Investigation of Underground Water at Paiko Using Vertical Electrical Sounding Technique in Paiko, Nigeria

Mamman H. Mamman and Ojo T. John
Department of Science Technology,
Federal Polytechnic,
Ado-Ekiti, Ekiti State, Nigeria
*e-mail: mammanharuna@gmail.com

***Abstract*— This is a comprehensive investigation of underground water level in a selected environ of Paiko. Data was collected from 33 Vertical Electrical Sounding (VES) points and interpreted using win resist, excel and golden surfer software to show areas where the level of underground water would be highest. Each of the VES points was made up of 3 layers. Six (6) VES stations have been chosen as the most viable locations for the development of groundwater resources in the study area. These locations have depth ranging from 0.5m to 37.8m i.e. from the first layer to the third layer. Conclusively, the study area has a relatively low potential for groundwater development.**

Keywords—Paiko environs, Vertical electrical Sounding, underground water.

I. INTRODUCTION

Water is the most essential element to life on earth. It is known scientifically that the human body contains 60% of water. Due to these facts, the search for water in areas with hard rock has increased enormously. Groundwater is an important source of water supply and plays an important role in industry, agriculture and domestic use Achyara (2004). Surface water sources are often inadequate or do not exist Bamba, A.A., (1978).There is a steady rise in the demand for groundwater in most hard rock areas most of which cannot boast of any constant surface source of water supply Adanu (1994).

The knowledge and science of geophysics has enabled the discovery of some of the world's largest ore bodies that were hidden under deep cover of sediments and would have remained forever undetected. In addition, the network of seismological stations developed during the cold war has enabled the monitoring of the testing of nuclear weapons because of their unique seismic signature. Environmental monitoring is now routinely performed using remote sensing tools. The scale of that monitoring can vary from the local to regional and even national scale with instruments as simple as hand held spectrometers to as high tech interferometers on satellites. Geophysical method can be used to see through cover of either vegetation or sediment to provide data on the subsurface. They also cost less than conventional exploration or monitoring methods. They provide long term and continuous data collection hence they can be used from satellites.

Geophysical methods

- Gravity Method: This involves measurement of the gravitational field at a series of different locations over an area of interest.
- Seismic Exploration Method: Seismic energy is artificially created near the surface and the generated waves move in the subsurface and get reflected off layer boundaries. Waves that have been reflected are recorded at the surface and the period and amplitudes are analyzed to map the surface.
- Magnetic method of exploration: This is the primary exploration tool in the search for minerals. It is used in mapping basement structure to include a wide range of new applications, such as locating intra-sedimentary faults, defining subtle lithologic contacts, mapping salt domes in weakly magnetic sediments and better refining targets through 3D inversion.
- Electromagnetic exploration method: This is based on Faraday's law of induction which states that the magnitude of the electromotive force (e.m.f) induced in a circuit is proportional to the rate of charge of the magnetic flux that cuts across the circuit. Electromagnetic data is collected from a moving platform such as an aircraft. Direct contact with ground is not needed in this method.
- Gamma ray exploration method: Gamma-ray methods Durance (1986) Hoover *et al* (1991) use scintillometry to identify the presence of the natural radioelements potassium, uranium and thorium; multichannel spectrometers can provide measures of individual radioelement abundances. Because gamma-ray spectrometry can provide direct quantitative measures of the natural radioelement, geo-environmental information concerning radiation dose and radon potential are provided.
- Electrical method of exploration: Electricity is simply the flow of electric current along a conductor. It could be explained as free moving electrons that navigate from one atom to another. The primary electrical parameters are; ampere, volt and ohm which are all related by Ohm's law states that the current passing through a conductor between two points is directly proportional to the potential difference across the two points. Mathematically, V=IR

Where V = potential difference across the conductor,

I = current through the conductor in ampere

R=resistance of the conductor in Ohms.

Electrical method is based on the electrical properties of rocks which depend on the salinity of the water, movement in or distribution the rock and the amount of water in the rock. When a rock is saturated, it tends to have a lower resistivity than a dry and unsaturated rock. There are two important properties in the application of electrical methods;

1) Induced polarization, which is as a result of electrical current passing through the rock.

2) The rock's ability to conduct electrical current.

In making electrical resistivity surveys, a commutated direct current or very low frequency (<1 Hz) current is introduced into the ground via two electrodes. When the four electrodes are arranged in any of the several usable patterns, the current and potential measurements may be used to calculate resistivity. Mathematically,

R α L/A

Or R = ρl/A (1)

Where ρ = constant of proportionality known as the electrical resistivity or electrical resistance, a characteristic of the material which is independent of its shape or size.

From Ohm's law,

R = ΔV/I (2)

Substituting (1) into (2) and rearranging, we have;

P = A ΔV/LI (3)

For a semi-infinite material, resistivity at all points must be defined. If the cross-sectional area and length of an element within the semi-infinite material are shrunk to infinitesimal size then the resistivity ρ may be defined as;

$$\rho = \lim_{L \to 0} \left(\Delta \frac{\frac{V}{L}}{A \to 0^{lim} \frac{(I)}{A}} \right)$$

Or $\rho = E_L/J$ (4)

Where E_L is the electric field and J is the vector form. Where E_L is the electric field and J is the current density. Generalizing, we have;

$\rho = E/J$ (5)

Equation (5) above is Ohm's law in its differential vector form.

Geography of Paiko

Paiko is 18km from Minna along Minna-Suleja express-way located in the eastern part of Niger state's capital, Minna. It is located on latitude 0.946521^{0}E to 0.946551^{0}E and longitude 06.63672^{0}N to longitude 06.63871^{0}N. Paiko has an annual rainfall that ranges from 381cm along the coast to 64cm Ajibade A.C(1980). Temperatures are mostly between 22^{o-}36^{0}C which makes it possible for farming as the major occupation of its inhabitants. An average adequate duration of 210 days of wet season is experienced annually. Paiko covers an area of 2,066km^2(789sqmi) with an estimated population of 158,086 according to the 2006 population census. The topmost layer of Paiko's soil is the Loess unsaturated topsoil with a depth of about 0.9-1.5m. This is followed by slightly weathered/fractured basement with a thickness of 4.6-12m and a depth range of 15-30m. The fresh basement unit is the last layer with a fairly infinitive depth. It should be noted that borehole depth in the study area ranges between 30-60m. Also, fractures in the study area are discrete, localized and discontinuous.

2. MATERIALS AND METHOD

Vertical electrical sounding (VES) is by far the most used method for geo-electric surveying, because it is one of the cheapest geophysical method and its results are very good in numerous areas of study. The principle of this method is to inject an electric current of known intensity, through the ground with the help of two electrodes(power electrodes – AB) and measuring the potential difference with another two electrodes(measuring electrodes – MN). The investigation depth is proportional with the distance between the power electrodes.

After data collection using 33 VES points, at the initial stage of interpretation, the obtained field data were plotted manually on the log-log graph to obtain the rough field curve. The model layers were obtained by the curve matching using auxiliary and master curves. The digital interpretation was carried out with the aid of the winresist computer program for iteration. Winresist is preferred to other interpretation softwares because it allows for the entry of certain parameters by the interpreter, thereby minimizing the RMS error, unlike other purely automatic inversion interpretation programs without any assumptions of the layering Reinhard (2006). Winresist was used to calculate the theoretical curves, outputting the layers resistivity and thickness at various depths. The SAS (signal averaging system) 4000 is a microprocessor that has the ability to take consecutive readings automatically and their results are averaged continuously. Other instruments used in the field include;

- Cutlass: For clearing the bush and having a clear path to walk and work on.
- Hammer: For driving the electrode into the ground before taking measurements.
- Paper tape: Used in insulating wires during measurement.
- Recording sheets: All readings taken in the field are been recorded here before interpretations are made.
- GPS device: This is used in getting the coordinates of the region where reading is being taken. It works with the global satellite system.

3. RESULTS AND DISCUSSION

The tables below present the values of the apparent resistivity of the three profiles. WINRESIST version 1.0 was used for the data analysis which has a graph that shows the thickness, depth and resistivity of each VES point. Winresist is preferred to other interpretation softwares because it allows for the entry of certain parameters by the interpreter, thereby minimizing the RMS error unlike other purely automatic inversion interpretation programs without any assumptions of the layering Reinhard (2006). In the graph, The apparent resistivity values (Ohms) were plotted against current electrode spacing (AB/2)(m) by the software. A root mean square error value is obtained after an iteration process to generate a good fit. Each of the VES points was made up of 3 layers. The first layer in most of the VES points was mainly comprised of topsoil and clayey soil while the second and third comprised of clayey and marl, fresh basement, groundwater (in igneous rock), sandy soil.

Figures 4.4a and 4.4b show the resistivity contour map of the first layer and the second layer respectively. These were obtained using the golden surfer version 11.0.64. The resistivity at the dark colored point decreases northwards which indicates an increase in conductivity. This point is viable for structural development.

Table 3.1: Data obtained for VES 1,2,3,4 & 5

AB/2	MN/2	K	RESISTIVITY (ohm-meter)				
			VES 1	VES 2	VES 3	VES 4	VES 5
1	0.5	2.36	785.3608	751.896	535.6256	869.5892	737.8776
2	0.5	11.8	217.6864	1279.238	2648.274	786.8358	662.6998
3	0.5	27.8	116.73498	1528.1938	140.68468	501.8178	560.1422
5	0.5	77.8	110.77164	1822.076	131.91768	254.8495	536.25206
6	0.5	112	122.0912	1675.744	138.9584	166.7008	540.288
6	1	55	130.8615	1645.49	147.0975	202.5925	815.595
8	1	99	168.6861	1406.493	181.8333	191.9016	894.4551
10	1	156	211.9104	1395.2328	220.4436	219.2736	918.7776
10	2.5	58.9	205.13103	1257.8095	215.26772	227.4012	891.5104
15	2.5	137	321.9774	1280.9089	347.6101	303.7290	864.6755
20	2.5	245	430.4895	1473.43	503.671	400.5995	969.4895
30	2.5	562	641.8602	2097.5526	795.3424	531.7195	1149.571
40	2.5	1001	799.44865	2587.3848	1126.7256	669.1986	1377.376
40	7.5	323	897.7462	2724.4404	777.9424	716.0910	1417.4532
50	7.5	512	1106.5856	3206.6048	1323.7248	927.4368	1852.8768
60	7.5	742	1272.9752	3739.1606	1546.5506	1092.892	2299.3096
70	7.5	1014	1547.9724	4580.3394	1640.2464	1310.595	2711.1318
80	7.5	1329	1828.704	5106.8154	1710.5559	1535.128	2996.895
80	15	647	1843.8206	3967.3393	1700.5101	1587.933	2666.934
90	15	825	2103.09	4239.2625	1784.5575	1827.7875	2961.915
100	15	1024	2325.504	4709.376	1808.384	2066.2272	3298.7136

Table 3.2: Data obtained for VES station 6-10

AB/2	MN/2	K	RESISTIVITY (ohm-meter)				
			VES 6	VES 7	VES 8	VES 9	VES 10
1	0.5	2.36	1310.460	294.5516	235.4878	830.2008	0.41833
2	0.5	11.8	958.5376	148.5148	170.4982	362.614	225.214
3	0.5	27.8	555.0826	106.5018	175.2067	190.4161	197.099
5	0.5	77.8	350.2945	138.2895	228.2263	149.1348	202.007
6	0.5	112	294.2016	154.0010	268.24	162.0416	213.841
6	1	55	341.5445	166.9085	254.6775	165.319	213.675
8	1	99	348.1038	242.7876	337.5207	193.9509	259.073
10	1	156	408.4236	324.9948	421.3248	224.3436	326.445
10	2.5	58.9	417.2534	329.8812	398.5763	213.8894	338.716
15	2.5	137	519.9287	565.7689	632.0358	301.2356	445.962
20	2.5	245	631.806	810.0435	953.883	417.3575	602.871
30	2.5	562	746.5046	1243.368	1305.357	623.6514	789.104
40	2.5	100	976165.1	1688.687	1589.487	805.0642	1123.62
40	7.5	323	902.5912	1748.237	1521.297	-816.5117	999.588
50	7.5	512	1092.403	1909.555	1775.104	-1038.284	1323.82
60	7.5	742	1306.068	1559.980	2225.183	-1100.311	1672.02
70	7.5	1014	1603.134	1408.344	2629.099	-1282.811	2015.62
80	7.5	1329	2736.809	1612.741	2932.172	1501.637	2340.63
80	15	647	1920.94	1362.970	2879.279	1516.373	2123.51
90	15	825	2128.08	1470.727	3310.56	1769.955	2259.26
100	15	1024	2376.39	1596.518	3594.9568	2116.1984	2238.976

Tale 3.3: Data obtained for VES station 10-15

AB/2	MN/2	K	RESISTIVITY (ohm-meter)				
			VES 11	VES 12	VES 13	VES 14	VES 15
1	0.5	2.36	481.5816	523.7784	452.7188	257.8536	137.53608
2	0.5	11.8	476.6374	349.398	309.16	93.39228	73.95178
3	0.5	27.8	285.1168	319.283	273.47694	79.98894	60.16754
5	0.5	77.8	148.50464	436.1079	390.7505	130.61064	55.710246
6	0.5	112	133.4583	591.6724	427.85825	142.82975	68.99072
8	1	99	179.1702	873.4176	547.6383	162.0135	108.6327
10	1	156	217.00735	1030.57935	721.5544	159.90563	156.256795
15	2.5	137	303.4413	1491.519	1122.7424	209.8155	281.6446
20	2.5	245	428.4805	2073.484	1440.502	265.0165	786.3275
30	2.5	562	657.54	1338.0096	1548.6472	374.6292	462.67212
40	2.5	1001	928.6843	1817.1659	2209.20855	722.22546	605.62694
50	7.5	512	1186.816	2489.7536	2670.5408	1176.1152	733.184
60	7.5	742	1364.538	2839.1888	3053.8494	1386.056	944.8628
70	7.5	1014	1552.941	3281.6082	3494.3454	1493.8248	1188.7122
80	7.5	1329	1897.2986	2021.1396	4013.8932	9631.2215	1429.3711
90	15	825	2146.7325	3383.985	4256.2575	17948.7	1661.88
100	15	1024	2028.7488	3255.808	4457.7792	28717.056	1871.7696

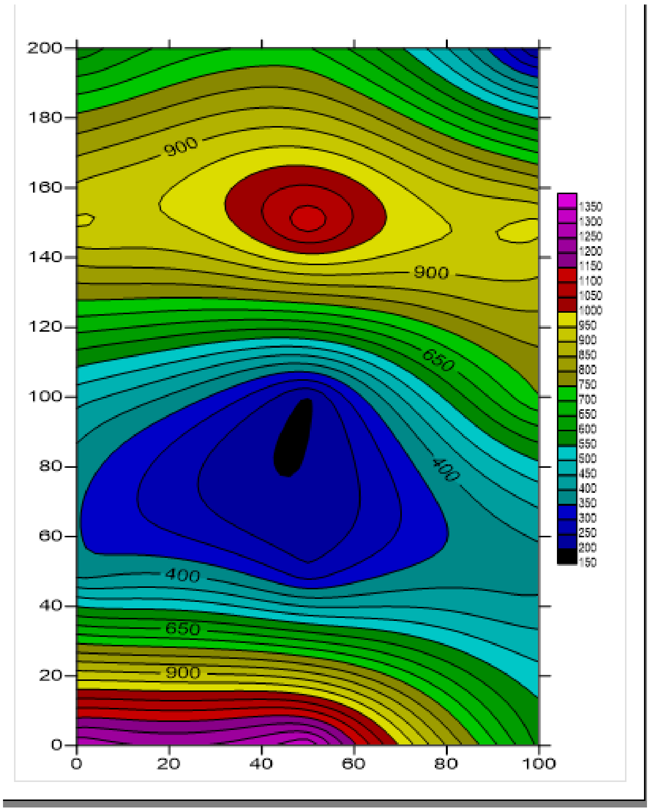

Figure 1: Contour resistivity map of the first layer.

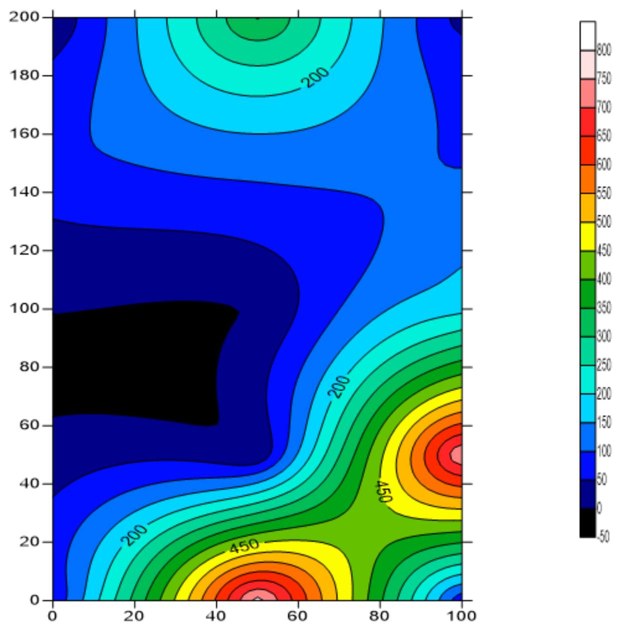

Figure 2: Contour resistivity map of the second layer

4. CONCLUSION

Groundwater exploration in the basement is based on weathered basement aquifer and fractured basement aquifer. Based on all the findings made in the interpretation of the VES data, 6 VES stations have been chosen as the most viable locations for the development of groundwater resources in the study area. These include VES stations 2, 3, 4, 5, 6, 7 and 8. The depth and resistivity of the aquifer at these VES stations indicates a very good potential for groundwater. Conclusively, the study area has a relatively low potential for groundwater development.

Successful groundwater exploration requires a thorough geologic and geophysical survey of the area so as to gain deep insight of groundwater occurrences in the area. Therefore an integrated multi-sensor geological and geophysical exploration technique should be employed for successful groundwater exploration in the basement complex of Paiko.

REFERENCES

E.A. Adanu “Groundwater Development and Management in the Basement Complex Terrain in Zaria, Kaduna Area “Water Resources 1994. Vol.4: 64-68

G. Achyara The role of economic analysis in groundwater management in semi-arid regions the case of Nigeria. *Hydrogeology Journal*, 2004. Vol 12, 33-39.

A.C. Ajibade, Protozoic Crustal Development in the Pan-African Regime of Nigeria. In C.A Kogbe (Editor) Geology of Nigeria. Published by Rockview (Nigeria) Ltd., 1980. Pp 57-63

A.A. Bamba,.Resistivity and refraction method for groundwater exploitation unpublished M.Sc thesis ABU, Zaria1978.

D. Durrance, Geoelectric Soundding for predicting Aquifer properties. 1986. Vol.19, No.2 Groundwater, Pp163.

M.O. Eduvie, Groundwater Assessment and Borehole characteristics, a paper presented at a workshop organized by Kaduna Water Board National Teacher Institute , 1998.

V.O. Olarewaju, M.O Olorunfemi. and, O. Alade, Chemical characteristics of groundwater from some parts of the Basement Complex of Central Nigeria. J.Min. Geol., 1996. Vol 33 no 2, 135-139

R. Reinhard, Groundwater Geophysics. Springer-Verlag Berlin Heidelberg Press London, 2006 Pp 92.