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Overburden Properties of Abua in Rivers State, Nigeria, from Vertical Electrical Sounding

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ABSTRACT

Twelve vertical electrical soundings, VES, were carried out in parts of Abua in northwestern part of Rivers State in the sedimentary basin of the Niger delta of Nigeria, to determine the overburden layering and infer the aquifer depth/thickness and probable safe structural foundation depths in the region. The Schlumberger array method was employed using an ABEM 300B Terrameter and maximum current electrode spread of 400 m. The computed apparent resistivity field log values were plotted against the current electrode spreads and interpreted with IPWIN 2 and Sulphure 8 software to obtain the overburden thickness/depth, resistivity and the isopach map and then infer the subsoil layering thickness including potential aquifer zones within the depths of investigation in the area. The curve types revealed that three and four geoelectric sections were penetrated by the survey array with overburden thickness ranging from 4.2 m in Elok community to 91.7 m in Ilghom community. Potential aquifers with variable thickness from 5 to 60 m at depths of from 4.5 m and below the earth surface were identified. The subsurface soils types can support structural foundations from depths of 1.0 m and below the earth surface based on the type of building/engineering structures.

Keywords: *Vertical Electrical Sounding, Overburden Thickness, Aquifer, Geoelectric Sections, Groundwater, Sounding Curve, Subsurface Soils.*

1. Introduction

Exploratory geophysics generally is aimed at the determination of the overburden layering and thickness in an area with the specific objectives of obtaining information on; subsurface minerals, structural stratigraphy, archaeological sites and other useful geological/geophysical information that may be needed for; exploitation of the mineral resources, studies of the region or engineering/structural construction purposes [1]. For overburden information on aquifer depth/thickness/properties, and for engineering/building construction purposes, the electrical resistivity method is very suitable because the electrical resistivity of soils and its constituents can be mapped and related to the above properties [2]. The operational principle is the electrical conductivities of different rock formations and their contents which can be exploited to determine; soil layering, aquifer depth/thickness and their characteristics. Apart from these, many authors have shown that the apparent resistivity from the field surveys using this method when interpreted can be used for; groundwater exploration [3;4]; mapping underground river channels [5]; assessment of soils for structural foundations [6;7]; landfill site investigations [8] and more.

The presence of hydrocarbon in the Niger delta, Nigeria and its exploration has led to the emergence of urban towns in the region and subsequent pressure on social amenities as water, roads and housing. One of such area is Abua town and its environs in Rivers State, south-south of the Niger delta, Nigeria. The region is witnessing rapid development with increased population and pressure on available social amenities. To accommodate this, more structures and water facilities are daily springing up in this region. Currently, to meet with the demands associated with these developments, conventional methods as excavation and blind drilling of boreholes for ground water and building of structural facilities are carried out without adequate information of the subsurface soil information. These methods have limitations because they are risky and destructive of the environment. Therefore, non-destructive approaches as the electrical resistivity survey methods which are cost effective and can provide

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reasonable information on subsurface that can be used for soil profiling, determination of aquifer thickness/depths and characterization among others should be adopted.

The study area has several settlements that include the Abua Central and Okpedan clans and with the rapid development in these areas, they require statistical information on the topographical and subsurface composition to aid in the planning and development of the area. This work provides information on soil layering and aquifer thickness/depths for borehole drillings and construction of engineering/building structures in this region.

2. Geology and Lithology of Study Area

Abua and its environs is south of the Niger delta, south-south of Nigeria in latitude 4^{o}4650.3 E and longitude 6^{o}3825.2 N at an elevation of 25 m (Fig.1). The area is within the Abua Local Government Area that shares boundary with Ahoada East, Emuoha and Degema Local Government Areas of Rivers State. It also shares boundary with part of Bayelsa State of Nigeria [9]. The lithologic rock types in the region are laterites, clay, sands and shales [10]. According to NDRDMP [9] it is a tropical region with two seasons of dry and raining seasons. The average annual rainfall is about 2340 cm with about 50% of it infiltrating and recharging the groundwater and occurring mostly within the months of April to October. The rivers in the area are of both fresh and saline water.

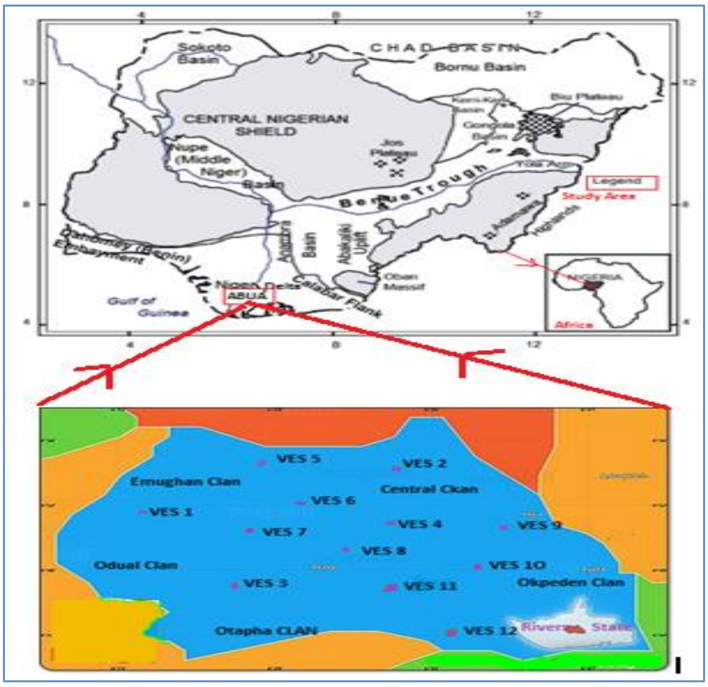

Fig.1: The study area (Google and MapHills [1]

Three major Formations, the Benin, Agbada, and Akata formations have been identified by several authors in the Niger delta [4]. The Benin Formation is the topmost of the formations with partly unconsolidated sand and sandstones which are coarse to fine and granular in texture; and it contains the aquifer zones of the region [12; 13]. These same authors have identified two types of aquifers in the region; one of Holocene age that is more prolific and is unconfined and the second of Oligocene age that is less prolific and underlies the first. The water table depths range from about 3 m to 15 m below the earth surface with existing boreholes in most parts of the region at depths of 15 m to 40 m [13]. Eke and Umuokoro [7] have identified that top soils in the region from depths of 1.0 m and below the earth surface can support building and engineering structures depending on the structural type.

3. Material and Method

Ground resistivity of formations are influenced by several factors such as grain size, porosity, density moisture content and its composition; and other geological factors. From [1] the apparent resistivity, ρ_a, in a homogenous ground determined from electrical surveys with arbitrary electrode spacing is related to the voltage, v (Volts), and current, I (Ampere) by

$$\rho_a = k\frac{v}{I} \quad 1$$

$$k = \frac{1}{2\pi}[(\frac{1}{AM} - \frac{1}{BM}) - (\frac{1}{AN} - \frac{1}{BN})] \quad 2$$

k is the geometric factor, A and B are the current electrode points, while M and N are the potential electrode points. For the Schlumberger array adopted in this work,

$$k = \frac{\pi}{MN}(\frac{AB}{2})^2 \quad 3$$

with $AB >> MN$ and is approximately five times the depth of investigation.

To obtain the vertical layering of the subsurface in this survey, a stepwise increase in the current injecting electrode spacing AB was increased from 5 m to 400 m and MN expanded accordingly in smaller steps to obtain the current and voltage figures which were used to determine the apparent resistivity of the subsurface. Twelve VES profiles were taken in the study area; and a sounding curve of log ρ_a against log $AB/2$ using IPWIN2 software revealed the layering resistivities, thickness and depths. The transverse resistivity, $T/\Omega m^2$, and the longitudinal resistivity, S/mho, in each geoelectric section were computed from

$$T = \rho t \quad 4a$$

$$S = \rho / t \quad 4b$$

respectively, where ρ is the layer resistivity and t/m is the layer thickness.

An isopach map of the area was also obtained using Sulfur 8 software.

4. Results and Discussion

The twelve VES points are located in; Abua Dumpsite (VES 1), Omelema Waterside (VES 2), Emoh Road Abua (VES 3), Abua Peter Environs (VES 4), Omelema Primary School (VES 5), Odaga Community (VES 6), Ogbom (VES 7), Iyak Community (VES 8), Ighom (VES 9), Elok (VES 10), Government Secondary School Abua (VES 11) and Omeraka (VES 12).

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Figure 2 shows the sounding curve plots of log ρ_a against log *AB/2* and Tables 1 and 2 are summary of the interpreted field values from the curve plots. The sounding curve types include types A, H, K, KA, HK and KH.

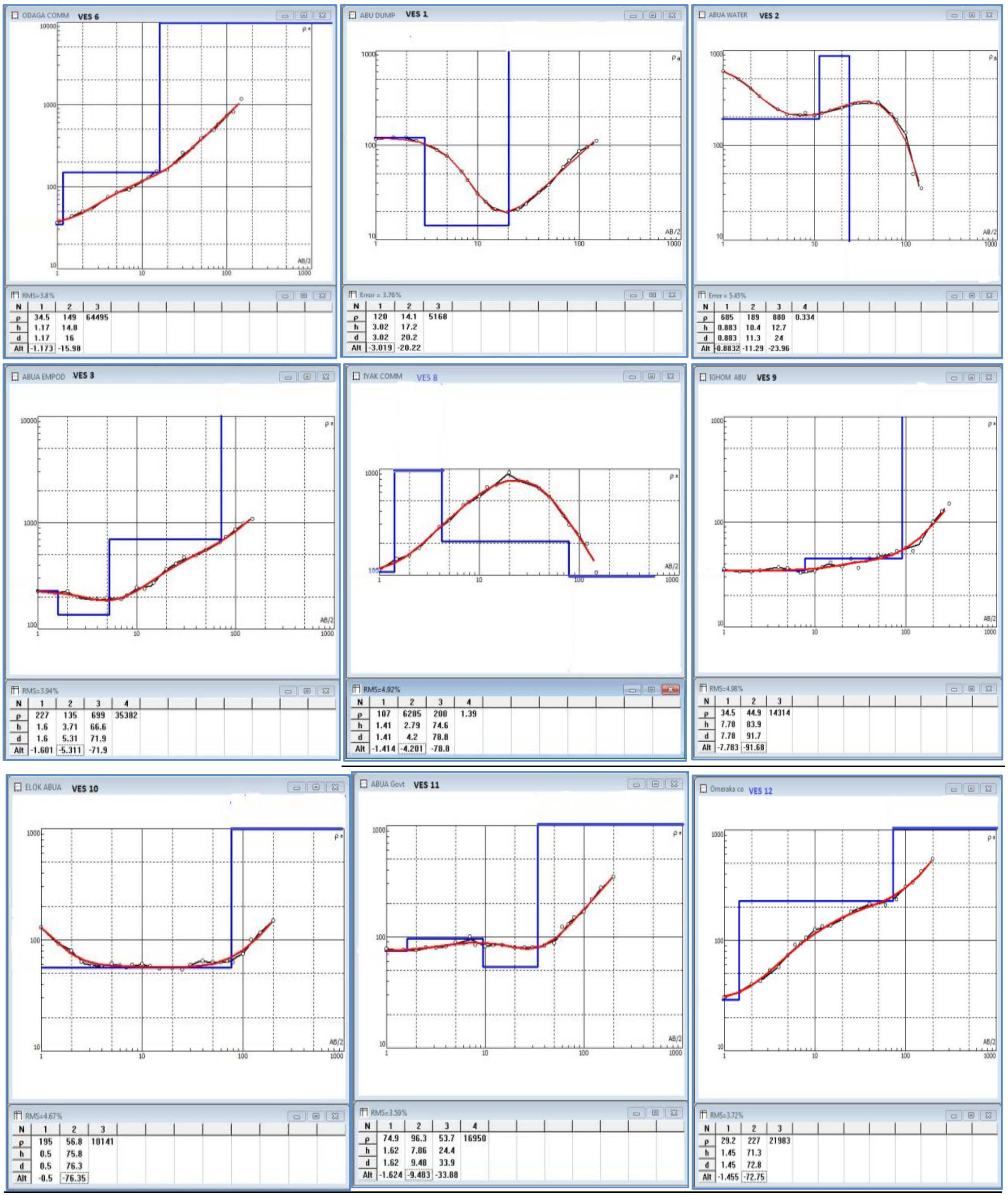

Fig.2: Sounding Curves of log ρ_a against log *AB/2* for the twelve profiles

Table 1: Overburden Resistivity and Geoelectric Layers in Study Area

VES Location	Layer 1 $\rho_1(\Omega m)$	Layer 2 $\rho_2(\Omega m)$	Layer 3 $\rho_3(\Omega m)$	Layer 4 $\rho_4(\Omega m)$	Curve Types/ Characteristics	Number of Geoelectric Layers
1	120.0	14.1	5160.0	-	$H: \rho_1 > \rho_2 . < \rho_3$	3

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2	685.0	189.0	880.0	0.3	$HK: \rho_1 > \rho_2 . < \rho_3 > \rho_4$	4
3	227.0	135.0	699.0	35382	$KA: \rho_1 > \rho_2 < \rho_3 < \rho_4$	4
4	101.0	199.0	332.0	-	$A: \rho_1 < \rho_2 < \rho_3 :$	3
5	117.5	292.5	484.2	-	$A: \rho_1 < \rho_2 < \rho_3 :$	3
6	34.5	149.0	6449.5	-	$A: \rho_1 < \rho_2 < \rho_3 :$	3
7	35.7	237.0	6993.8	-	$A: \rho_1 < \rho_2 < \rho_3 :$	3
8	107.0	6285.0	208.0	-	$K: \rho_1 < \rho_2 > \rho_3 :$	3
9	34.5	44.0	1431.4	-	$A: \rho_1 < \rho_2 < \rho_3 :$	3
10	195	56.8	1014.1	-	$H: \rho_1 > \rho_2 < \rho_3 :$	3
11	74.9	96.3	53.7	16950	$KH: \rho_1 > \rho_2 < \rho_3 :$	4
12	29.2	227.0	2198.3	-	$A: \rho_1 > \rho_2 < \rho_3 :$	3

Table 2: Aquifer Properties Thickness, Depth and Resistivity

VES Location	**Resistivity** $\rho(\Omega m)$	**Overburden Thickness (m**	**Elevation (m)**	**Transverse Resistivity** (Ω **m**^{2}**)**	**Longitudinal resistivity (mho)**	**Aquifer Thickness (m)**
1	14	20.2	9	282.2	0.6931	17.2
2	880	24	34	21120	36.6667	12.7
3	699	71.9	13	50258	9.7218	66.6
4	199	34.1	9	6786	5.8358	33.1
5	292	4.2	21	1226	69.5238	3.33
6	149	16	17	2384	9.3125	14.8
7	522	26.7	11	13937	19.5506	30.1
8	208	78.8	20	16390	2.6396	74.6
9	45	91.7	25	4127	0.4907	83.6

10	57	76.3	23	4349	0.7471	75.8
11	54	33.9	32	1831	1.5929	24.4
12	227	72.8	15	329	156.5517	71.3

From the sounding curves in Figure 2, locations 2, 3 and 11 are four layered geoelectric sub-sections implying that the survey penetrated four different subsurface soils with the bottom depths of the fourth layers not defined. The others are three layered geoelectric subsurface with overburden thickness of between 4.2 m at location VES 5 in Omelama community and 91.7 m at location VES 9 in Ighom community. The region has high resistivity values with 14.1 Ωm in location VES 1 and 35382 Ωm in location VES 3 with potential aquifers from the depths of 4.5 m and below the earth surface in the region.

The thickness of the soil profile gives an insight of the groundwater potential as shown from the isopach map in Figure 3.

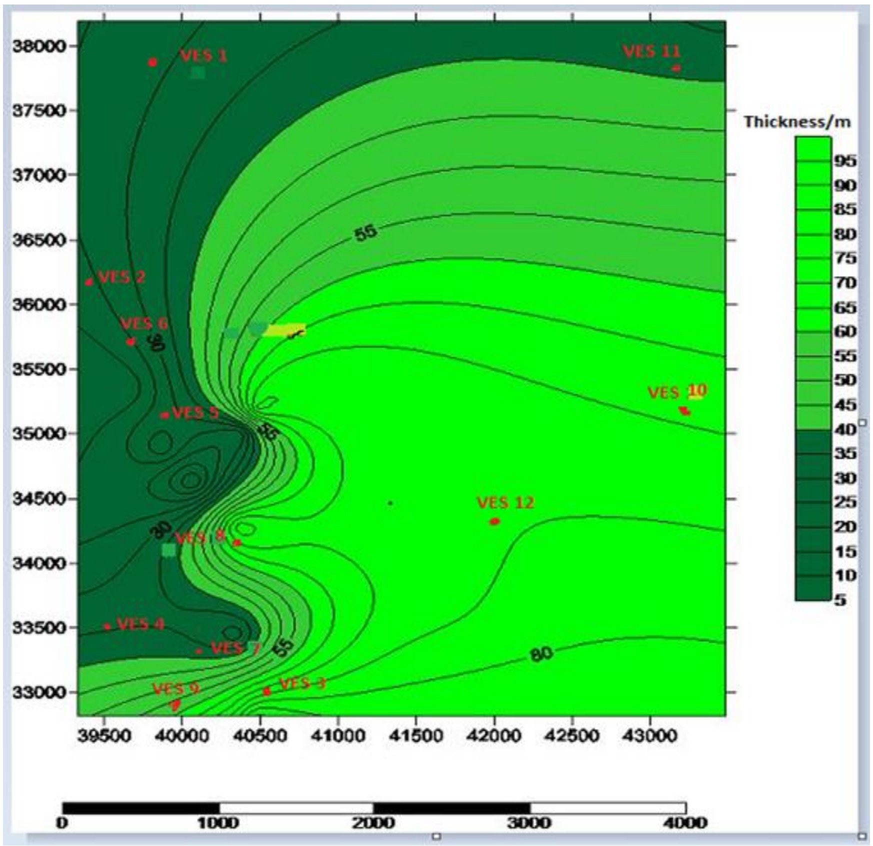

Fig.3: Isopach Map of Study Area

The area is made up of shallow aquifers that are highly variable in thickness as in VES 1, 2, 4, 5, 6, 7 and 11. The segments with colour legend green and leave green corresponds to the first and second zones with thickness ranging from 5 to 40 m and 40 to 60 m respectively. VES 3, 8, 9, 10 and 12 falls within the third zone, colour legend light green, which corresponds to the relatively thick aquifers with thickness ranges of between 60 m to 90 m. The high transverse resistivity values in most of the locations are indications that the aquifer materials are highly permeable to fluid movement within the aquifer with good groundwater potentials [14] whereas the opposite is the

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case for locations VES 1 and VES 12. Boreholes located at locations within the high transverse resistivity values will also have high trasmissivity values suggesting that a greater part within the study area is of considerable permeability to groundwater movement within the aquifer.

The resistivity of the subsoil layers in this area suggest top soils of sand and silts down to coarse sands common in the region as in the seen from the studies of [7]. These soils can support engineering foundation from depths of 1.0 m depending on the type of building/engineering structure.

5. Conclusion

The subsurface layering of this region down to a depth of 91.7 m has been inferred from this study. The soil resistivity values, which are high, are typical of soil bodies of sands, silts and coarse sands common in this region from earlier studies. These sand bodies can support foundational structures of building/engineering structures from depths of 1.0 m and below. Potential aquifers of variable thickness of between 5 to 60 m thickness at depths of from 4.5 m and down the earth surface can also been identified from the study which means that portable boreholes for groundwater can easily be drilled in this region. The aquifers also have high transverse resistivity values in most of the locations, an indication that the aquifer materials are highly permeable to fluid movement with good groundwater potentials.

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