International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 9 Sep 2021, pp: 708-716 www.ijaem.net ISSN: 2395-5252

Geophysical Investigation for Groundwater Potential Assessment at a Proposed Site along Ife-Ede Road, South-Western Nigeria

Orohundusi, O.P., Ogunrinde, I.S., Imodu, C.A., Akinyemi, F.E., Adejuyigbe, T.O., Olawoyin, V.T., Oladeji, A.T.
[1,2,4,5,6]*Student, Obafemi Awolowo University, Ile-Ife*
[3,7]*Student, University of Ibadan*

Submitted: 01-09-2021 Revised: 09-09-2021 Accepted: 12-09-2021

ABSTRACT:Geophysical investigation involving the magnetic and the electrical resistivity methods of prospectingwas carried out at a sitelocated along Ife-Ede Road, Southwestern Nigeria. The study was carried out with a view to assessing the groundwater potential of the area.Fivegeophysical traverses trending NW-SEwere established over the study area along which reconnaissance survey was carried out using the magnetic method.The electrical resistivity survey involved the Vertical Electrical Sounding (VES) technique. SixteenVES stations were occupied based on the results of the magnetic survey.Magnetic lows correspond to shallower magnetic sources while magnetic highs correspond to deep-seated sources in a low magnetic latitude like Ile-Ife, South-western Nigeria.

Four subsurface layers, which include the top soil, laterite, weathered layer and Basement rock, were delineated from the geo-electric sections. Two aquifer systems were delineated with the weathered layer constituting the aquifer unit in the study area. The thickness ranged between 12 m and 64 m with resistivity values, which range from 81 to 555 Ωm. The values of transverse unit resistance, longitudinal unit conductance and coefficient of anisotropy which are indicative of transmissivity and recharge capability, aquifer protective capacity, hydro-geologic significance and aquifer productivity ranged from 6.617×10^4 to3.99×10^4 Ωm^2, 0.03 to 0.36 mhos and 1.04 to 1.9 respectively.

The longitudinal unit conductance indicates a poor-to-weak protective capacity;therefore, the basement aquifer is vulnerable to infiltration.Groundwater yield in the study area is generally moderate based on the result of the coefficient of anisotropy and presence of dry, relatively thick lateritic layer which makes groundwater recharge in the area moderate. The study area has high groundwater potential and the groundwater should be able to serve domestic needs.

KEYWORDS: GroundwaterPotential, Microprocessor, Aquifer, Geo-electric section, Dar-Zarouk Parameters.

I. INTRODUCTION

Water is an indispensable requirement for the sustainability of life; without water, life will be impossible. The sustenance of man is largely dependent on the availability and quality of water. Access to clean water is a human right and a basic requirement for economic development. The safest kind of water supply is the use of groundwater.

Groundwater refers to water present beneath the earth surface in soil pore spaces and interstices or crevices or fractures of rock formations[11]. At some depth beneath the earth surface, the pores of the soil or rock are saturated with water. The top of the zone of saturation is called the water-table[1]. The water stored in this zone of saturation is known as groundwater. Groundwater is derived from surface waters (lakes and rivers) and precipitation (rain and snow) that permeates into the subsurface either through pores, joint, and fracture planes and is filtered by earth media into the pore spaces to be stored. A unit of rock or an unconsolidated deposit is called an aquifer when it can store and transmit a usable quantity of water[13]. Groundwater accounts for about 1.69% of earth's water and about 95% of the earth's fresh water resources.

Groundwater geophysics is an aspect of geophysics that adopts geophysical principles and

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 9 Sep 2021, pp: 708-716 www.ijaem.net ISSN: 2395-5252

techniques to provide a database for hydrogeological decisions such as aquifer location and drill-hole positioning, structural features that favours the accumulation of and estimating the quantity and quality of the groundwater[20].

A geophysical investigation was done to assess the groundwater potential of a site (Olokun Park One) along Ife-Ede Road, Ile-Ife, South-western Nigeria.

II. GEOLOGY AND HYDROGEOLOGY

The study area falls within the Ife-Ilesa Schist Belt which consists of three major units: the Ilesa Amphibolite Complex, the Ilesa Metaclastics (various micaceous schist) and the Effon Quartzitic Sequence.

The study area is believed to be underlain by Mica Schist as shown in Fig.1 (the geological map of Obafemi Awolowo University Campus, Ile-Ife). Mica schist has a dark grey colour with texture varying from medium to coarse grain. It is characterized by foliation defined by platy alignment of minerals (biotite). It contains biotite, quartz, muscovite, plagioclase feldspar and potassium feldspar. The mica schist in the study area is severely weathered, hence, no outcrops were encountered within the study area.to the square of the current and inversely proportional to the square of the length of the air gap[18].

Groundwater in a typical Basement Complex environment is contained in porous and permeable weathered zone and/or in fractured Basement. Groundwater occurs under water-table conditions in the clayey sand/sand aquifer as well as under semi-confined to confined conditions in the weathered/fractured basement. However, the occurrence of groundwater is affected by topography, climate, geology, geologic structures (fractures), hydraulic properties of the rocks (porosity and permeability) and proximity to rivers. The water-table in the region is generally less than 12m from the ground surface.

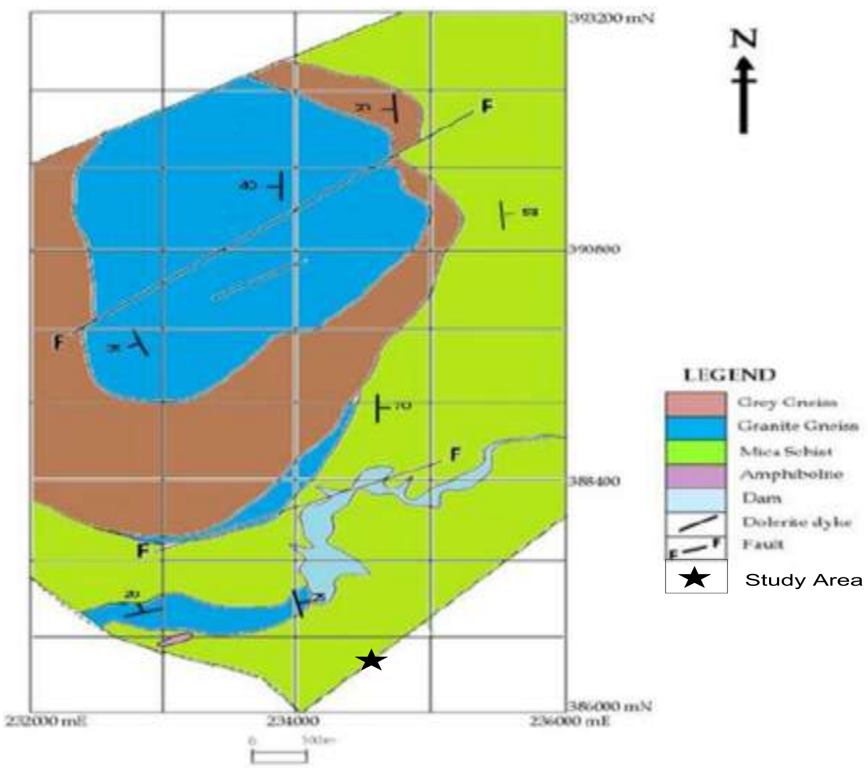

Figure 1: Geological Map of Obafemi Awolowo University Campus, Ile-Ife (Boesse, 1979)

III. METHODOLOGY

Five geophysical traverses trending NW-SE were established over the study area as shown in Figure 2 along which reconnaissance survey was carried out using the magnetic method of geophysical prospecting. Total field magnetic measurements were taken at 5 m interval along the traverses using the Proton Precision Magnetometer for data acquisition.The data obtained werecorrected for secular and diurnal variation. The residual anomaly which is due to shallow sub-structure was interpreted qualitatively to characterize depth to basement and possible geologic structures, such as, fault.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 9 Sep 2021, pp: 708-716 www.ijaem.net ISSN: 2395-5252

A follow-up electrical resistivity survey was carried out using the Vertical Electrical Sounding (VES) technique. The Schlumberger electrode configuration was used for the VES technique with current electrode separation (AB/2) varying between 1 to 100 m and potential electrode separation (MN/2) varying between 0.25 to 2.5 m. Sixteen (16) VES stations were occupied along the five traverses based on the result of the magnetic survey. The ABEM SAS 300C Resistivity metre was used for the data acquisition. The VES data were presented as depth sounding curves and interpreted quantitatively using the partial curve matching technique. The result of the partial curve matching served as initial parameters for the computer 1D forward modelling using WINRESIST software. The interpreted layer resistivity and thickness were used to construct geo-electric sections along each traverse.

Dar-Zaroukparameters which include the transverse unit resistance (T), longitudinal unit conductance (S) and the coefficient of anisotropy (λ)was computed using the layer resistivities and thicknesses to assess the groundwater potential of the study area.

The geo-electric sections, bedrock relief, thickness of aquifer units, coefficient of anisotropy transverse unit resistance and longitudinal unit conductance were used to characterize the identified aquifer in the study area.

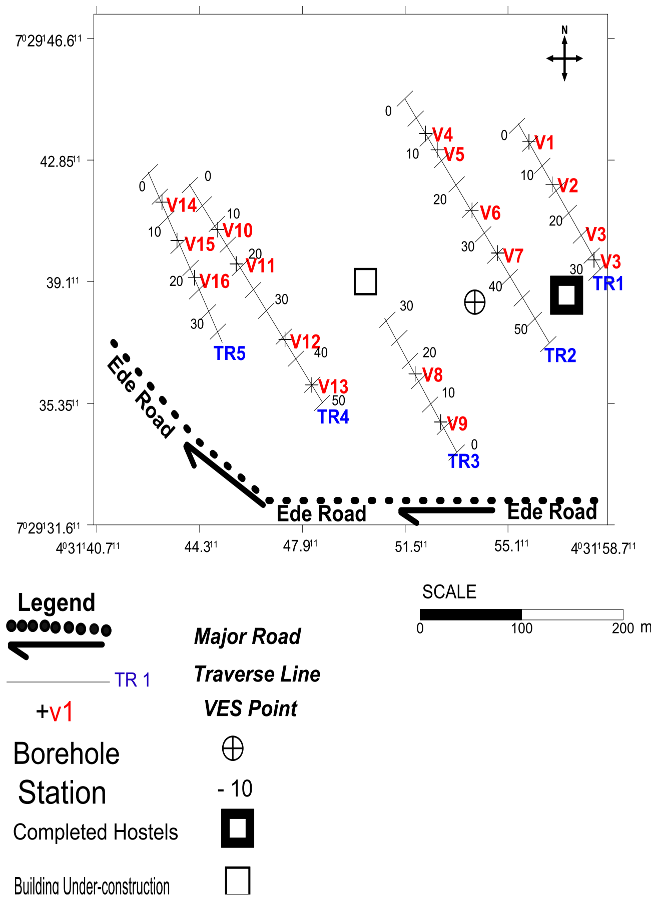

Figure 2: Sketch of Study Area Showing the Traverses and VES Stations

IV. DISCUSSION OF RESULTS

Residual anomaly obtained from the magnetic susceptibility survey suggests that there is variation in basement topography due to variation in amplitude of residual magnetic intensity (nT). Lower magnetic response corresponds to shallower magnetic sources while higher magnetic response corresponds to deeper-seated sources of magnetic anomaly in places of low latitudes like Ile-Ife, South-western Nigeria. This corresponds with the result obtained from the VES survey, where the depth to the Bedrock (fresh Basement) is greater for deep-seated structures with higher magnetic response than shallower structures with lower magnetic response.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 9 Sep 2021, pp: 708-716 www.ijaem.net ISSN: 2395-5252

Based on difference in amplitudes in the residual anomaly, which showed variation in the depth to Basement, magnetic anomalous zones were selected for Vertical Electrical Sounding in order to evaluate the geo-electric property of the subsurface.

Result of the VES is as presented in Table 1.The curves obtained in the study area include KH, AH, HKH, KQH and AKH type curve. Four geo-electric layers was delineated which include the topsoil, laterite, weathered and fresh basement (typical section is as shown in Fig. 3).The first layer is the lateritic topsoil has resistivity values ranging from 345 to 1867 Ωm. The thickness varies from 0.7 to 3.6 m. The second layer is laterite (sandy clay)has resistivity values ranging from 495 to 3725 Ωm. The thickness varies from 0.6 to 14.7m. The third layer constitutes the weathered Basement has resistivity values ranging from 81 to 555 Ωm. The thickness varies from about 12.6 to 64.6 m. The fourth layer is the fresh Basement has resistivity values ranging from 647 to 13753 Ωm with infinite depth extent.

The aquiferous units in the study area is the Weathered Basement which is considerably very thick (greater than about 40m at VES 1, 2, 4, 5, 7, 8, 9 and 16). The aquifer system in the study area is the weathered semi-confined aquifer system except at VES 14, which is an unconfined weathered layer aquifer. Groundwater occurs under water-table conditions in the clayey sand/sand aquifer as well as under semi-confined to confined conditions in theweathered/fractured zone.

The anisotropy coefficient values obtained range from 1.04 to 1.9. The Anisotropy coefficient map reveal the degree ofhomogeneity that characterizes the subsurface earth materials and associated fluid content within the study area. The western part of the area (VES 10, 11, 12, 13) is characterized by higher anisotropy coefficient values (ranging from 1.3 to 1.9), which is attributed principally to the influence of shallower Basement ridge and adjacent fluid-saturated reservoirs, thus, suggesting that it arises from near surface inhomogeneity materials such as topsoil, laterite and weathered layer that could not support groundwater development.While the prospective groundwater exploitation sites identified (VES 1, 2, 4, 5, 8, 9 and 16) are characterized byrelatively lower coefficient of anisotropy values (ranging from 1.04 to 1.3), which implies that the materials are relatively homogeneous.

The transverse unit resistance of the area (fig. 4) varies from 6.617×10^4 to $3.99\text{x}10^4$ Ωm^2. These values are high (greater than 400 Ωm^2).The high transverse unit resistance values are associated with zones of high transmissivity and recharge capability, hence, highly permeable to fluid movement. This renders the prospective groundwater exploitation sites identified (VES 1, 2, 4, 5, 8, 9, and 16) good for groundwater exploitation.

The longitudinal unit conductance of the area (fig. 5)varies from 0.03 to 0.36 mhos. Longitudinal unit conductance is directly proportional to the protective capacity of the overburden rock materials. The capacity of the overlying materials to prevent infiltration into the aquifer is evaluatedbecause the earth medium acts as a natural filter to percolating fluid. Its ability to retard and disallow the percolating fluid is a measure of its protective capacity. Thus, the geologic materials could act as seal in preventing the fluid from penetrating the aquifer thus protecting it. The longitudinal unit conductance indicates a poor-to-weak protective capacity. Therefore, the basement aquifer is vulnerable to infiltration.

The thick aquifer units (Fig.6) make the study area generally very productive for groundwater exploitation. The basement relief shows a basement depression favorable for groundwater accumulation as depicted by the cross-section along A-A’ (Fig.7), which makes the Eastern part possible groundwater reservoir for exploitation. The thick weathered layer has a low percentage of clay in which the intergranular flow has a dominant role to play which makes groundwater abstraction possible.

Groundwater yield in the study area is generally moderate based on the result of the coefficient of anisotropy and presence of dry, relatively thick lateritic layer which makes groundwater recharge in the area moderate.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 9 Sep 2021, pp: 708-716 www.ijaem.net ISSN: 2395-5252

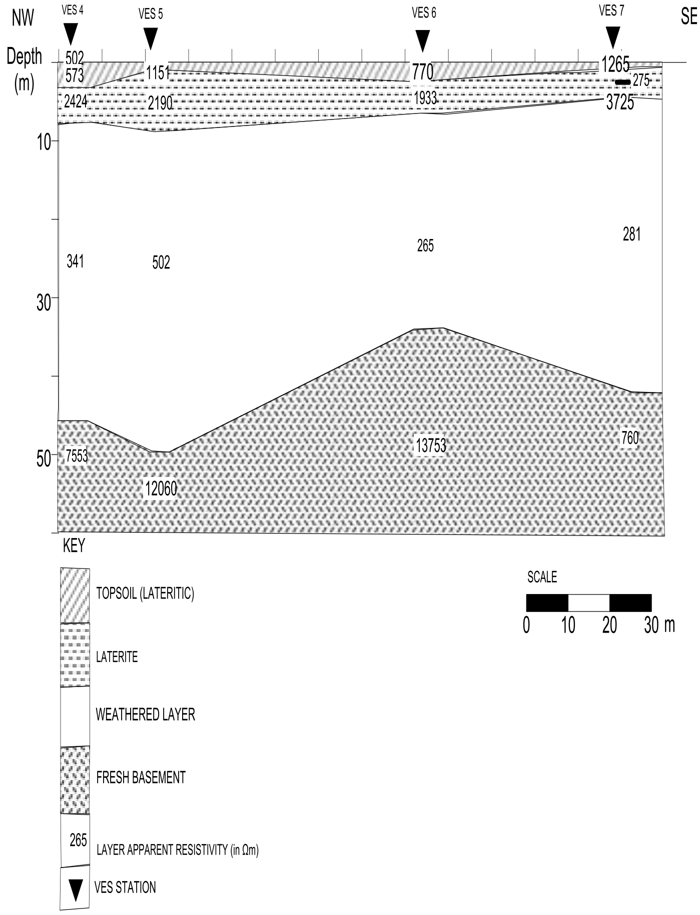

Figure 3: Typical Geo-electric Section

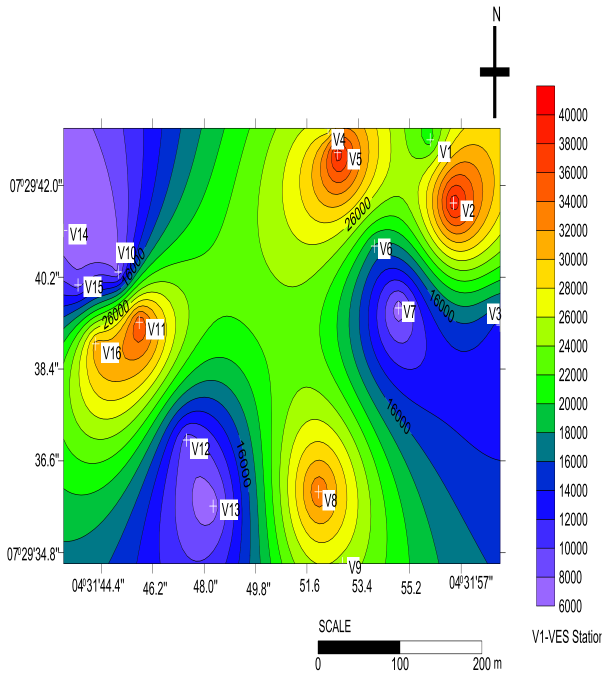

Figure 4: Map of Transverse Unit Resistance

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 9 Sep 2021, pp: 708-716 www.ijaem.net ISSN: 2395-5252

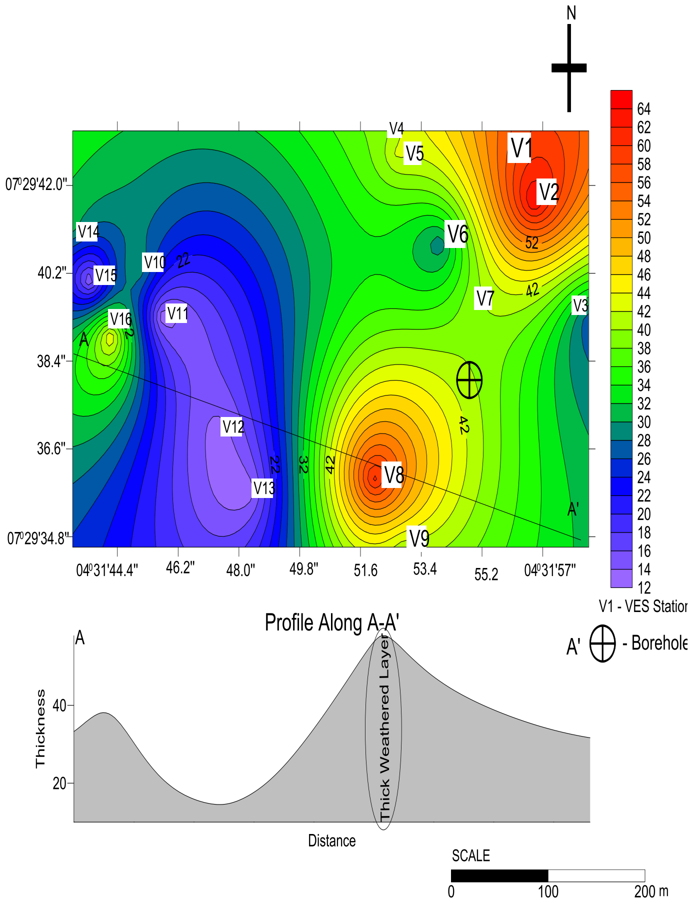

Figure 6: Isopach Map of the Weathered Layer

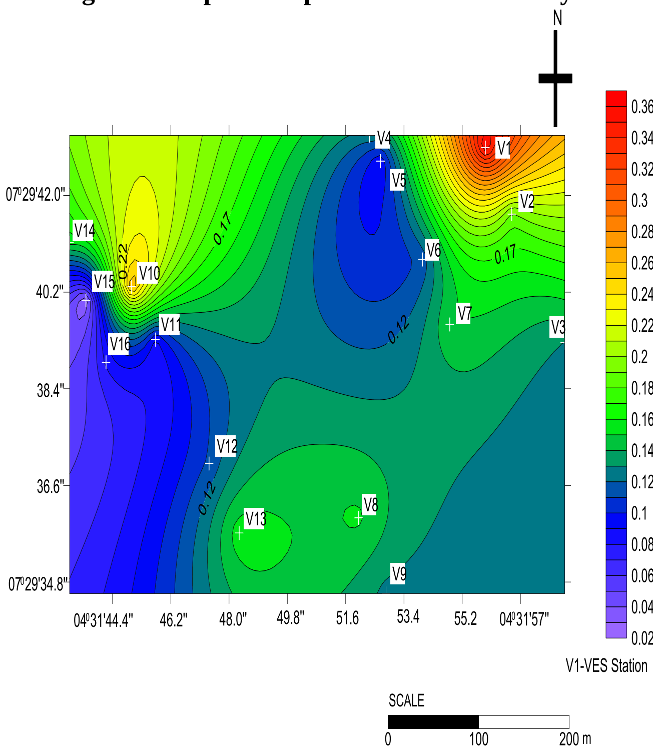

Figure 5: Map of Longitudinal Unit Conductance

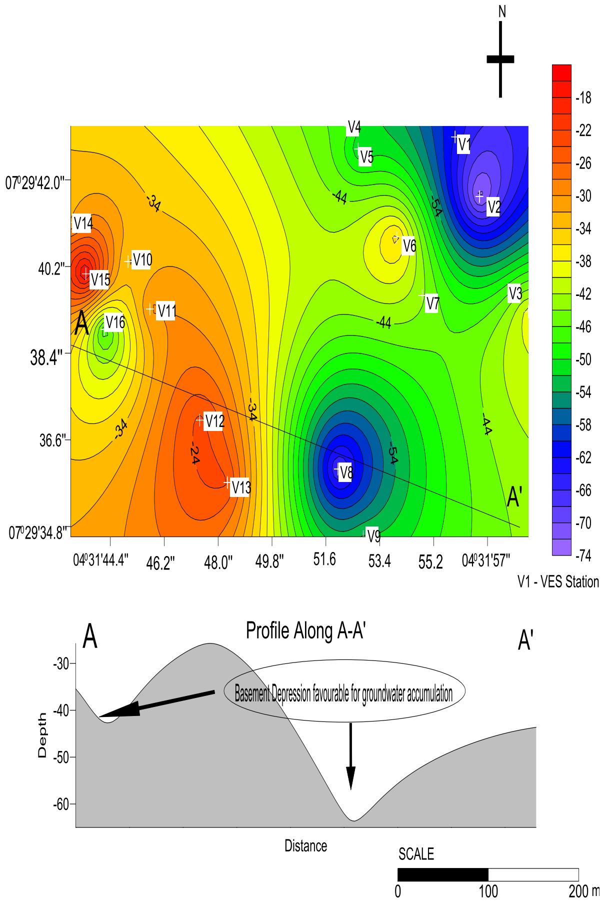

Figure 7: Bedrock Relief Map

Table 2: Summary of VES Interpretation

VES Points	Layer Resistivity $\rho_1/\rho_2/\rho_3/\ldots/\rho_n$ (Ω-m)	Thickness $h_1/h_2/\ldots/h_{n-1}$ (m)	Depth $H_1/H_2/\ldots H_{n-1}$	Geo-electric Units	Curve Type
1	926/1224/316/81/3892	1/5.8/36/19.5	1/6.8/42.8/ 62.2	Topsoil(lateritic)/Laterite/ Weathered Basement/ Fresh Basement	KQH
2	1449/911/2250/ 353/7587	0.9/0.9/6.7/64.4	0.9/1.8/8.5/ 72.9	Topsoil(lateritic)/Laterite/ Weathered Basement/ Fresh Basement	HKH
3	482/345/572/253/752	1.4/2.2/8.9/26.5	1.4/3.6/12.5/39	Topsoil(lateritic)/Laterite/ Weathered Basement/ Fresh Basement	HKH
4	502/573/2424/ 341/7553	0.9/2.4/4.8/39.3	0.9//3.2/8/ 47.3	Topsoil(Sandy)/Laterite/ Weathered Basement/ Fresh Basement	AKH
5	1151/127/2190/ 502/12060	1/0.3/7.9/42.5	1/1.2/9.1/ 51.6	Topsoil(lateritic)/Laterite/ Weathered Basement/ Fresh Basement	HKH
6	771/1933/265/ 13753	2.5/4.2/28.5	2.5/6.7/35.2	Topsoil(lateritic)/Laterite/ Weathered Basement/ Fresh Basement	KH

7	1265/275/3725/ 281/760	0.5/2.8/1.4/39	0.5/3.2/4.6/ 43.6	Topsoil(lateritic)/Laterite/ Weathered Basement/ Fresh Basement	HKH
8	1209/1698/411/ 8345	1.4/4.3/60.9	1.4/5.7/66.6	Topsoil(lateritic)/Laterite/ Weathered Basement/ Fresh Basement	KH
9	1863/809/356/ 8777	1.7/9.4/40.6	1.7/11.1/ 51.7	Topsoil(lateritic)/Laterite/ Weathered Basement/ Fresh Basement	AH
10	194/55/1694/129/3967	0.5/1.2/15/12.5	0.5/1.7/3.8/ 34.2	Topsoil(Clayey Sand)/Laterite/Weathered Basement/ Fresh Basement	HKH
11	790/450/2195/ 162/5301	1.1/1.2/15/12.5	1.1/2.2/17.2/29.8	Topsoil(lateritic)/Laterite/ Weathered Basement/ Fresh Basement	HKH
12	1759/613/138/ 7206	0.6/9.8/13.2	0.6/10.4/ 23.5	Topsoil(lateritic)/Laterite/ Weathered Basement/ Fresh Basement	AH
13	574/495/95/3684	1.6/9.5/12.7	1.6/11.1/ 23.8	Topsoil(Sandy)/Laterite/ Weathered Basement/ Fresh Basement	AH
14	172/375/186/647	1/6.9/24	1/7.9/32	Topsoil(Clayey-sand)/Laterite/Weathered Basement/ Fresh Basement	KH
15	350/3655/485/ 807	0.7/0.6/13.7	0.7/1.3/15	Topsoil(Sandy)/Laterite/ Weathered Basement/ Fresh Basement	KH
16	683/2877/555/ 1535	1.3/1.9/44.4	1.3/3.2/47.6	Topsoil (Sandy)/Laterite/ Weathered Basement/ Fresh Basement	KH

V. CONCLUSION

Integrated geophysical investigation using the magnetic and electrical resistivity methods of prospecting were effectively used to evaluate the groundwater potential of an area located on out-skirt of South-eastern flank of Obafemi Awolowo University, Ile-Ife, South-western Nigeria.

Residual magnetic intensities were interpreted qualitatively and they depict variation in the depth to the bedrock as lower magnetic response corresponds to shallower magnetic sources while higher magnetic response corresponds to deeper-seatedmagnetic sources.

The Vertical Electrical Sounding (VES) survey was done using the Schlumberger electrode configuration at sixteen locations. Typical curves obtained include the AH, KH, KQH, AKH and HKH curve types. The geo-electric section using layer resistivity and depth shows Topsoil, Laterite (sandy clay), Weathered Basement and Fresh Basement underlie the subsurface.Based on the magnetic anomaly, rock resistivities, thickness of aquifer zones, hydraulic conductivities and coefficient of anisotropy,the study area has high groundwater potential and the groundwater should be able to serve domestic needs. VES stations 1, 2, 4, 5, 8, 9 and 16 are the most probable productive stations within the area.

The aquifer types recognized in the area are semi-confined and unconfined weathered layer aquifer types with good groundwater quality and moderate yield.

REFERENCES

[1]. Adepelumi A.A.;Ako. B.D. and Ajayi T.R., 2001, “Groundwater Contamination in the Basement Complex area of Ile-Ife, Southwestern Nigeria: A Case Study using the Electrical Resistivity Geophysical Method”, Hydrogeology Journal, Vol. 9: pp. 611-622.

[2]. Adepelumi A.A.; Yi-j M.J; Kim J.H;Ako B.D. and Son J.S., 2006, “Integration of Surface Geophysical Methods for Fracture

Detection in Crystalline Bedrocks of Southwestern Nigeria", Hydrogeological Journal, 14: 1284-1306.
[3]. Ajayi O. and Adegoke-Anthony C.W., 1988, "Groundwater Prospects in the Basement Complex Rocks of Southwestern Nigeria", Journal of African Earth Sciences, Vol. 7(1): 227-235.
[4]. Akinrinade O. J. and Olabode O.P., 2016, "Integrated Geophysical Approach to Aquifer Delineation in Crystalline Basement Environment", International Journal of Scientific and Engineering Research, France, 6(10): pp. 107-127.
[5]. Akintorinwa O.J. and Olowolafe T.S., 2012, "Geo-electric Evaluation of Groundwater Prospect within Zion Estate, Akure, Southwestern Nigeria", International Journal of Water Resources and Environmental Engineering, Vol. 5(1): pp. 12-28.
[6]. Ako B.D. and Abiola 2009, "Groundwater Potential and Aquifer Protective Capacityof Overburden UnitsinAdo-Ekiti, Southwestern Nigeria",International Journal of Physical Sciences, Vol. 4 (3): pp. 120-132.
[7]. Ayuk M.A;Adelusi A.O. and Adiat K.A.N., 2012, "Evaluation of Groundwater Potential and Aquifer Protective Capacity Assessment at Tutugbua-Olugboyega Area, off Ondo Road, Akure Southwestern Nigeria", International Journal of Physical Sciences, Vol. 8(1): pp. 37-50.
[8]. Boesse J.M., 1979, "Geological Map of Obafemi Awolowo University Campus" (unpublished).
[9]. Henriet J. P., 1976, "Direct Application of the Dar Zarouk Parameters in Groundwater Surveys", Geophysics Prospective, 24: pp. 344–353.
[10]. Idowu O.A. and Ajayi O., 1998, "Groundwater Occurrence in Southwestern Nigeria. A Comparism of Two Environments", J. NAH, 9: 33-40.
[11]. Kearey P. and Brooks M., 2002, "An Introduction to Geophysical Exploration", Third edition.
[12]. Mogaji K.A., 2015, "Geoelectrical Parameter-based Multivariate Regression Borehole Yield Model for Predicting Aquifer Yield in Managing Groundwater Resource Sustainability", Journal of Taibah University for science, 10 (2016): pp. 84–600.
[13]. Olorunfemi, M.O. and Fasuyi S.A., 1993, "Aquifer Types and the Geo-electric Hydrogeologic Characteristics of Parts of the Central Basement Terrain of Nigeria, Niger State", Journal of African Earth Sciences, volume 16/3: pp. 309-317.
[14]. Olorunfemi, M.O and Olorunniwo M.A., 1985, "Geoelectric Parameters and Aquifer Characteristics of some Parts of Southwestern Nigeria", Geological Application, Vol. 20: pp. 99-109.
[15]. Omosuyi G.O., 2010, "Geo-electric Assessment of Groundwater Prospect and Vulneability of Overburden Aquifer at Idanre, Southwestern Nigeria", Ozean Journal of Applied Sciences, 3(1): 19-28.
[16]. Orellana E. and Mooney H.M., 1966, "Master Tables and Curves for Vertical Electrical SoundingOver Layered Structures", Madrid, Interciencia, 150: pp. 66.
[17]. Palacky G.J.,1989, "Resistivity characteristics of Geologic Targets", In MN Nabighion, Ed., Electromagnetic methods in Applied Geophysics, Vol. 1 (Theory) IG, No.3 (Society of Exploration Geophysicist): pp. 53-129.
[18]. Rahaman M.A., 1988, "Recent Advances in the Study of the Basement Complex of Nigeria", In Precambrian Geology of Nigeria G.S.N: pp. 11-41.
[19]. Reynolds J.M., 1998,"Material Characterization using Geophysical Methods". In: Forde M.C. (ed.). Proceedings of the fifth International Conference, Re-use of Contaminated Land and Landfills, Brunnel University, London, UK (7-9 July, 1988), Engineering Technics Press Edinburg, UK: pp. 145-149.
[20]. Telford W.M;Geldert L.P; Sheriff R.E and Keys D.A., 1990 "Applied Geophysics" (Second Edition), Cambridge University Press: pp.344-536.
[21]. Woakes W;Ajibade C.A and Rahaman M.A., 1987, "Some Metallogenic Features of the Nigerian Basement", Journal of Africa Science, Vol. 5: pp. 655-664.