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Geophysical study of the aquifer characteristics along River Niger, Delta State, Nigeria

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Abstract

Geophysical survey was carried out in order to study aquifer characteristics (such as the depth, thickness and nature of soil materials above it) in the major communities along River Nigeria. Schlumberger vertical electrical sounding was conducted at Anieze, Obeza, Asaba-Okpai, Akashakpu, Obobo-Oyibo, Okpai, Oluchi, Umu-Ugboma, Iyede-Ame, Umuti-Agboh and Aboh town. The resistivity soundings were carried out with half electrode spacing in the range **1-681*m*** ***and six point per decade. The results were used to determine the depth, thickness of the recommended aquifer and the thickness of clay above it. The results showed a recommended aquifer of thicknesses,*** **14.40-68.75*m*** ***at depths,*** **21.65-34.20*m*, *and a clay of thicknesses,*** **0-10.80*m* *above it.***

***Keywords*:** Vertical electrical sounding, Schlumberger configuration, aquifer characteristics, Nigeria River, Delta State.

1.0 Introduction

The superiority of the geoelectric method over other geophysical methods in the groundwater research is confirmed by the work of [1]. The ability of the resistivity method to furnish information on the subsurface geology unobtainable by other methods in groundwater studies was reported [2, 3]. They also attested to th e ability of the electrical techniques been successfully utilized in: assessing water supply potential in basement aquifers [4]. Exploring aquifer boundaries in the plains of Yemen [5], and the assessment of the groundwater resources potentials within the Obudu basement area of Nigeria [6].

The earlier works [7, 8] used this method to identify the depth/thickness of the near surface fresh water above the salt water layer with the depth to the deep fresh water aquifer below the salt water in the saline water environment along the Benin and Forcados rivers. Also in [9], the depth/thickness of the near surface fresh water above the brackish water zone with the depth to the deep fresh layer below the brackish water horizon along the brackish water environment along the Warri river. Though, the region along the Nigeria river is fresh water environment which makes it better than the other rivers in terms of fresh water availability there is need to find aquifers within the Benin Formation of the Nigeria Delta basin that are naturally sealed from pollution through vertical and horizontal flow of pollutant. Moreover, the Benin Formation aquifers investigated here differ from the Nanka sand aquifer of the Anambra basin in Orifite.

The study reported here was carried out primarily using geophysics to determine the aquifer characteristics such that depths, thicknesses and the nature, thicknesses of soil materials above the recommended aquifer for the purpose of potable water production.

1.1 Brief geology and hydrogeology of thestudy area

The study area is underlain by the continental sands of the Benin Formation (Figure 1). The geology of the Niger Delta has been extensively described by several authors including [10, 11]. The subsurface sedimentary sequence has been subdivided into three stratigraphic units: the Benin , Agbada and Akata Formations. The Benin Formation consists of sand, gravely sand sandy-clay and clay intercalations. The formation is known for its high aquifer potential. The lithological units of this area are generally composed of sands and clayey-sand. The area has a flat topography and is situated by the bank of Niger River.

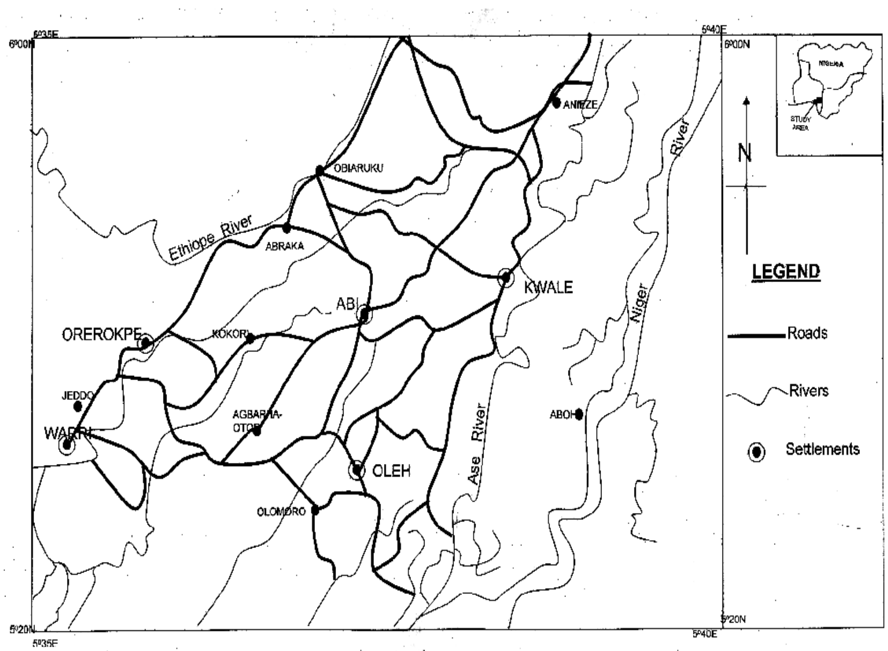

FIG. 1: MAP SHOWING THE STUDY AREAS

2.0 Theory

For resistivity measurements several types of electrode arrangements can be applied. However, when the earth could be approximated to be composed of horizontally stratified isotropic, and homogenous media in such a way that the change of resistivity is a function of depth, the Schlumberger configuration is the most widely used array which could provide useful information in solving hydrogeological problems. An important aspect of the Schlumberger is the less sensitivity of this array to the influence of near surface lateral heterogeneities and easy recognition of their effects [12, 13, 14, 15]. Besides smoothing interpretation techniques are much more developed for the Schlumberger array.

In resistivity sounding, four electrodes are earthed along a straight line in the order AMNB (with AB as current electrodes and MN as potential electrodes). The apparent resistivity for Schlumberger array is calculated according to:

$$\ell_a = \pi\left(\frac{a^2}{b} - \frac{b}{4}\right) \cdot \frac{\Delta V}{I} \tag{2.1}$$

where a = half current electrodes spacing

b = half potential electrodes spacing

ΔV and I represent the difference in milli Volts and current intensity in milli Amperes respectively.

The techniques of data interpretation used involve seeking a solution to the inverse problem namely the determination of the subsurface resistivity distribution from surface measurements.

A very good solution to the inverse problem is the kernel function. It is used in interpreting apparent resistivity measurements in terms of lithology variation with depths. The function assumes the earth to be locally stratified, inhomogeneous and isotropic layers, and unlike apparent resistivity function, it is independent of electrode configuration. It cannot be measured in the field but has to be obtained from the transformation of measured apparent resistivities. The kernel function utilized in this work is derived after [16, 17], if the observed apparent resistivity is given by

$$\ell_a(r) = r^2 \int_0^\infty \lambda T(\lambda)\, J_1(\lambda r)\, d\lambda \qquad (2.2)$$

then the kernel function is given by [17] as:

$$T(\lambda) = \int_0^\infty \frac{1}{r} \ell_a(r)\, J_1(\lambda r)\, dr \qquad (2.3)$$

Where J_1 is the first order Bessel function of the first kind and $T(\lambda)$ is the transformed resistivity data.

3.0 Methods

The vertical electrical sounding (VES) using the Schlumberger array was employed for this study, details of the method have been documented [18]. Eleven (11) Schlumberger soundings were conducted using the ABEM SAS 300C Tetrameter and the SAS 2000 Booster.

Measurements were taken at expanding current electrodes distance such that the injected electrical current penetrates greater depths. The maximum current electrodes separation (AB) was 1362m (or AB/2 was 681m) and at six points per decade. The operation and efficiency of the six points per decade in subsurface study in the Niger Delta have been document [7, 8, 9, 19, 20, 21] the end result of the field measurement is the computation of the apparent resistivity (ℓ_a) using equation (2.1).

The apparent resistivity values were plotted against the half-current electrode spacing, a , using log-log sheet. These plot were interpreted by the well-known method of partial curve matching, and the results were subjected to computer assisted iterative interpretation. The computation employs 9-point digital linear filters [22]. The resulting sets of layer parameters were interpreted in terms of their lithologic equivalents called the geoelectrical section.

4.0 Results and Discussion

The results of previous works as presented in Tables 1, 2 and 3 [7, 8, 9] showed: that the saline water environment along the Benin river has a near surface fresh water aquifer of thicknesses (with depths in bracket), 1.0-9.7m (0.2-1.5m), and deep fresh water aquifer of depths, 100-218m with a sandwiched saline water aquifer of thicknesses, 65-209m; the saline water environment along the Forcados river has a near surface fresh water aquifer of thicknesses (with depths in bracket), 0.8-10.8m (0.3-1.4m), and a deep fresh water aquifer of depths, 66.8-198.5m, with a sandwiched saline water aquifer of thicknesses, 64.8187.8m; and the brackish water environment along Warri river has a near surface fresh water aquifer of thicknesses (with depths in bracket), 0.5-3.2m (1.0-47.6m), and a deep fresh water aquifer of depths, 33.4-237.4m, with a sandwiched brackish water aquifer of thicknesses, 11.3-202.8m. And the results recommended the deep confined fresh water for large scale water supply and the near surface unconfined fresh water aquifer (with water purification mechanism in place) for only domestic water supply.

However, the results of the geophysical investigation are as presented in Figure 2 and Table 4, Figure 2 reflects the multi-layered nature of the study area which is typical of the Nigeria Delta Basin by the multi-segmented field curves. The initial rise in the field curves in eight locations indicates the presence of dry sands and thin clay of thicknesses below 4m above
the aquifers, a situation which makes any aquifer at depths below 20m unsuitable for exploitation since such aquifers are not naturally sealed from pollution [23]. Also, the initial fall in the field curves in three locations (Obodo-Oyibo, Oluchi, and Aboh) reflects the presence of a thick near surface clay of thickness 5m in Obodo-Oyibo, 6.88m in Oluchi and 10.80m in Aboh hence these aquifers are said to be naturally sealed from pollution [23].

The depth (with thickness in bracket) to the recommended aquifer is 23 (17m) in Anieze, 33m (18m) in Obeza, 33m (47m) in Asaba-Okpai, 29m (14m) in Akashakpu, 23m (33m) in Obodo-Oyibo, 29m (14m0 in Okpai, 35m (26m) in Oluchi, 23 (17m) in Umu-Ugboma, 28m (16m) in Iyede-Ame, 26m (69m) in Umuti-aboh and 34m (20m) in Aboh. Moreover, the presence of a near surface clayey soil at depths, 0-3.15m and thicknesses, 0-3.74m is revealed in eight out of the eleven locations. However, apart from the aquifer identified by the bell shaped rightmost segment of the VES curves there are some aquifers before the recommended aquifer (sand bodies) at depths below 10m but these aquifers are not recommended for exploitation because they are not naturally sealed and are therefore exposed to pollution through vertical and horizontal flow of pollutants.

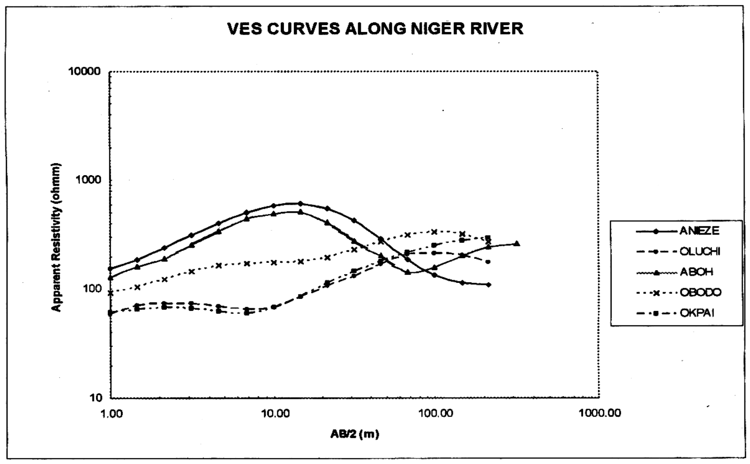

Figure 2: VES curves for Anieze, Obodo-Oyibo, Okpai, Oluchi and Aboh, Delta State.

Table 1: Summary of VES results along the Benin River and its Environs [7]

Location (Communities along Benin River)	**VES No.**	**Max. AB/2 Value (m)**	**No. lf Layers**	**Curve shape**	**The thickness (depth in bracket) of near surface fresh water aquifer (m)**	**Depth to the deep fresh water aquifer (m)**	**Total depth penetration (m)**
Koko	1B	666	6	QHAK	7.3 (1.5)	217.6	217.6
Obonteghareda	2B	440	5	QQH	1.2 (1.0)	Not penetrated	67.5
Ogaghoro	3B	430	6	KQHA	2.3 (1.3)	141.7	141.7
Ebrohimi	4B	316	6	QHKH	4.8 (1.3)	126.2	126.2
Daleketa	5B	316	6	QHKH	1.2 (1.1)	Not penetrated	68.2
Otunla	6B	464	6	QHQQ	None	Not penetrated	45.9
Bateren	7B	681	6	QQKH	9.7 (0.9)	102.5	102.5
Ebokiti	8B	681	6	HQKH	1.0 (0.2)	100.0	101.9

Table 2: Summary of VES results along the Forcados River and its Environs [8]

Location	**VES No.**	**Max. AB/2 (m)**	**No. lf Layers**	**Curve shape**	**The thickness of near surface fresh water aquifer (m)**	**Depth to the deep fresh water aquifer (m)**	**Total depth penetration (m)**
Ogulagha	1.	100	5	KQH	7.5M	Note penetrated	45.7

”	2.	”	5	KQH	1.2	”	17.4
”	3.	”	6	KHKH	1.8	”	17.8
”	4.	”	5	QQH	2.3	”	37.8
”	5.	”	15	KQH	2.0	”	31.2
”	6.	”	4	QQ	0.8	”	16.5
”	7.	”	4	QQ	1.1	”	29.8
”	8.	”	5	QQQ	0.9	”	27.3
Yobebe	1	”	5	KQH	10.8	”	61.7
”:	2	”	5	KQH	1.4	”	27.7
Okunti	1	1000	7	AKHAA	9.7	198.5	198.5
Burutu	1	681	6	QHAK	2.0	66.8	107.8
Kautu	1	316	6	KQHK	2.3	80.3	97.7

Table 3: Summary of VES results in the Communities along the Warri River [9]

Location	Max. AB/2 value (m)	VES No.	Curve shape	Thickness of first aquifer (m)	Depth to the first aquifer (m)	Thickness of second aquifer (m)	Depth to the second aquifer (m)
Ogbe-Ijoh	417	1	AKQ	87.6	1.3	Not penetrated	Not penetrated
Ugbodede	650	2	KHKQQH	1.0	0.8	36.2	38.3
Egbokodo	650	3	HKHA	22.1	3.2	>103.3	70
Omadino	681	4	KQQH	16.8	0.5	Not penetrated	>202.8
Ode-Itsekiri	681	5	QHKHA	8.36	2.7	11.31	30.0

Table 4: Results of the interpretation of some VES curves in the study area

Location and VES No.	Curve shape	Total depth penetrated (m)	Depth to the recommended aquifer (m) with the thickness(m) in bracket	Depth to the clayey soil above the aquifer (m)	Thickness of clayey soil above aquifer (m)
Anieze	AKQ	23.10	23.10(16.80)	No clayey soil	No clayey soil
Obeza	HKHK	51.10	18.00(33,10)	0.80(clayey-sand)	1.92 (clayey-sand)
Asaba-Okpai	HKHK	78.79	32.79(46.50)	0.85(clay)	1.11(clay)
Akashakpu	KHK	48.02	24.22(14.40)	2.25(clay)	2.57(clay)
Obodo-Oyibo	KHAK	54.65	21,65(33.00)	3.15(clayeye-sand)	5.00(clayey-sand)
Okapi	KHA	32.45	29.45(14.13)	1.58(clay)	3.74(clay)
Oluchi	KHAK	60.71	34.71(26.00)	1.08(clay)	6.88(clay)
Umu-Ugboma	KQHA	40.08	22.83(17.25)	2.03(clay)	1.80(clay)
Iyede-AMe	AA	34.75	27.65(16.15)	0.90(clayey-sand)	1.62(clay)
Umuti-Aboh	AKH	75.43	25.67(68.75)	No clayey soil	No clayey soil
Aboh	QHA	34.20	34.20(20.25)	3.15(clay)	10.80(clay)

4.0 Conclusion

The results of the interpreted VES data revealed an unconfined aquifer which is recommended for water production. Water intercepted at 22-35m is an aquifer that may not dry up for a long time after borehole completion hence it is recommended for production. From the study, the geophysical investigation is recommended as a precondition for borehole drilling to establish the depths and subsurface lithology before drilling. The study therefore stands as a reliable guide for groundwater development in this part of Delta State where source of potable water that are naturally protected from pollution is a major problem in most of the towns.

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