International Journal of Physical Sciences Vol. 4 (9), pp. 477-485, September, 2009
Available online at http://www.academicjournals.org/IJPS
ISSN 1992 - 1950 © 2009 Academic Journals

Full Length Research Paper

Hydrogeological deductions from geoelectric survey in Uvwiamuge and Ekakpamre communities, Delta State, Nigeria

Atakpo Edmund

Department of Physics, Delta State University, Abraka. E-mail: e_atakpo@yahoo.com.

Accepted 06 July, 2009

The vertical electrical resistivity survey (VES) utilising the surface Schlumberger electrode array with a maximum current electrode spacing varying from 50 - 500 m has been used to provide valuable information on the hydrogeologic system of the aquifers and the subsurface lithology in Ekakpamre and Uvwiamuge communities. A total of twenty three (23) VES stations were sounded. Four to five geoelectric layers were delineated from the survey area. The first layer is the topsoil and has resistivity values ranging from 37 - 926 Ωm and thickness between 0.5 - 1.5 m. The second layer composed of clay, clayey sand and laterite has resistivity values varying from 22 - 1044 Ωm and thickness ranging from 0.4 and 3.6 m. The third and fourth geo-electric layers consisting of fine grained and medium to coarse grained sand with thickness varying from 12 - 105 m corresponds to an aquifer horizon. The resistivity values of the aquifer range from 302 - 2844 Ωm. The results of the study show that an aquifer is encountered from the depth of about 5 m in Ekakpamre and Uvwiamuge communities. It extends beyond 45 m depth in Ekakpamre and 105 m in Uvwiamuge. The resistivity survey revealed that the parameters obtained through interpretation of VES curves corroborate the lithologs of boreholes from the area.

Keywords: Aquifer, resistivity, hydrogeology, Delta State.

INTRODUCTION

Ekakpamre and Uvwiamuge are oil producing communities in Delta State that play host to several oil fields, a glass factory, electricity generating plant, flow station, an engineered dumpsite and extensive network of pipe lines within the fields as well as small networks of flow lines that carry oil from wellheads to the flow station. The oil and gas related installations allow many opportunities for oil leaks and spills in the area which may occur due to a variety of reasons (Ozumba et al., 1999; Emoyan et al., 2008) such as blowouts due to overpressure, equipment failure, operators errors, corrosion, vandalisation of pipelines, pigging operations, flow line replacement, flow station upgrades, tank rehabilitation and natural phenomena such as heavy rainfall, flooding, falling of trees, lightening and poor management practices around oil installations.

Apart from a few boreholes providing potable water the communities rely mostly on water from dug wells for domestic and agricultural purposes. Leaks and spills may impact directly on the groundwater as a result of the flat topography and depth to water is on the average less than a meter in the wet season. The peculiar nature of the area requires a detailed hydrogeological picture of the subsurface using geophysical method to investigate the subsurface integrity and the hydrogeoelectric behavior of the aquifer and the relationship between the earth resistivity and the subsurface formation.

The electrical resistivity method involving vertical electrical sounding (VES) technique was adopted for this survey. It involves the measurement of apparent resistivity of subsurface as a function of depth or position by changing the electrode spacing interval while maintaining a fixed location for the center of the electrode spread.

The resistivity techniques have applications in ground water exploration (Van Overmeeren, 1989; Olorunfemi et al., 1999; Atakpo and Akpoborie, 2008). Oseji et al. (2005) used the geoelectric method to investigate the aquifer characteristics and groundwater potential in parts of the western Niger Delta. In their findings the shallowest aquifer horizon in that area was at a depth of 4 to 17 m. A related study by Etu-Efeotor and Michhalski (1989) revealed that the depth to the aquifer in some parts of the

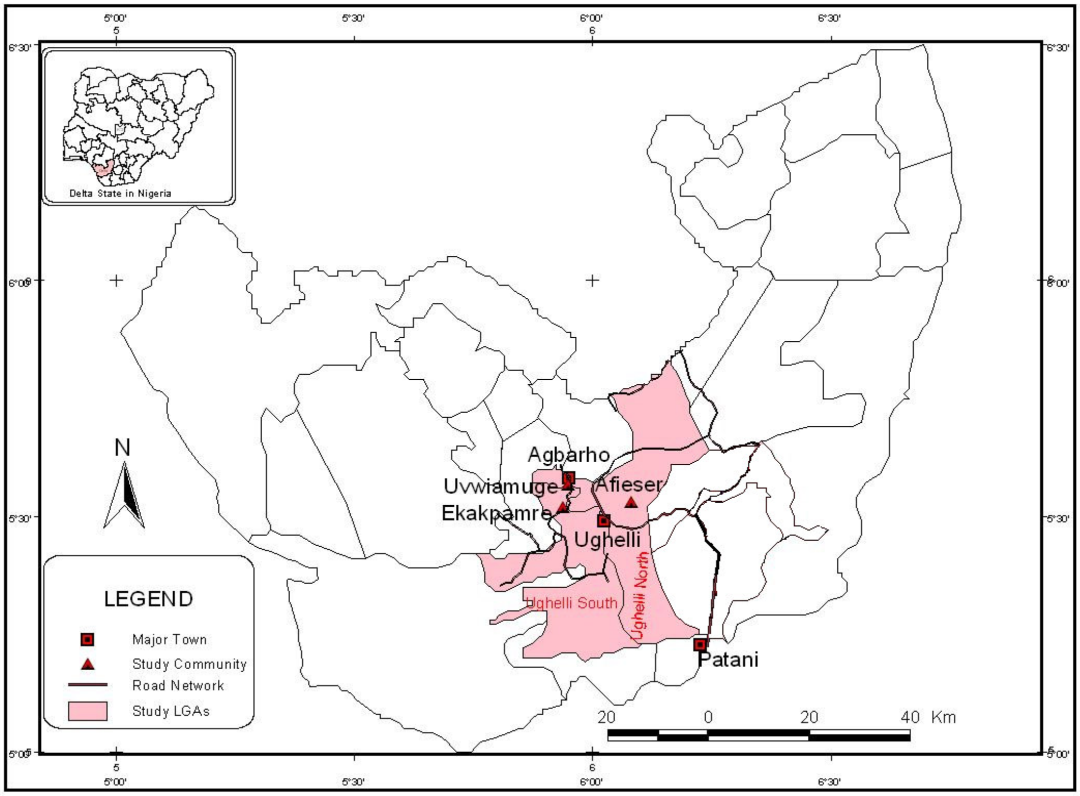


Figure 1. Map of Delta State, Nigeria showing the study area.

eastern Niger Delta varied from 4 - 8 m.

Electrical resistivity method has been used successfully for investigating saltwater intrusion in coastal areas (Adepelumi et al., 2008 and Frohlich et al., 1994). The theory of resistivity and its application to ground water studies have been much discussed (Telford et al., 1990; Sharma, 1997). This study was undertaken with the aim of delineating the subsurface geoelectric sequence and determining the layer geoelectric parameters, evolve a general geologic sequence of the area and determine the aquifer units beneath the surface and their depth of occurrence.

PHYSIOGRAPHY AND GEOLOGY

Ekakpamre and Uvwiamuge communities (Figure 1) lie within longitude 5° 52.5′ - 5° 54.6′E and Latitude 5° 30.6′ - 5° 33.6′N in the western Niger Delta. The area is characterized by a seaward sloping plain terrain with elevation of less than 10 m above mean sea level (Akpokodje and Etu-Efeotor, 1987). Some parts get flooded during rainy season and then remain dry during the dry season. The area forms a part of the featureless Sombreiro Warri Deltaic Plain with fresh water swamps. The vegetation is typical rainforest. The study area is well drained by rivers and creeks that flow into the Atlantic Ocean. The depth to water is high at a maximum of 5 m below the ground surface in the dry season and less than 1 m in the wet season (Akpoborie et al., 2000).

The Niger Delta consists of three main Tertiary stratigraphic units overlain by Quaternary deposits (Short and Stauble, 1967). The base is the Akata Formation (Palaeocene to Eocene) comprising mainly of marine shales and sand beds (Figure 2) The Agbada Formation (Eocene to Oligocene) is the intermediate paralic sequence consisting of interbedded sands and shales. The youngest Benin Formation (Oligocene to Recent) is a prolific aquifer comprising fluviatile gravels and sands. The formation however is masked in the Sombreiro - Warri Deltaic plain by a sequence of Silts, medium to coarse grained sands, sandy clays and clay bands. The local hydrogeological setting indicates that the study area is underlain by fine to medium and coarse grained unconsolidated Sombreiro - Warri Deltaic Plain sands. The hydraulic conductivity of the sands varies from 3.8×10^{-3} cm/s to 9×10^{-2}.cm/s, which indicates potentially productive aquifer (Akpoborie et al., 2000).

METHODOLOGY

Twenty three (23) vertical electrical sounding by adopting the Schlumberger method was carried out at preferred points in the study

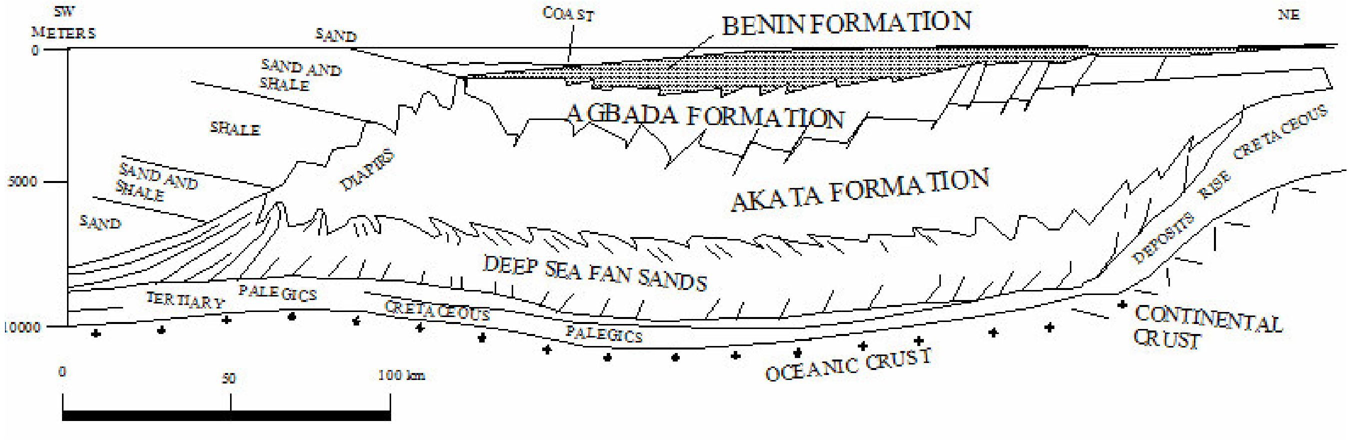


Figure 2. Structure of the Niger Delta (Asseez, 1989).

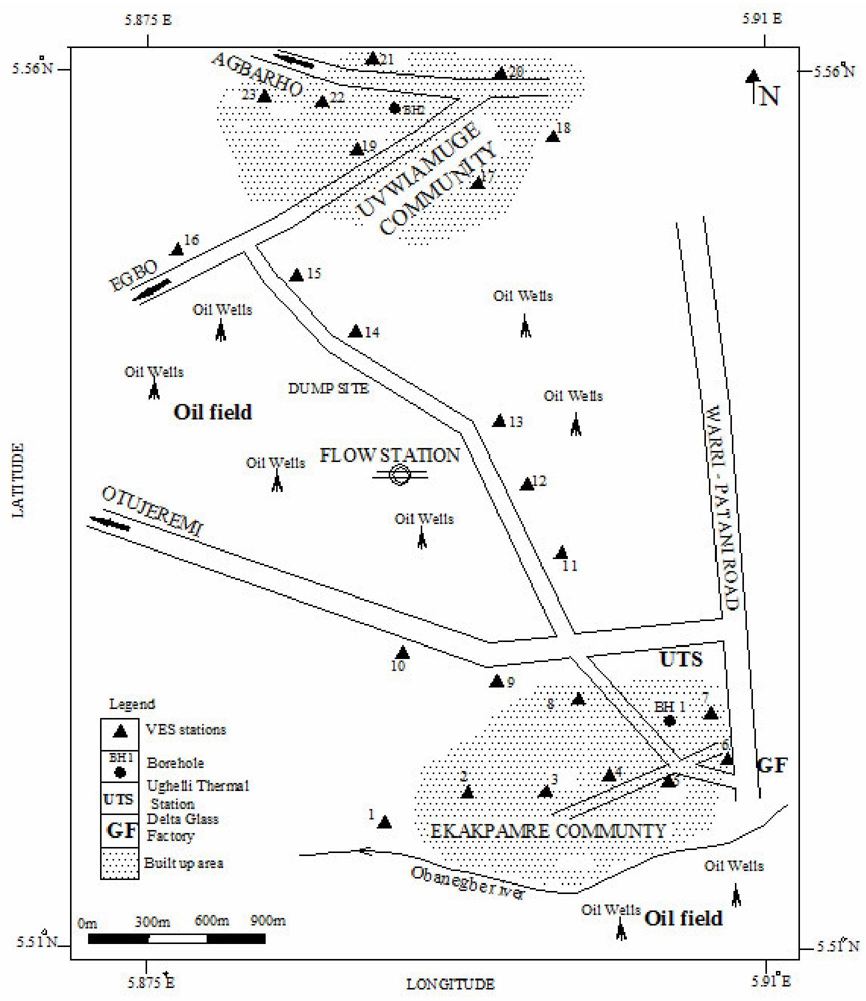


Figure 3. Data acquisition map of study area.

area (Figure 3). The ABEM SAS 1000 Terrameter was used for the resistivity measurement. The maximum current electrode separation varied from 50 - 1000 m depending on accessibility of the area.

The data obtained from the electrical resistivity survey was plotted on a log-log graph paper with the electrode separation (AB/2) on the abscissa and apparent resistivity on the

Table 1. Resistivity sounding results.

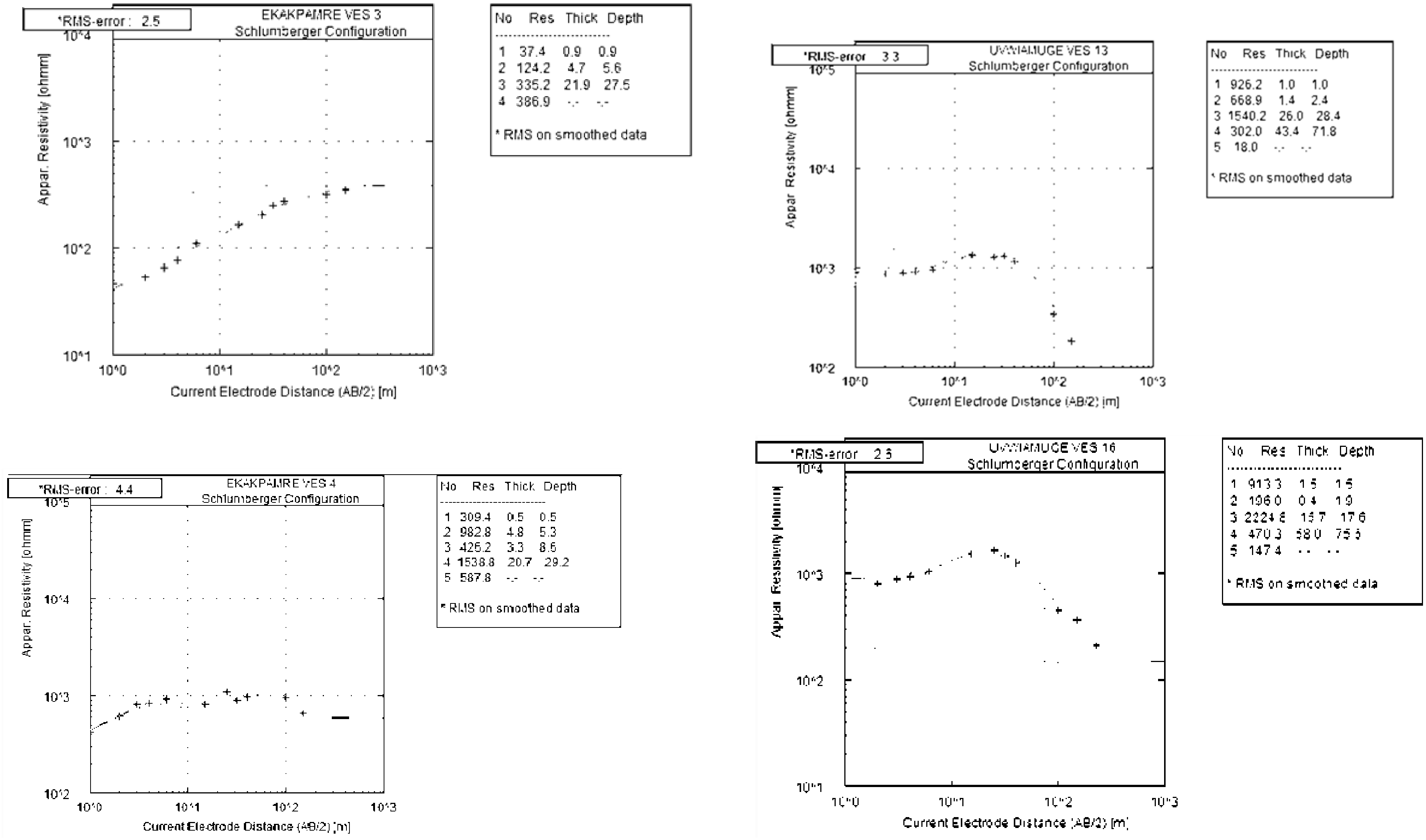
VES Stn.	Resistivity ($\rho_1/\rho_2/\rho_3/.../\rho_n$) Ohm-m	Thickness ($h_1/h_2/h_3/.../h_n$) m	Inferred Lithology	Curve types
1	133/172/2104/345	0.8/3.7/28	Topsoil/Clayey sand/Sand/Sand	AK
2	68/145/1232/502	1.3/5.0/35.5	Topsoil/Clayey sand/Sand/Sand	AK
3	37/124/335/387	0.9/4.7/21.9	Top soil/Clayey sand/Sand/Sand	AA
4	151/143/1402/589/141	0.9/3.1/8.4/9.6	Topsoil/Clayey sand/Sand/Sand/Clayey sand	HKQ
5	309/983/426/1539/588	0.5/4.8/3.3/21	Topsoil/Laterite/Sand/Sand	KHK
6	120/202/1608/552	1.1/2.3/25.2	Topsoil/Clayey sand/Sand/Sand	AK
7	502/323/1524/332	1.0/3.4/25.8	Topsoil/Clayey sand/Sand/Sand	HK
8	98/425/890/411	0.6/5.6/15.3	Topsoil/Laterite/Sand/Sand	AK
9	125/166/1502/400	1.2/2.9/21	Topsoil/Clayey sand/Sand/Sand	AK
10	606/720/554/367/932	0.9/1.9/12.5/18.8	Topsoil/Laterite/Sand/Sand	KQH
11	223/336/2004/845	1.5/4.1/26	Topsoil/Laterite/Sand/Sand	AK
12	1112/1044/2118/722/180	1.0/2.1/10.9/17.2	Topsoil/Laterite/Sand/Sand/Clayey sand	HKQ
13	926/669/1540/302/18	1.0/1.4/26/43	Topsoil/Laterite/Sand/Sand/Clay	HKQ
14	659/214/697/383/60	1.3/3.6/25/78	Topsoil/Clayey sand/Sand/Sand/Clay	HKQ
15	836/149/1667/3.1	0.6/3/10.7	Topsoil/Clayey sand/Sand/Clay	HK
16	913/196/2225/470/147	1.5/0.4/16/58	Topsoil/Clayey sand/Sand/Sand/Clayey sand	HKQ
17	830/154/1338/529/206	0.8/2.2/15.1/12	Topsoil/Clayey sand/Sand/Sand	HKQ
18	121/87/1844/877/250	1.2/3.6/12.4/11.1	Topsoil/Clay/Sand/Sand/Clayey sand	HKQ
19	78/22/418/947/2844	0.5/1.3/4.1/20.1	Topsoil/Clay/Clayey sand/Sand/Sand	HKH
20	206/902/1977/1243	1.0/2.9/33.3	Topsoil/Laterite/Sand/Sand	AK
21	188/395/1583/425	1.3/2.8/28.0	Topsoil/Clayey sand/Sand/Sand	AK
22	103/55/2538/344	0.7/3.3/36.0	Topsoil/Clay/ Sand/Sand	HK
23	342/132/1134/519	1.4/4.1/34.6	Topsoil/Clayey sand/Sand/Sand	HK

abscissa and apparent resistivity (ℓa) values as the ordinate. The true resistivity and thickness of the subsurface layers were interpreted by partial curve matching with the two layer model master curves and the corresponding auxiliary curves. The thickness and resistivity values obtained from the partial curve matching were then used for a quantitative computer iteration using the Resist Software (Vander, 1988). The results obtained from the computer modelling are presented in Table 1.

RESULTS AND DISCUSSION

The interpretation of the sounding curves shows the following curves types; AK, HK, AA, KQH, KHK, HKQ and HKH (Figure 4). The geoelectric section in Ekakpamre along the traverse in the east-west direction (Figure 5a) shows four distinct geoelectric layers namely the top soil, laterite/clayey sand/clay, fine grained sand and medium to coarse grained sand. The resistivity of the first layer varies from 37 - 502 Ωm, while its thickness ranges from 0.5 - 1.0 m. This resistivity reflects the variable composition and moisture content of the topsoil. The second geoelectric layer is composed of clayey sand and laterite. The resistivity of the clayey sand overburden ranges from 124 - 323 Ωm and thickness of 2.4 - 4.7 m while the lateritic material has resistivity of 983 Ωm and thickness of 4.8 m. The third and fourth geo-electric layer represents an aquifer unit. The resistivity values of the third layer range from 1232 - 2104 Ωm diagnostic of fine grained sand with thickness ranging from 25 - 45 m except beneath VES 3 where the inferred lithology is clayey sand with resistivity value of 335 Ωm. The fourth layer is composed of medium to coarse grained sand with resistivity values ranging from 332 - 588 Ωm. The exact thickness of this layer cannot be determined as the electrode current terminated within this layer.

The geoelectric section in Uvwiamuge (Figure 5b) shows three to four distinct geoelectric layers. The first layer is the topsoil whose resistivity values range from 78 - 926 Ωm with thickness varying between 0.5 - 1.5 m. The resistivity values of the second layer comprising of clay, clayey sand and lateritic soil range from 22 - 1044 Ωm. The thickness ranges from 0.4 and 3.6 m. The third and fourth layers comprising of fine grained sand and medium to coarse grained sand having resistivity values ranging from 302 - 2844 Ωm and thickness of 12 - 105 m corresponds to an aquifer. Clay and clayey sand were intercepted at the fourth layer beneath VES 15 and the fifth



a)

b)

Figure 4. Some resistivity curves obtained from the study area.

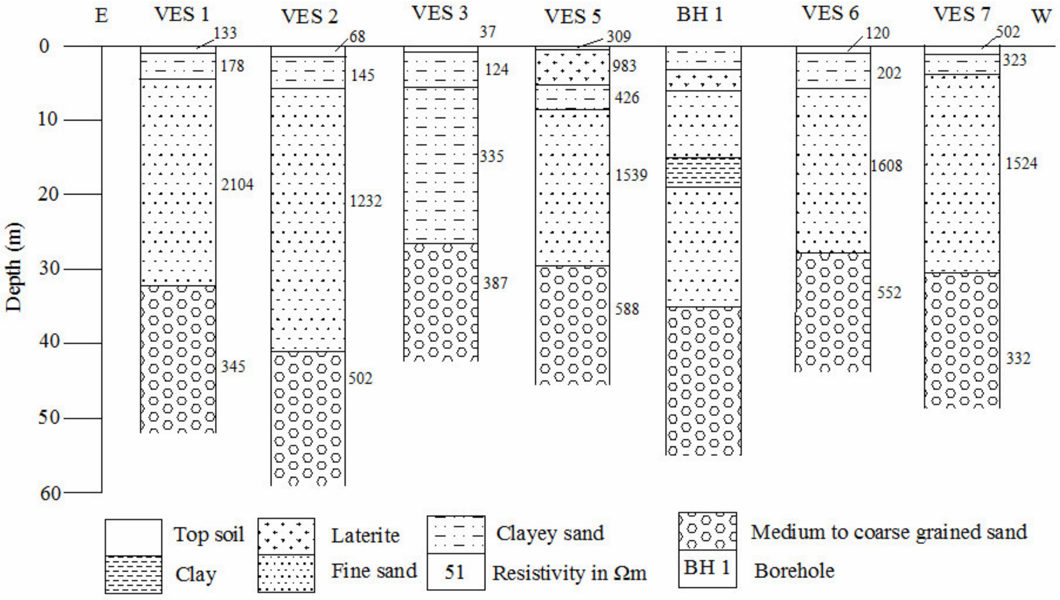


Figure 5a. Geoelectric section of Ekakpamre area.

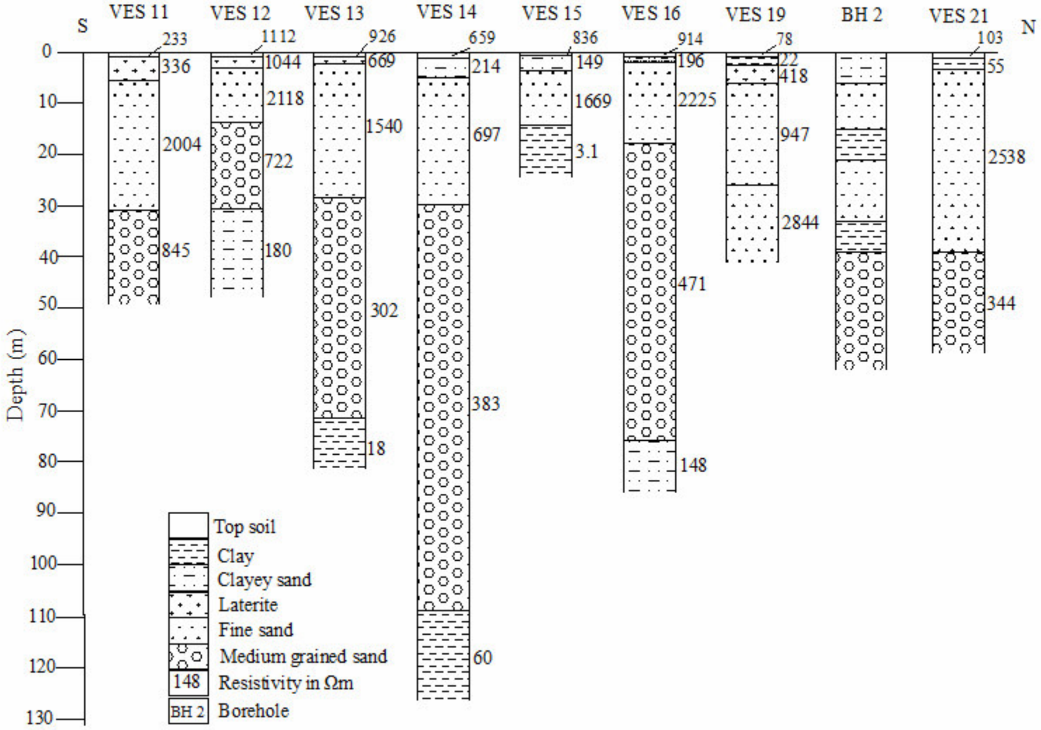


Figure 5b. Geoelectric section of Uvwiamuge area.

layer beneath VES 12, 13, 14 and 16. The resistivity values of the clay and clayey sand layers range from 3.1 to 148 Ωm at depths of 12, 30, 72, 105 and 148 m respectively.

The results of the study show that an aquifer is encountered at an average depth of about 4.3 m in Ekakpamre and Uvwiamuge communities as shown in the depth to the top of aquifer map (Figure 6a). The isopach map produced from the VES results shows a variation in aquifer thickness from 10 - 105 m. The maximum aquifer thickness is encountered beneath VES 14 in Uvwiamuge (Figure 6b). This area may be good prospects for drinking boreholes with high yield expectations (Omosuyi et al., 2008). The resistivity survey indicates that the parameters obtained

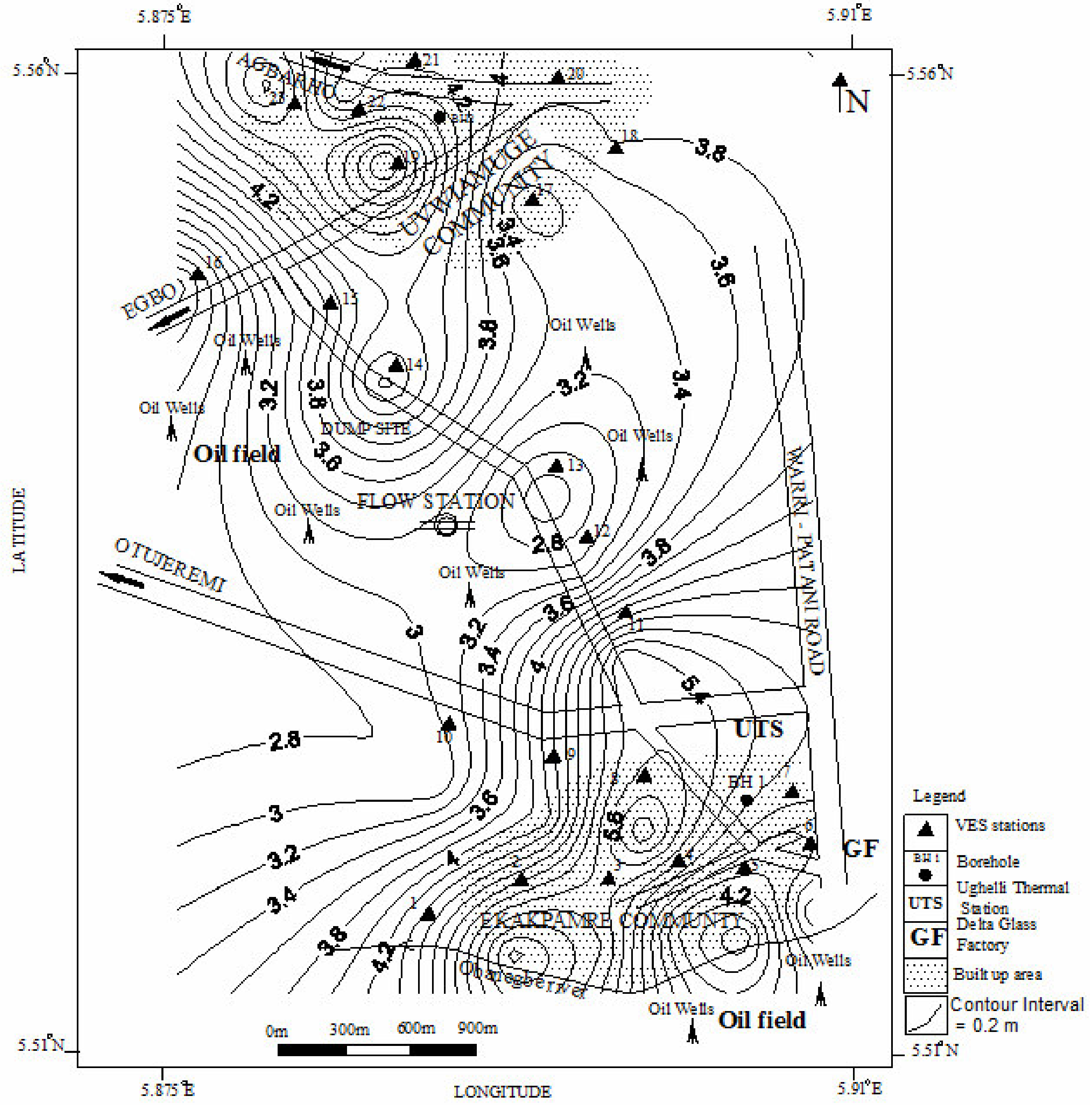


Figure 6a. Depth to the top of aquifer in the area.

interpretation of VES curves corroborates the lithologs of boreholes drilled into the area.

Conclusion

Surface electrical resistivity surveys was conducted in Ekapkamre and Uvwiamuge communities with the aim of providing valuable information on the hydrogeologic system of the aquifer and delineate the subsurface configuration of the area. Range of resistivity values for different formations has been established using the interpreted VES results and borehole lithologs which can help to understand the subsurface litological variation prevailing in the area. The groundwater occurs basically under unconfined condition at depths of about 4.3 m to about 105 m. The near surface part of the aquifer may be vulnerable to contamination as a result of the thin overlying geoelectric layer, however

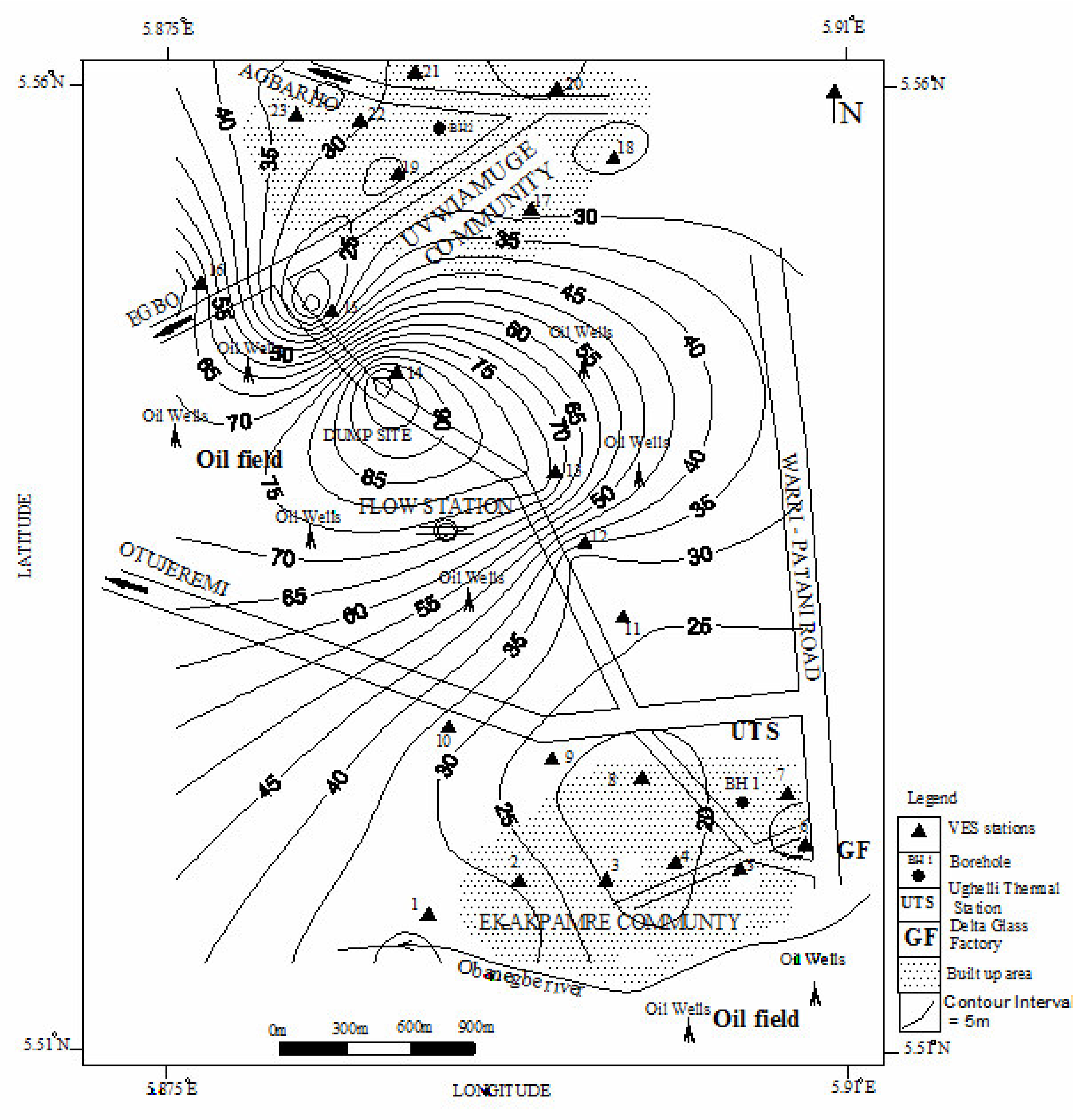


Figure 6b. Isopach map of aquifer in the area.

the presence of clay lenses at different depths may play the role of forming confining layers. The thickness of the clay layer could not be completely resolved as the electrodes terminated within this layer. This therefore calls for further investigation using wider current electrode separation. It is recommended that aquifer vulnerability studies should be carried out while groundwater monitoring should be conducted regularly in the area. This study has provided an insight into the subsurface disposition of the shallow aquifer systems and delineated areas for groundwater development programme in the area.

REFERENCES

Adepelumi AA, Ako BD, Ajayi TR, Afolabi O, Omotoso EJ (2008). Delineation of saltwater intrusion into the freshwater aquifer of Lekki Peninsula, Lagos, Nigeria. Environ Geol, Springer-Verleg. DOI 10.1007/s00254-008-1194-3.

Akpoborie IA, Ekakitie OA, Adaikpoh EO (2000). The Quality of Groundwater from Dug wells in parts of the Western Niger Delta. Knowl. Rev. 2(5): 72-79.

Akpokodje EG, Etu-Efeotor JO (1987). The Occurrence and Economic Potential of Clean Sand Deposits of the Niger Delta. J. Afr. Earth Sci., 6 (1): 61-65.

Asseez OL (1989). Review of the Stratigraphy, Sedimentation and Structure of the Niger Delta. In: Kogbe, C.A. (Ed.) Geology of Nigeria, Rock View (Nig.) Ltd. Jos. pp 311-324.

Atakpo EA, Akpoborie AI (2008). Geoelectric mapping of Amukpe area of Delta State, Nigeria. Niger. J. Sci. Environ. 7: 73-82.

Emoyan OO, Akpoborie IA, Akporhonor EE (2008). The Oil and Gas Industry and the Niger Delta: Implications for the environment. J. Appl. Sci. Environ. Mgt. 12(3): 29-37.

Etu-efeotor JO, Michalski A (1989). Geophysical investigation for groundwater in parts of the eastern Niger Delta. J. Mining Geol. 25 (1&2): 51-54.

Frohlich RK, Urish DW, Fuller J, Reilly MO (1994). Use of geoelectrical method in groundwater pollution surveys in a coastal environment. J. Appl. Geophys. 32: 139-154.

Olorunfemi MO, Ojo JS, Akintunde OM (1999). Hydrogeophysical evaluation of ground water potentials of Akure metropolis, south-western Nigeria. J. Mining Geol. 35(2): 207-228.

Omosuyi GO, Ojo JS, Olorunfemi MO (2008). Geoelectric Sounding to Delineate Shallow Aquifers in the Coastal Plain Sands of Okitipupa Area, Southwestern Nigeria. Pac. J. Sci. Technol. 9(2): 562-577.

Oseji JO, Atakpo EA, Okolie EC (2005). Geoelectric investigation of the aquifer characteristics and the groundwater potential in Kwale, Delta State, Nigeria. J. Appl. Sci. Environ. Mgt. 9(1): 157-160.

Ozumba CI, Ozumba MB, Obobaifo CE (1999). Striking a balance between oil exploration and protecting the environment. NAPE Bull., 14 (2): 130-135.

Sharma Prem V (1997). Environmental and Engineering Geophysics. Cambridge University Press, Cambridge, p. 475.

Short KC, Stauble AJ (1967). Outline of Geology of Niger Delta: AAPG Bull. 51: 761-779.

Telford WM, Geldart LP, Sheriff RE (1990). Applied Geophysics. 2nd Edition, Cambridge University Press, Cambridge. p 770.

Vander Velpen BPA (1988). RESIST Version 1.0. M. Sc Research Project. ITC, Deft, Netherlands.

Van Overmeeren RA (1989). Aquifer boundaries explored by geoelectric measurement in the Coastal plain of Yamen: A case of equivalence. Geophysics, 54: 38-48.