 4 layer show topsoil or laterite, wheathered/ fractured basement and fresh basement (Fig. 5) while the the 3 layer curves shows laterite, fractured basement and fresh basement rocks (Fig. 6). The subsurface lithology varies from place to place within the study area and the finding conforms to the work done other researchers (Olorunfemi and Olayinka, 2002; ***Osazuwa, I. B., &Abdullahi, N. K. (2008). Dan-Hassan, M.A., &Olarinfemi, M. O. (1991).***

More so, the geo-electric sections of the study area (Fig. 7 and Fig. 8) show that the subsurface lithology of the area is not uniformly distributed. Area with thick regolith materials shows great potential for groundwater exploitation (Ako, 1996). The regolith are a product of weathering which induces the geological materials to be porous and permeable, which qualifies them as aquifers, since they can store and transmit groundwater in economic quantity (Amadi et al., 2012; Momoh et al., 2012).



No	Res	Thick	Depth
1	27.3	0.7	0.7
2	35.3	15.7	16.4
3	654.7	21.1	37.5
4	1877.9	--	--

Fig.7: A typical VES curve for 4 layer system in the area



No	Res	Thick	Depth
1	106.8	2.0	2.0
2	21.5	10.5	12.5
3	1095.9	--	--

Fig. 8: A typical VES curve for 3 layer system in the area

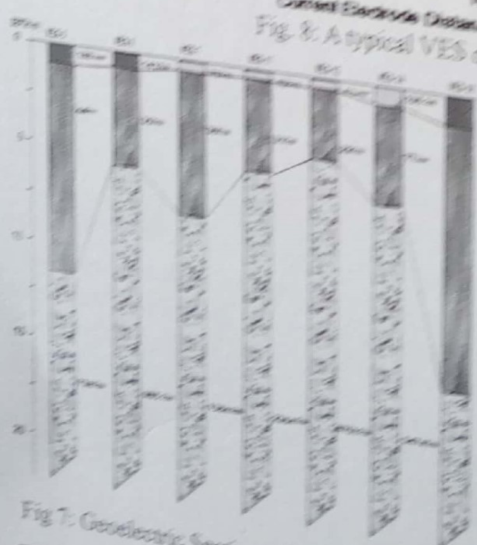


Fig 7: Geoelectric Sections for 3 Layer System

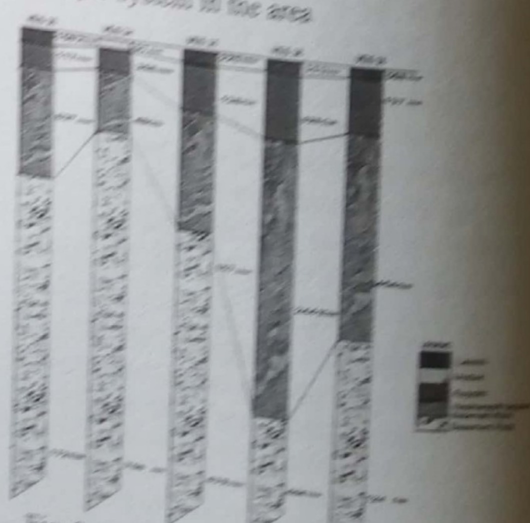


Fig. 8: Geoelectric System for 4 Layer System

Isoresistivity and Isopach maps of a three layer model curves

From the isopach map of regolith thickness for three layered curves (Fig. 9), it can be established that the northern portion of the area shows deep/thick overburden/regolith thickness, while south-western portion shows shallow overburden. This corresponds to the isoresistivity map, as the shallow overburden materials are seen around the ridge which shows lower resistivity values. The thicker the overburden materials the better chance for groundwater storage and this implies that the northern sector correspond to groundwater recharge zone while the southern portion are areas of groundwater discharge. The average thickness of regolith/overburden materials for the three layered curve is about 11m.

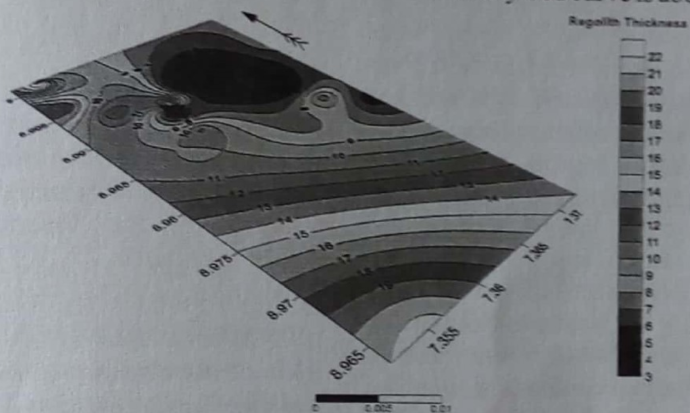


Fig. 9: Isopach map of regolith thickness for three layered model curves

The isoresistivity map of the three layer model curves indicates that the resistivity value is lower at the northern portion of the area compared to the southern portion of the area (Fig. 10). From the countour map the area with higher resistivity values indicate presence of no water or conducting materials while lower resistivity values are indicative of a thick overburden. For the 3 layer system, the weathered/fractured zone is the second layer which is regarded as the regolith aquifer zone (Amadi et al., 2015b; Olasehinde et al., 2016). It is characterized by low resistivity values (high conductivity) compared to the first and third layers as illustrated in Fig.10.

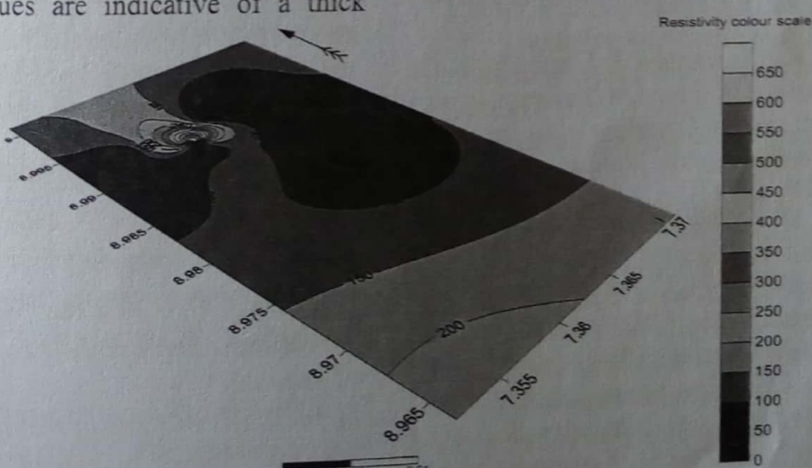


Fig. 10: Isoresistivity map of three layered model curves

Conclusions and Recommendations

The study aimed at investigating the groundwater potential of the Millennium City Housing Estate, Kaduna State, Nigeria using Vertical Electrical Sounding of the Electrical Resistivity method. The study became necessary due to the increase in population of the area. A total number of 40 VES points were conducted and the data obtained were analysed through curve matching and computer software. The area comprises of both 3 layer and 4 layer system. The 3 layers were predominantly H-type curve while the 4 layer system was mainly HA-curve type and are typical of the basement complex terrain. The field data, geoelectric section, isopach and isoresistivity maps of both the 3 and 4 layer model curves show that the northern parts of the study area correspond to recharge zone due thickoverburden materials which pave way for groundwater while the southern portion are areas of groundwater discharge as a result of low thickness of the overburden materials. The average thickness of regolith/overburden materials for the three layered curve is about 11m. A total drill depth of 40 to 55 m was recommended for optimum groundwater yields in the area.

References

Aiyegbusi, M.N. and Akujieze, C.N. (2010).Aspect of Geophysical Exploration for Groundwater using VES in Delta North District. Journal of African Sciences, 7(2), 61-68.

Annor, A. E., Olasehinde, P. I. and Pal, P. C. (1990). Basement Fracture Patterns in the Control of Water Channels – An example from Central Nigeria. Journal of Mining Geology 26(1), 5-11.

Ako, B. D. (1996). An Integration of Geophysical and Geological Data in Damsite Investigation-The Case of Opa Dam. Journal of Mining and Geology, 13 (1), 1-6.

Amadi, A. N., Olasehinde, P. I., Okoye, N. O., Momoh, O. L. and Dan-Hassan, M. A. (2012). Hydrogeophysical exploration for groundwater potential in Kataeregi, North-Central Nigeria. International Journal of Scientific Research, 2(1), 9 – 17.

Amadi, A. N., Ameh, M. I., Idris-Nda, A., Okoye, N. O. and Ejiofor, C. I. (2013) Geological and Geophysical Investigation of Groundwater in parts of Paiko, Sheet 185, North-Central Nigeria. International Journal of Engineering Research and Development, 6(1), 1 – 8.

Amadi, A. N., Olasehinde, P. I., Ameh, I. M., Okunlola, I. A. and Dan-Hassan, M. A. (2015b). Investigating the groundwater potential at the Boys Hostel, Bosso Campus, Federal University of Technology Minna, using electrical resistivity method. Water Resources, Journal of the Nigerian Association of Hydrogeologists, 25(1&2), 92– 107.

Baimba, J.I. (1978). Electrical resistivity tomography applied to geologic, environmental and engineering investigation at a former waste-disposal site. Geophysics 71.6. B231:B339

Breusse., G. (1963).Detection of Groundwater contamination near waste disposal sites with Electromagnetic methods Geotech.Envviron.Geophys.73-79 *II.S.E.G.*

Dan-Hassan,M.A. & Olarinfemi, M.O. (1991).Hydro-geohysical investigation of a Basement Terrain in the North-Central part of Kaduna State, Nigeria. Journal of Mining & Geology.Vol 35 (2). 18206

Edet, A.E. and Okereke, C.S. (1997).Assessment of Hydrogeological Conditions in Basement Aquifers of the Precambrian Oban Massif, Southeastern Nigeria. Journal of Applied Geophysics, 36, 95-204.

Eduvie, M.O.(1998). Groundwater Assessment and Borehole characterization: Case study from parts of Kaduna Metropolis (Kaduna State). Paper presented at workshop organized by Kaduna StateWater Board.

National Teachers Institute.

Eduvie, M.O.(2005).Exploration, Evaluation and Development of groundwater in Southern Kaduna State, Nigeria: unpublished PhD thesis, Department of Geology, A.BU, Zaria.

Frohlich, M.O., (1974). Assessment of Groundwater Potentials of Abuja Environs. 29th WEDC International Conference Abuja, Nigeria, 2003 towards the millennium development goals, 185-187.

Ikpokonte, A.E. (2010). Assessment of Groundwater Potential of Crystalline Aquifer for Gidanwaya and its Environs, Southern Part of Kaduna State, Northwest Nigeria. Journal of African Earth Science, 7(8), 66-71.

Mbonu, P.D.C., Ebeniro, J.O., Ofoegbu, C.O. and Ekine, A.S. (1991).Geoelectrical Sounding for the Determination of Aquifer Characteristics in Part of Umuahia Area of Nigeria. Journal of Geophysics, 56, 284-291.

McCurry, P. (1976). The Geology of Precambrian to lower Paleozoic rocks of Northern, Nigeria–A review in: Kogbe, C.A (Ed) Geology of Nigeria-Elizabeth and Published co. Lagos. 436pp.

Momoh, O. L., Amadi, A. N., Abdulfatai, I. A., Omananyi, Y. A., Onoduku, U. S. and Onah, M. (2012). Exploration of groundwater within the Mariam Babangida Girls Science Secondary School, Minna, Northcentral Nigeria using Schlumberger vertical electrical sounding techniques. Journal of Science, Technology, Mathematics and Education, 8(3), 21-32.

Ministry of Environmental and Natural Resources Kaduna. (2016). The Nigerian Climate Records. Unpublished Report, 26-28

Nigeria Geological Survey Agency (NGSA, 2006.): Generalized geological map of Nigeria.

Geological Survey of Nigeria Bulletin.39:46

Olugboye, N.O. (1975). Hydrogeology of Kaduna Town. G.N.S Report No 1539.

Olasehinde, P.I. and Awojobi, M.O. (2004). Geological and Geophysical Evidences of a North South Fracture System, East and West of the Upper Gwiara River in Central Nigeria. Water Resources, 15, 33-38.

Olasehinde, P. I., Amadi, A. N., Enwedo, E. O., Dan-Hassan, M. A. and Okunlola, I. A. (2016). Assessing the Groundwater Potential in Wuye District, Federal Capital Territory, Abuja, Nigeria. Development Journal of Science and Technology Research, 5(1), 67 – 78.

Olorunfemi, M.O. & Olayinka, A.I. (2002). An integrated used of geoelectrical imaging and hydrogeochemical methods in delineating limits of polluted surface and groundwater at a landfill site in Ibadan area, Southwestern Nigeria. Journal of Mining and Geology. 37.1:53-68.

Osazuwa, I.B. & Abdullahi, N.K.(2008). 2-D Electrical Resistivity and Induced Polarisation Investigation at an open solid Waste Dump site: Case Study from Kaduna North Central Nigeria, Journal of Environmental Hydrology. 16(29)1-11

Olorunfemi, M.O. and Okakune, E.T. (1992). Hydrogeological and Geological Significant of Geoelectrical Survey of Ile-Ife. Nigerian Journal of Mining and Geology, 28(1), 221 – 222.

Omeji, M., Husin, W., Noorddin, I., Oha, I.A., Onwuka, O.S., Ugwuoke, P.E. and Meludu, O. (2013).Geoelectrical Investigation of **Aquifer** Problems in Gosa Area of Abuja, Northcentral, Nigeria.
International Journal of Physical Sciences, 8(13), 549-559.

Perez, J. W. & Barber, M. (1965). Distribution and chemical quality of groundwater in northern Nigeria; Geological Survey of Nigeria Bulletin, 36

Russ, D. M. (1957). *The generalised reciprocal method of seismic refraction interpretation*. Society of Exploration Geophysicists, Tulsa. 53, 345-352