Groundwater Potential Detection Possibility in Southern Ondo State, Nigeria

[1]Onifade Yemi Sikiru and [2]Egbejule Kingsley Arerebo

[1& 2]Department of Physics, Federal University of Petroleum Resources, Effurun, Delta State, Nigeria

Contributions of the Authors

Onifade YS worked on the Data got by Egbejule KA from the field work. Analysics of the Data and graphical representation were done by the two Authors.

doi: 10.51505/ijaemr.2023.8320 URL: http://dx.doi.org/10.51505/ijaemr.2023.8320

Abstract

A new simple and quick geophysical method for groundwater exploration of the coastal plains sands and alluvial deposits of parts of Ondo State, Nigeria has been developed. A geophysical evaluation using Electrical Resistivity method for groundwater exploration at the study area was carried out which involved the utilization of Vertical Electrical Sounding (VES) technique with schlumberger array system. About eight (8) points of vertical electrical sounding (VES) survey using ABEM tetrameter (SAS 300) was tabulated in a table which shows the resistivity, the thicknesses and the number of layers for each VES station. The field results were plotted, the curve types and lithologic layers were revealed. The plots showed type-Q, type-K, type-A and type-H curve merging while VES-3 did not reveal any type of curve. This was because of that point understudy being homogenously deposited and non-horizontally layered. Some of the VES points have horizontal layers not more than two for example, VES-1 and VES-3 whiles others have a maximum of four layers within them. The resistivity of the basement within the area ranges from 163.1 ohm-m to 9113.4 ohm-m with an average resistivity of 2627.76 ohm-m. In terms of geological structures and aquifer potential, VES-7 and VES-8 showed to possess characteristically a good geological structures and aquifers for groundwater potentials.

Keywords: Groundwater, Detection, Schlumberger array, Vertical Electrical Sounding (VES) and Tetrameter.

Introduction

Water is still one of the essential components of life and is crucial to human survival. It is one of the natural resources that are crucial for both the continued existence of both humans and the natural world. All civilizations have developed in direct relation to the availability of water. In fact, a lack of water, particularly in the past, hindered the growth of communities. Lack of dependable water supplies may also hinder social welfare and economic growth. The principal water resource in the research area, underground water, is under more pressure as a result of the study area's rapid population growth brought on by urbanization [1]. Our societies' primary concern has always been the availability and quality of water resources, particularly in semiarid and arid regions as well as in areas with abundant rainfall, such as the tropical region. Because of the ever-increasing population, irrigation, and industrialization, the problem of obtaining an adequate supply of quality water is becoming increasingly severe. Because of this, surface water cannot be relied on all year; therefore, other alternatives are required to supplement surface water. Groundwater is the water that lies beneath the ground and is the best-quality fresh water on which the entire world is dependent. It is the water held in the subsurface, under hydrostatic pressure in the saturated zone below the water table. Groundwater can be found in sedimentary terrain, which is easier to exploit, or in complex basement terrain, which is more difficult to locate, particularly in areas surrounded by crystalline rocks. [2]. Groundwater is a critical source of freshwater for humans, serving domestic, industrial, and agricultural needs. In fact, groundwater contains more than 90% of the world's readily available freshwater [3],[4]. As a result, groundwater is the primary source of freshwater provisioning in many parts of the world, particularly in Sub-Saharan Africa, where water recycling and reuse are practically nonexistent. Coastal areas around the world have higher net human migration than inland areas, owing to their function as commerce, industrialization, and international trade hubs. Six megacities are expected to emerge in Africa by 2030, with 50% of them being coastal cities [5]. Coastal population densities are currently approximately three times the global average [6]. Coastal areas only cover 5% of the world's surface, but they are estimated to house 50–70% of the world's human population [7]. These realities have resulted in increased water consumption and potential overexploitation of coastal groundwater [8]. Groundwater is a critical source of freshwater for humans, serving domestic, industrial, and agricultural needs. In fact, groundwater contains more than 90% of the world's readily available freshwater [3][4] . As a result, groundwater is the primary source of freshwater provisioning in many parts of the world, particularly in Sub-Saharan Africa, where water recycling and reuse are practically nonexistent. One of the major challenges confronting communities in any nation's coastal regions is the encroachment of seawater into coastal aquifers, which is caused in part by excessive groundwater abstraction in the coastal area. The salinity of water-bearing units may also be caused by polluted water infiltration into the pervious and semi-pervious geological formations that host groundwater. Groundwater keeps coastal streams and rivers flowing and provides fresh water to coastal ponds, wetlands, and other coastal ecosystems.

The Water Exploitation Index (WEI), which is been calculated as the mean yearly overall demand for freshwater divided by the long-term mean freshwater resources available, has been found to be extremely high in several sub-Saharan African regions [9]; [10]. According to[11], population trends and patterns in water usage will cause more, African countries to exceed their economically, usable land-based water resources before 2025. Over-exploitation and high WEI in coastal aquifers have the potential to lower groundwater levels while also having the unusually negative impact of seawater intrusion. This is due to the aquifers' proximity to the ocean or creeks, as well as the hydraulic pressure differences between saltwater and freshwater. According to[12], the annual rate of groundwater abstraction is approximately $1000km^3$, with approximately 67% abstracted for irrigation, 22% for domestic, and 11% for industrial uses. The potential groundwater resource in Nigeria is estimated to be around 51.9 billion m^3 per year [13]). Its availability, however, varies according to rainfall, location, and geological formations.

Vol. 8, No. 03; 2023

ISSN: 2456-3676

Materials and Method

Vertical Electrical Sounding (VES) with a Schlumberger array were used in the field, with eight (8) VES stations. The profiles were kept in a regular north-south orientation, with a current electrode spacing of 1/2AB=100 M. Four (4) collinear electrodes make up the Schlumberger array. The two electrodes on the outside are current source electrodes, while the two electrodes on the inside are potential (receiver) electrodes (Figure 1). The potential electrodes are installed in the center of the electrode array with a small spacing, usually less than one-fifth the spacing between the current electrodes. During the survey, the current electrodes are separated further, while the potential electrodes remain in the same position until the observed voltage becomes too small to measure. The ABEM terrameter (SAS 300) was used for this survey, which is a modern instrument in which the resistance readings at each VES point were automatically displayed on the digital read out screen and were jotted down in the survey book. The Schlumberger array has the advantage of requiring fewer electrodes to be moved to each sounding and having a shorter cable length for the potential electrode. Schlumberger soundings have higher resolution, greater probing depth, and require less time to deploy in the field than Wenner arrays. (EPA, 2016)[14]. With the aid of ABEM Terrameter SAS 300 and its accessories, the apparent resistivity (ρ_a)

was measured in twelve locations using Equation (1)

$$\rho_a = \pi \left[\frac{(\frac{AB^2}{2}) - (\frac{MN^2}{2})}{MN} \right] R \qquad 1$$

The equation is simplified in equation (2) as thus

$$(\rho_a) = K.R \qquad 2$$

Where the geometric factor

$$K = \pi \left[\frac{(\frac{AB^2}{2}) - (\frac{MN^2}{2})}{MN} \right] \qquad 3$$

AB and MN are the current and potential electrode separations respectively and R is the measured resistance. This was done by measuring the earth's resistance through the effect of injected current sent into the ground. The measured R was multiplied by the geometric factor k, determined by the electrode configuration. The processing of apparent resistivity values were done using Resist Software. The software employs the principle of inversion with the help of a well-known Resistivity Transform.

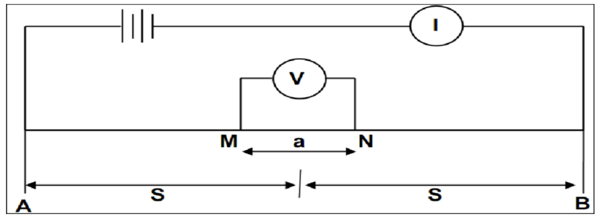


Figure 1: Schematic of Schlumberger array for data acquisition (adapted from researchgate)

Study Area

The study area is located in southern Ondo State and includes towns such as Igbotu, Igbekebo, Shabomi, and Arogbo as shown in figure 1. Ondo state is located in the South-Western part of Nigeria. The study area lies between Longitudes 40 30' and 60 0'E and Latitudes 50 30' and 80 15'N. It covers a geographic area of 14,500 km^2. It is bounded by Kwara, Kogi and Ekiti State in the North, Edo and Delta in the east, Ogun, Oyo and Osun States in the west and in the South by the Atlantic Ocean. The terrain is undulating, surrounded by isolated hills and inselbergs. The topographical elevations vary from 320 m to 450 m above the sea level [15]. The area is drained by River Ala and its tributaries. The drain pattern is dendritic flowing in N-S direction. In areas with complex basement rocks, waters are contained in the weathered and fractured zones within the aquifers, since water cannot be found everywhere like in the sedimentary terrain. The Ondo state is underlain by rocks of the Precambrian basement complex of the south western Nigeria [16]). The major lithological units include the granite gneiss and migmatite gneiss [17]. These rocks form inselbergs, isolated or residual hills and continuous ridges. The area exhibit varieties of structural setting such as foliations, folds, faults, joints and fractures. The gneiss shows the evidences of ancient tectonic activity in the form of a major strike slip fault trending approximately N-S and oilier minor faults, joints and folds in NE-SW [18]. The general strike direction of faults, joints and fractures trend N-S. The river Ala and its tributaries constitute die surface water resources of the study area. The foliation trends of the area are NNW-SSE, the lineament of the rocks in the area is E-W [18]. However, in some parts the basement rocks are concealed. Ondo experience high annual rainfall with a mean of 1333.2 m [15].

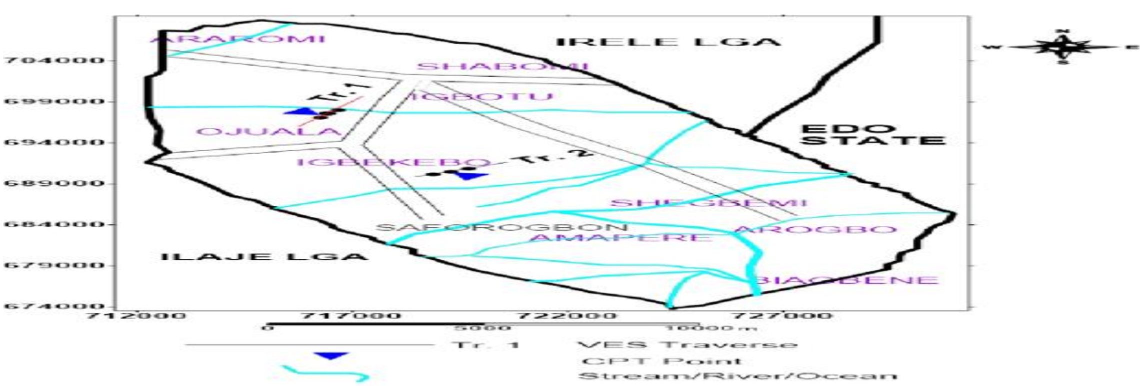


Figure 2: Data acquisition map showing VES and CPT points (adapted from)[7]

Vol. 8, No. 03; 2023

ISSN: 2456-3676

Results and Discussions

Vertical Electrical Sounding (VES) is a technique in Geophysics used to determine the resistivity variation of places with depth. Single VES was applied in areas where the ground was assumed to be horizontally layered with very little variation, since the sounding curves can only be interpreted using a horizontally layered earth model. Results from the surveyed data in this work are presented as VES curves and resistivity layered models as shown in (Figures 3, 4, 5, 6, 7, 8, 9 and 10). The VES plots showed different curve merging types including Type-Q, Type-K, Type-A, and Type-H. Although, VES-3 (Figure 3) showed no curve, it has only a layer that runs from top surface down to the basement having an apparent resistivity of $973.05ohm-m$ and thickness of $24.17m$. This is as result of homogeneity of the lithology within the area. VES-1 and VES-2 showed type-Q and type-K with two layers and three layers respectively (Figures 4 and 5). The resistivity in VES-1 is between $58.53ohm-m$ in layer-1 to $694.90ohm-m$ in layer-2 and having thickness and depth of $0.529m$ on layer-1 from the surface, which bears the overburden material. The VES-2 which has three layers showed the resistivity of layer-1 to be less than resistivity of layer-2 greater than layer-3. The resistivity of the three layers are $610.20ohm-m$,$9113.40ohm-m$ and $92.05ohm-m$; and thickness of $2.11m$ overburden, $14.81m$, and $13.33m$ respectively down to the basement.

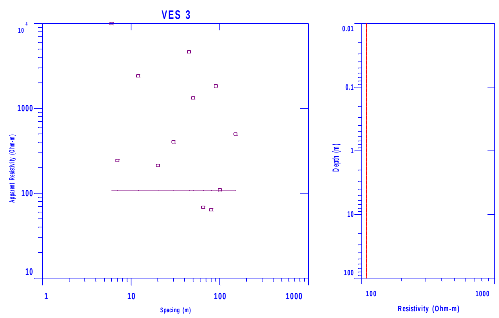


Figure 3: Curve-less type plot with one layer.

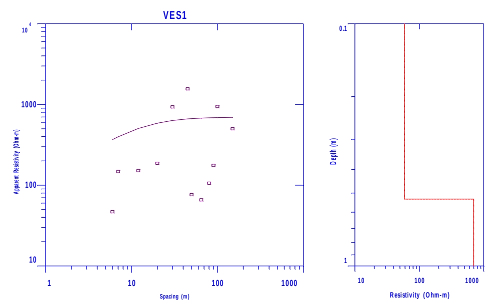


Figure 4: Type-Q VES curve with two layers.

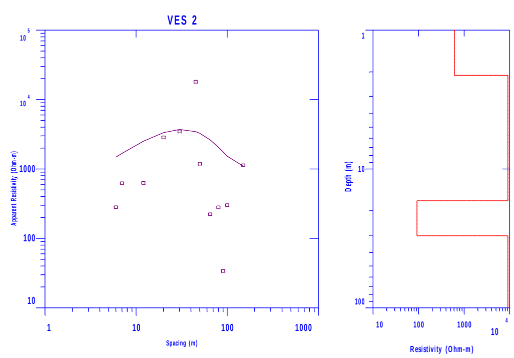


Figure 5: Type-K curve with three layer

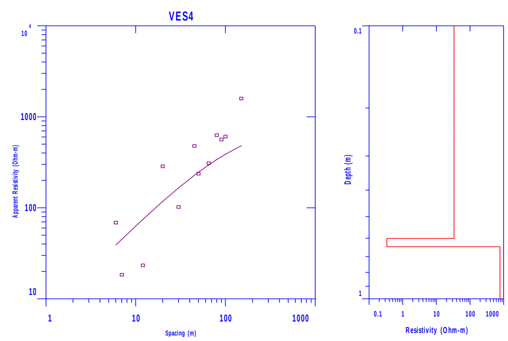
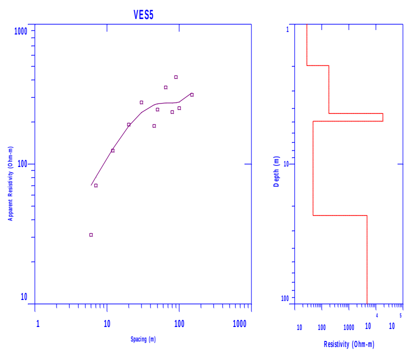


Figure 6: Type-A curve with three layer

ISSN: 2456-3676

From the VES plots also, VES-4, 5 and VES-6 depicts a type-A curve merging with their corresponding resistivities ranging from $0.337ohm - m$, $33.37ohm - m$ and $774.20ohm - m$ in VES-4; $28.08ohm - m$ through $181.70ohm - m$, $1799.10ohm - m$ to $4700.80ohm - m$ in VES-5; and $0.456ohm - m$, $45.18ohm - m$ to $2491.90ohm - m$ in VES-6 and VES-5. This showed that VES-5 has five layers while that of VES-4 and VES-6 has three layers each, all due to the heterogeneous nature of the surveyed area. However, in VES-4, the resistivities occurred within a thickness of $0.600m$ as top overburden material, $0.432m$ in-between and from here down to the basement within the area. While that of VES-5 occurred at the thickness of $1.97m$, $2.36\ m$, $0.593m$, $18.37m$; VES-6 has a corresponding thickness of $0.504m$ and $0.145m$. (See figures 6, 7 and 8).



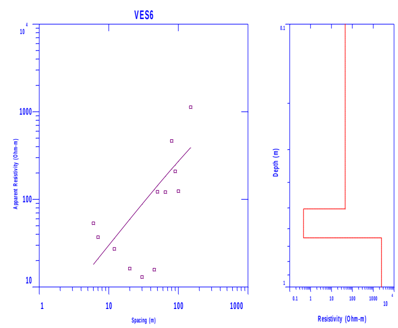


Figure 7: Type-A curve with five layer . Figure 8: Type-A curve with three layer.

The VES plots of VES-7 and VES-8 are shown to have type-H curves with four layers each. In this case, the resistivity of the first layer was found to be greater than layer-2 resistivity and this layer less than that of the third layer. The curves are shown in figure 9 and 10 below. In addition, their corresponding resistivities are $1135.60ohm - m$, $130.20ohm - m$, $1272.10ohm - m$ and $163.10ohm - m$ for VES-7 and that of VES-8 are $1272.10ohm - m$, $217.40ohm - m$, $21529.60ohm - m$ and $217.40ohm - m$. The thicknesses of the layers in VES-7 include; $7.34m$ for layer-1 which occurred at the depth of $7.34m$, $5.55m$ and $5.22m$ for layer-2 and 3, occurring at the depth of $12.90m$ and $18.13m$ respectively. In VES-8, the resistivities and their corresponding thicknesses and depths at a particular layer include, $1272.10ohm - m$, $6.44m$ at $6.44m$ depth for layer-1, $217.40ohm - m$, $6.85m$ at the depth of $13.30m$ for the second layer while the third layer are $21529.60ohm - m$ with thickness of 2.02 at the $15.32m$ depth.

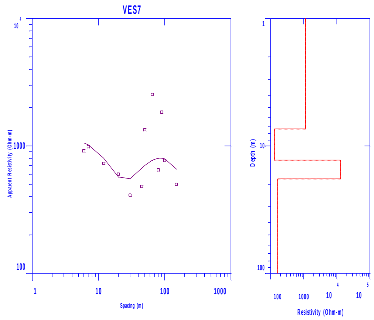


Figure 9: Type-A curve with three layer.

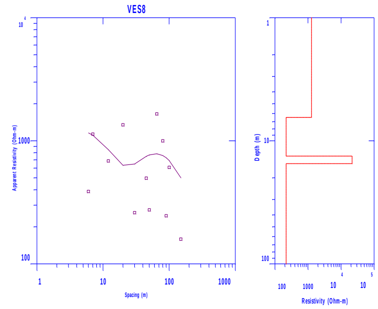


Figure 10: Type-A curve with three layer.

From the interpreted results, it is found that the resistivity of the topsoil and overburden material ranges from $0.337ohm - m$ to $1272.10ohm - m$ while its thickness varies from of 0.504m in VES-6 to 6.44m in VES-8. While the resistivity of the lateritic subsurface material ranges from $33.37ohm - m$ to $21529.60ohm - m$, the resistivity of the basement within the area ranges from $163.10ohm - m$ to $9113.40ohm - m$ with an average resistivity of $2627.75ohm - m$. The interpreted results from the VES curves showed that the area under study are horizontally layered with variations of distinct resistivity distributed on different lithologic units as seen on some of the plots. This implies that the area is made up of heterogeneous materials. In addition, this could be because of deposition processes in which different material were deposited at that time. Considering the nature of some of the plots in terms of geological structures and aquifer potential; unlike VES-1 to VES-6, VES-7 and VES-8 have a good geological structures for groundwater potentials. The two VES plots are almost same having tiny cap-rocks with high resistivity covering a low resistive body with enormous thickness as such could be a good aquifer for groundwater. It is recommended that from the depth of $11m$ down in both cases there will be enough available groundwater for exploitation.

Conclusions

The plots showed type-Q, type-K, type-A and type-H curve merging while VES-3 did not reveal any type of curve. This was as a result of that point understudy being homogenously, isotropic deposited and non-horizontally layered. Some of the VES points have horizontal layers not more than two for example, VES-1 and VES-3 whiles others have a maximum of four layers within them. The resistivity of the basement within the area ranges from $163.10ohm - m$ to $9113.40ohm - m$ with an average resistivity of $2627.75ohm - m$. In terms of geological structures and aquifer potential, VES-7 and VES-8 showed to possess characteristically a good geological structures and aquifers for groundwater potentials.

Reference

Alabi O.O, Adeolu O.O, and Akinpelu D.F (2016), Geophysical investigation for groundwater potential and aquifer protective capacity around Osun State University (UNIOSUN) College of Health Sciences." American Journal of Water Resources 4(6):137-143.

Fadele SI, Sule PO, Dewu BBM (2013). The Use of Vertical Electrical Sounding (VES) forGroundwater Exploration around Nigerian College of Aviation Technology (NCAT), Zaria, Kaduna State, Nigeria. Pacific Journal of Science and Technology 14: 549-555.

J.A. Boswinkel. Information Note. International groundwater resources assessment center (IGRAC).

Netherlands: Netherlands Institute of Applied Geosciences, 2000.

UNEP (United Nations Environment Programme). (2010): Clearing the Waters. A Focus on WaterQuality Solutions. Nairobi, UNEP. http://www.unep.org/PDF/Clearing_the_Waters. pdf

WUP- World Urbanization Prospects (2014). The 2014 Revision, Highlights. United Nations, Department of Economic and Social Affairs, Population Division.

Small, C. and Nicholls, R.J. (2003) A Global Analysis of Human Settlement in Coastal Zones.Journal of Coastal Research, 19, 584-599.

O. Falowo & Olayemi, Ojo. (2020). Assessment of Water Quality Index and Irrigation Indices in Ese Odo Area of Ondo State, Southwestern Nigerian. International Annals of Science. 9. 174-187. 10.21467/ias.9.1.174-187.

Darnault C.J.G & Godinez I.G (2008). Coastal Aquifers and Seawater intrusion. In Christophe J.G Darnault (Editor), Overexploitation and contamination of shared groundwater resources (pp. 185 - 201), New York, NY, United States: Springer science+Business Media B. V.

]Gueye, L., M. Bzioul & O. Johnson (2005). Water and sustainable development in the countries of Northern Africa: coping with the challenges and scarcity. Assessing sustainable development in Africa. Africa's sustainable development Bulletin, Economic Commission for Africa, Addis Ababa, 24-28.

Boko, M., I. Niang, A. Nyong, C. Vogel, A. Githeko, M. Medany, B. Osman-Elasha, R. Tabo and P. Yanda, 2007: Africa. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge UK, 433-467.

]Ashton, P.J., 2002: Avoiding conflicts over Africa's water resources. Ambio, 31,236-242

]AQUASTAT. (2011). Online database. Rome, Food and Agriculture Organization of the United Nations (FAO).http://www.fao.org/nr/water/aquastat/data /query/index. Html Dahomey basin, south western Nigeria, unpublished Ph.D thesis, University of Ibadan, pp 315

Federal Ministry of Water Resources (2007). Organization and Activities. Federal Republic of Nigeria http://aochycos.ird.ne/HTMLF/PARTNAT/FED WATER/INDEX/HTM accessed 28th February

EPA. (2016, May 18). Resistivity Methods (Rep.). Retrieved February 12, 2023, from https://archive.epa.gov/esd/archive-geophysics/web/html/resistivity_methods.html

Owoyemi FB (2012), A geological-geophysical investigation of rain-induced erosional features in Akure metropolis, PhD thesis, Federal University of Technology, Akure.

Akinluyi FO, Olorunfemi MO, Bayowa OG (2018), Investigation of the influence of lineaments, lineament intersections and geology on groundwater yield in the basement complex terrain of Ondo State, Southwestern Nigeria. J Appl Water Sci. 8:49.

Ayodele OS (2013), Geology and structure of the precambrian rocks in Iworoko, Are, and Afao area, Southwestern, Nigeria. Int J Nat Sci. 1:14-29.

Olorunfemi MO, Ojo JS, Akintunde OM (1999), Hydro-geophysical evaluation of the groundwater potentials of the Akure metropolis, southwestern Nigeria. J Geol Min Res. 35:207-228.