JEAS

JOURNAL OF ENGINEERING AND APPLIED SCIENCES

Journal of Engineering and Applied Sciences13 (2018),110-122

GEOPHYSICAL MAPPING AND ASSESSMENT OF GROUNDWATER POTENTIALS FOR SUSTAINABLE DEVELOPMENT IN UYO, AKWA IBOM STATE

Ekpo, A.E.[1*], Orakwe, L.C.[1] and Abarikwu, O. I.[2]

[1]Department of Agricultural & Bioresources Engineering,
Faculty of Engineering,
Nnamdi Azikiwe University,
Awka, Anambra State, Nigeria.

[2]Department of Civil Engineering,
College of Engineering,
Gregory University,
Uturu, Abia State, Nigeria.

[*]Corresponding Author's Email: akanimoekpo@gmail.com: (+2348067461419)

Abstract

Spatial variation of surface water has made groundwater the sustainable means of potable water supply, hence the need to delineate them into their bearing capacity. In this study geophysical evaluation of the groundwater is aimed at delineating the aquiferous units within the study area into their groundwater potentials zones. The Schlumberger Automatic Analysis (SAA) version 0.92 was used to analyze the data in order to determine their depths, thickness, resistivity and the potential depths of boreholes at various locations chosen arbitrarily within the study area. Seventeen (17) locations were probed. The VES curve types found within the study area include H, K and A, but it is predominantly made up of K type of curve. Results obtained showed three to six geoelectric layers of the soundings. The aquifer depths vary from 42 to 160m; the aquifer thickness varies from 33 to 153m. The hydraulic conductivities range from 0.0556cm/s to 0.4545cm/s while the transmissivity range from 2.5754cm^2/s to 38.6325cm^2/s. The final groundwater potential map shows that the study area has reasonable amount of groundwater reserve for sustainable groundwater infrastructural development ranging from low to high potentials

Keywords: Aquifer Thickness, Aquifer Resistivity, Anisotropy, Hydraulic Conductivity, Vertical Electrical Sounding (VES) and Transmissivity.

1. Introduction

The unequal distribution of rainfall has made the availability of water to be a subject of interest, since the ill-effect of water scarcity has caused tremendous havoc which has resulted to global concern. Water is life; the development of a particular area is determined by the quality and quantity of water available to the population of the area. Several millions of people do not have access to potable water and this has resulted to the prevalence of water borne diseases in some regions of the world, especially in developing countries. In the planning and management of water resources development, the first step is to estimate the future population of the area and their water consumption per capita per day so as to determine the quantity of water which must be provided. Secondly, the most important step is to determine a source of water supply of high quality with less treatment for potable water supply. In Uyo, the major source of water for domestic, industrial and agricultural uses is groundwater with little surface water available within the rural areas of Uyo which is of low and degradable quality. As such, for good supplies of groundwater, geophysical survey must be carried out carefully to make optimal use of the available groundwater through boreholes and wells.

Geophysical method is aimed at measuring the properties of the formation materials, which determine whether such formation may be sufficiently porous and permeable to serve as an aquifer. Conducting geophysical investigations include survey design, data acquisition and data analysis. These three aspects of an experiment are commonly treated independently and the applicability of the method under the geological conditions must be taken into account (Akpabio *et al.*, 2003).

A number of geophysical exploration techniques are available which gives an insight of the nature of the water bearing layers and these include geoelectric, electromagnetic, seismic and geophysical borehole logging (Alile, *et al.*, 2008). The electrical resistivity method and seismic refraction methods are the surface geophysical methods commonly used for groundwater exploration (Asawa, 2009; Ozegin and Oseghale, 2012). Geophysical techniques are powerful tools used to identify aquifer systems for sustainable development of groundwater resources in a basin and play important role in the delineation of aquifer configuration under varying hydro geologic condition (Alile *et al.*, 2008). The use of electrical resistivity measurements of geophysics for groundwater resource mapping, mining, geotechnical investigation, water quality evaluation and the vulnerability assessment of aquifers has been a favorite tool of geophysics for many decades and now tremendously increased over the last few years due to rapid advances in computer technology and associated numerical modeling techniques (Jha, *et al.*, 2008; Ekpo *et al.*, 2016).

2. Materials and Methods

2.1 Location and Geology of the Study Area

The study area is Uyo, Akwa Ibom State, Nigeria located in the Niger Delta region, lies between latitude 5^o 05’ North to 4^o 55’ N and Longitude 8^o 00’ East to 7^o 50’ East. The city has a hilly or undulating nature and semi equatorial type of climate. The major vegetation belt within the area is fresh water swamp and rainforest (Ekwere *et al*., 1994). Geologically, the study area belongs to the area classified as coastal plain sands known as the Benin Formation (Mbipom *et al*., 1996). The Benin Formation is the uppermost unit of the Niger Delta Complex and overlies the Agbada Formation.

The Benin Formation is Oligocene and the youngest formation of the Niger Delta sedimentary basin. It is composed of continental flood plain sands and fluvial deposits. The essential features of the Benin formation have been reviewed by various authors: (Akpabio *et al*., 2003; Short and Stauble, 1967).

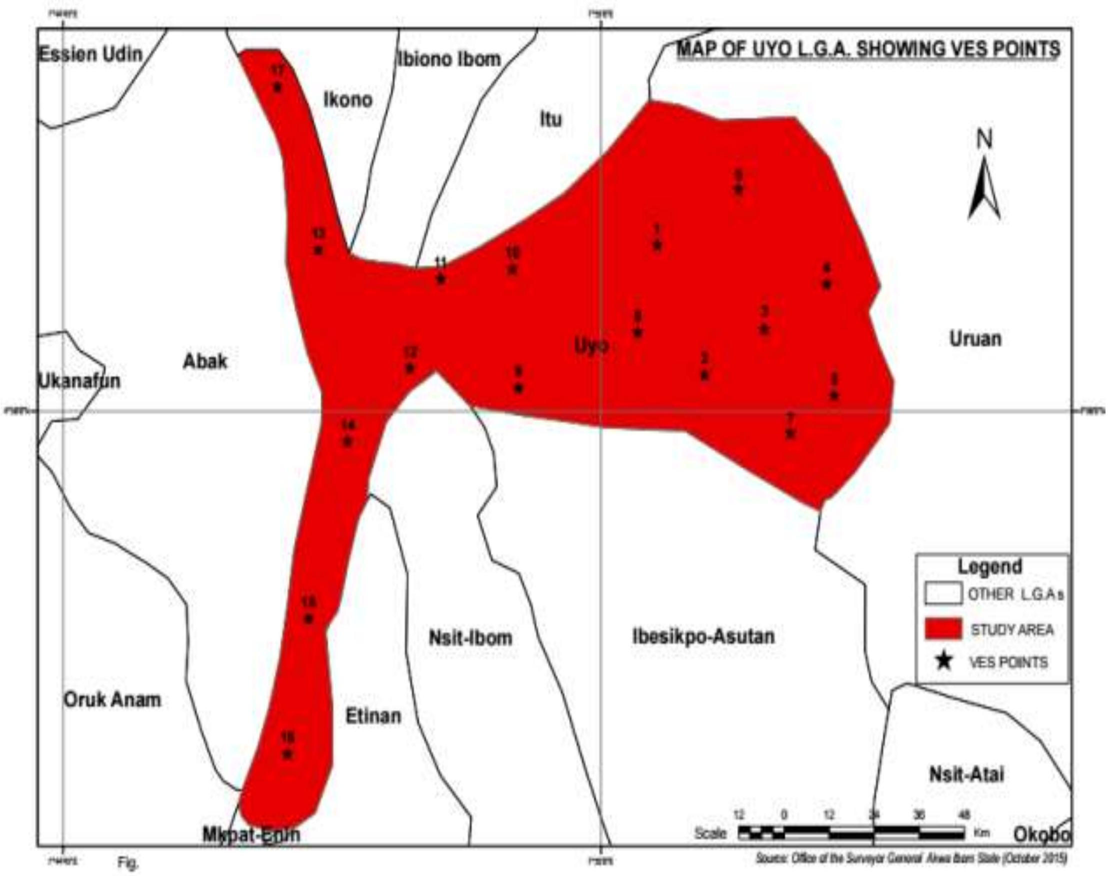

Fig.2.1 Map of the study area showing VES points.

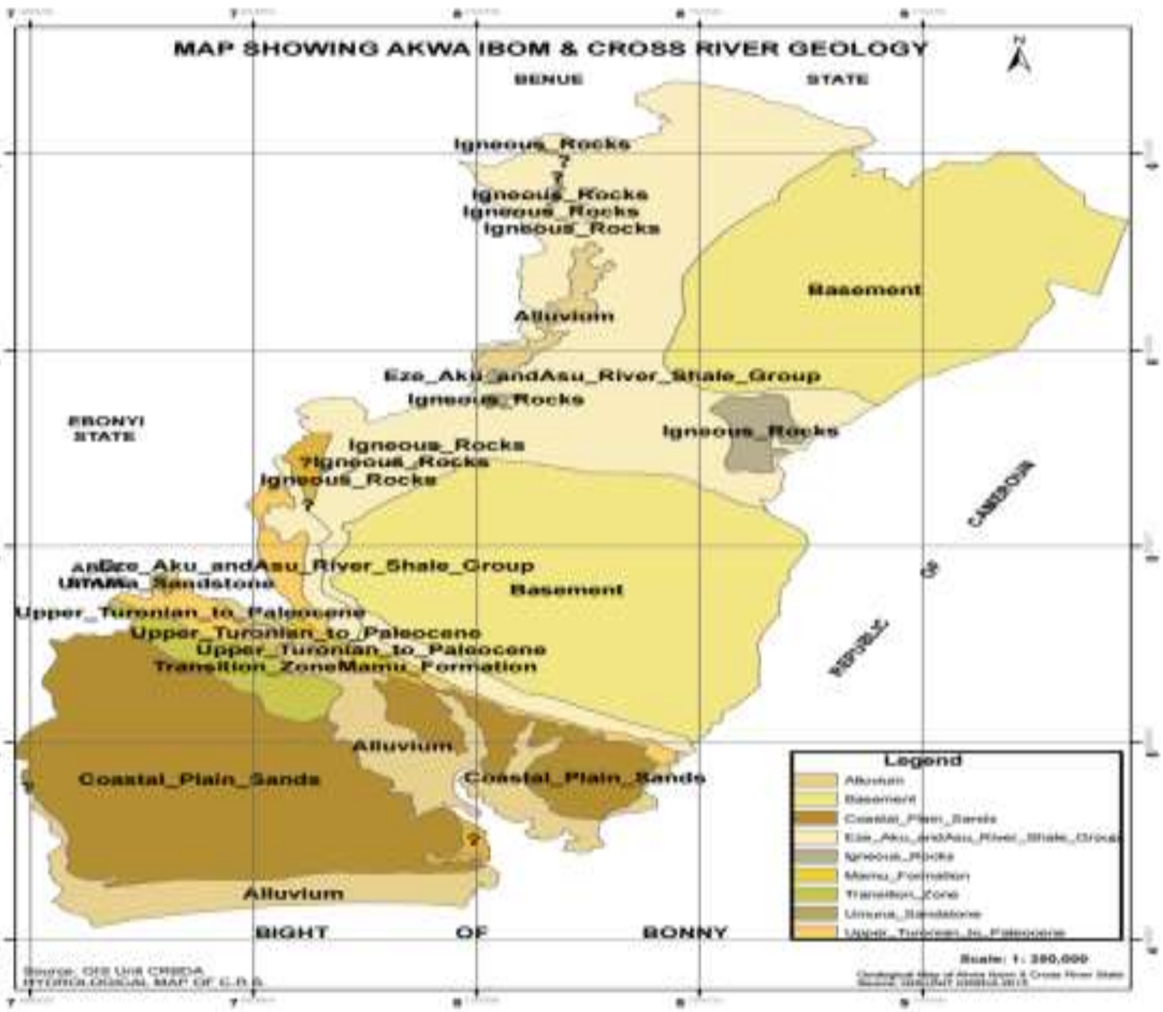

Fig.2.2 Geological map of the study area

2.2 Experimental Field Procedure and Data Acquisition

The ground resistivity is related to various geological parameters such as the mineral and fluid content, porosity, nature and degree of water saturation in the rock. Surface Electrical Resistivity surveying is a geophysical operation in which measurements of earth resistivity are made from the ground surface (Michael, 1978). Geophysical methods provide indirect evidence of the subsurface formation that may indicate whether the formations are possible aquifers (Michael, 1978). These methods, especially the resistivity method, measure properties of formation materials, which determine whether such formation may be sufficiently porous and permeable to serve as an aquifer. Anizoba et al., (2015) used areas of thick overburden (materials above the bedrock) and the iso-resistivity maps showing the resistivity distribution of the aquifer layers in mapping promising areas for groundwater abstraction.

The vertical electrical sounding (VES) is a field technique used to measure the variations of resistivity with depth. The field procedure involves measuring the apparent resistivity as the mid-point is kept fixed while the distance between the current is progressively increased. The

Schlumberger array was used during the sounding test. After data acquisition, the apparent resistivity values were plotted against half the current electrode spacing on bi-logarithmic graph paper. The curves obtained on the bi-logarithmic paper will be matched with the standard curves to produce the H, A, K or Q curves. Terrameter SAS 300B was used for this study; it transmits a well-defined and regulated square wave, which minimizes induction effects and attenuation. The depth of probe was between 300m to 800m, current was introduced into the ground by a pair of steel stakes driven into the ground and the corresponding potential difference (V) was measured by a pair of electrodes. The electrode separation allows for the calculation of apparent resistivity of the earth. The sounding data were interpreted using computer software (Schlumberger Automatic Analysis, V0.92). Seventeen (17) vertical electrical sounding (VES) points were conducted at various locations within the study area in order to study the variations in the resistivity distribution of the soil with depth. The spatial location of the VES points in the study was recorded using the GPS as shown in table 3.1 which is useful in producing the different maps of the study area. After the interpretation of the graph results obtained other parameters can be estimated which will be useful in the delineation of groundwater potentials such as transmissivity and the hydraulic conductivity of the aquifers for proper understanding.

Transmissivity is a measure of how much water can be transmitted horizontally. It is directly related to the horizontal hydraulic conductivity (K) and the thickness (b) of the aquifer. Expressing K in m/day or cm/s and b in m, the transmissivity (T) is found in unit m^2/day or cm^2/s.

$$T = Kb \quad (2.1)$$

The transmissivity of the aquifer is related to the field hydraulic conductivity (K) by the equation above. According to Niwas and Singhal (1981) in a porous medium is given by;

$$T_c = K_c b \quad (2.2)$$

Where;

T_c = Calculated transmissivity (m^2/day)

K_c = Calculated hydraulic conductivity (m/day) from VES data.

b = Thickness of saturated layer (m).

Hydraulic conductivity is symbolically represented as *K*, which is a property of rock that describes the ease with which water can move through pore spaces or fractures. It depends on the intrinsic permeability of the material and on the degree of saturation. Saturated hydraulic conductivity, K_{sat}, describes water movement through saturated media.

$$K_c = 1/\rho \quad (2.3)$$

where;

K_c is the calculated hydraulic conductivity

ρ is the resistivity of the saturated layer

Table 2.1: GPS locations of the Sounding points

VES No.	East (M)	North (M)	Elevation (M)
1	381885.354	555911.042	30
2	383541.63	552021.019	20
3	385665.008	553389.654	10
4	387845.539	554701.083	29
5	384754.289	557507.81	30
6	388127.085	551385.017	24
7	386577.38	550244.081	25
8	381193.118	553282.482	20
9	377005.205	551631.567	10
10	376781.87	555176.358	15
11	374258.885	554894.844	15
12	373164.931	552209.822	20
13	369960.649	555759.956	20
14	370982.46	550041.229	15
15	369597.117	544784.118	20
16	368844.541	540726.43	18
17	368536.248	560621.937	23

3.0 Results and Discussions

3.1 Graphical Representation of Sounding Results

In this section, Fig 3.1 to Fig 3.3 shows the graphical representation of the field data as computed by the computer software (Schlumberger Automatic Analysis, V 0.92). The vertical axis represents the resistivity of the earth while the horizontal axis represents half spacing of the electrode.

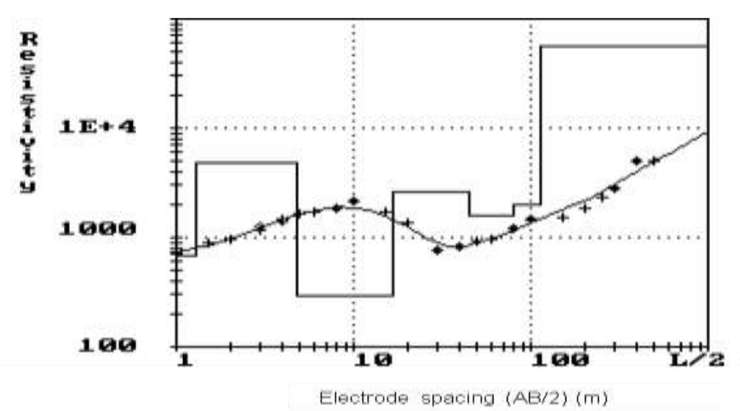

Fig.3.1: Resistivity graph of VES 1

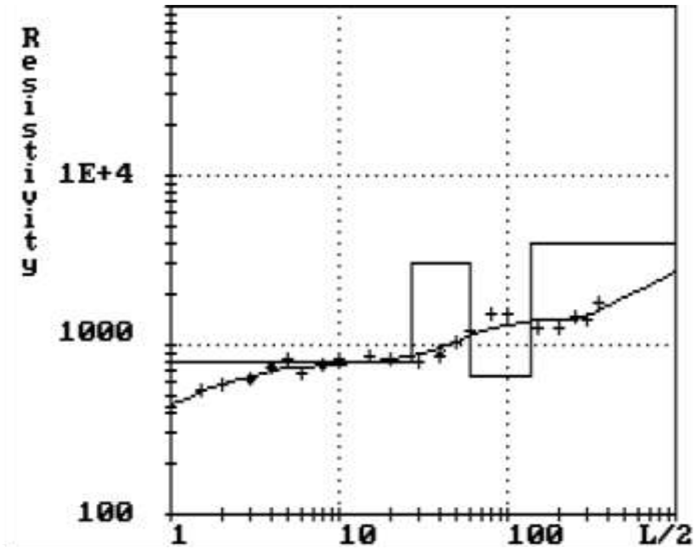

Fig.3.2: Resistivity graph of VES 2

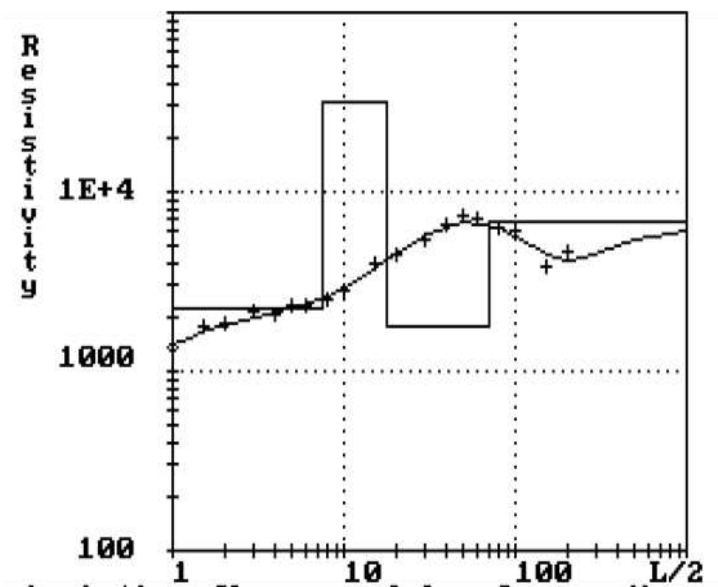

Fig.3.3: Resistivity graph of VES **3**

3.2 Aquifer Parameters Estimated From VES Data

This section shows the interpreted result of the graphs as shown in Table 3.1. The estimation of the aquifer parameters from the VES data are dependent on the aquifer resistivity and thickness of the aquifer where other parameters were generated.

Table 3.1 Aquifer parameters estimated from VES data

VES No	Location	No of Layers	ρ(ohm- m) b(m) 1	ρ(ohm-m) b(m) 2	ρ(ohm-m) b(m) 3	ρ(ohm-m) b(m) 4	ρ(ohm-m) b(m) 5	ρ(ohm-m) b(m) 6	Curve Type
1	Itam Etoi	6	695 0.48	4900 4.52	290 12.48	2500 37.52	1700 43.80	1900 76.20	H
2	Afaha Oku	4	800 29.00	3000 31.00	700 119.00	3900 -			K
3	Iba Oku	4	2200 7.80	32000 10.20	1800 59.80	6600 -			A
4	Afaha Effiat	3	1900 2.90	900 35.10	320 -				K
5	Ifa Atai	4	2900 2.80	220 6.20	1600 153.80	4500 -			K
6	Ifa Ikot Okpon	7	5000 2.80	1800 6.20	6500 14.80	500 27.20	1100 32.80	25000 87.20	H
7	Nsukara	6	1500 1.55	4900 2.25	998 4.75	3500 35.25	600 64.75	7000 -	K
8	Ikot Anyang	5	500 1.30	750 3.60	8500 46.40	310 101.60			A
9	Uniuyo	6	2500 2.00	1000 3.00	4000 22.00	600 55.00	11000 67.00	180000 -	H
10	Use Offot	4	800 28.00	3000 32.00	650 118.00	4900 -			K
11	Aka	5	2800 1.60	190 1.20	19000 13.80	2900 42.00	500 -		K
12	Ikot Ntuen	4	3900 4.90	1300 9.10	8000 45.90	220 -			A
13	Obot Ubom	5	2000 1.95	700 6.55	5200 33.45	1500 76.55	85000 -		K
14	Nduetong	4	900	3900	590	10200			A

	Oku		9.00	23.00	77.00	-			
15	Nung Uyo Idoro	5	790 3.00	4900 27.00	670 33.00	1900 58.00	10600 -		K
16	Mbak Etoi	4	800 29.00	3000 32.00	630 118.00	4100 -			A
17	Itam Itu	5	2800 1.60	390 2.30	5000 7.70	920 64.30	120 -		K

b represents thickness of the targeted aquifer

ρ represents the resistivity of the targeted aquifer

3.3 Aquifer Resistivity

The resistivity map as shown in (Fig3.4) depicts the resistivity distribution of the aquiferous layers measured in (ohm-m). This shows the resistivity of different layers of the earth and has proven useful in mapping promising areas for groundwater abstraction. The part of the resistivity map representing a low resistivity region (i.e. the blue region) could be potential ground water zones due to low resistivity value ranging from 500 ohm-m to 700 ohm-m except in cases where the anomalies are very high and increase in the thickness of the aquifer.

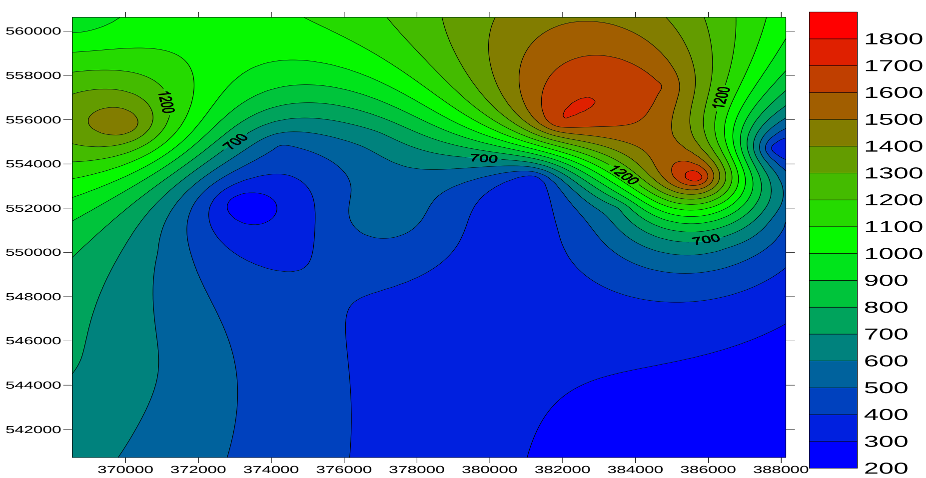

Fig.3.4. Resistivity Map of the study area.

3.4 Aquifer Thickness

The map of the aquifer thickness as shown in Fig3.5 shows that the thickness of the aquifer computed from the resistivity soundings ranges from 27.20m at VES 6 to 153.80m at VES 5. Other high aquifer thickness values are observed in VES 1, 4, 5, 8, 10, 12, and 16 with values exceeding 80meters. The thickness tends to spread throughout the map, this indicating that the aquifer of the study area is thick and prolific and can be tapped by many productive boreholes and wells.

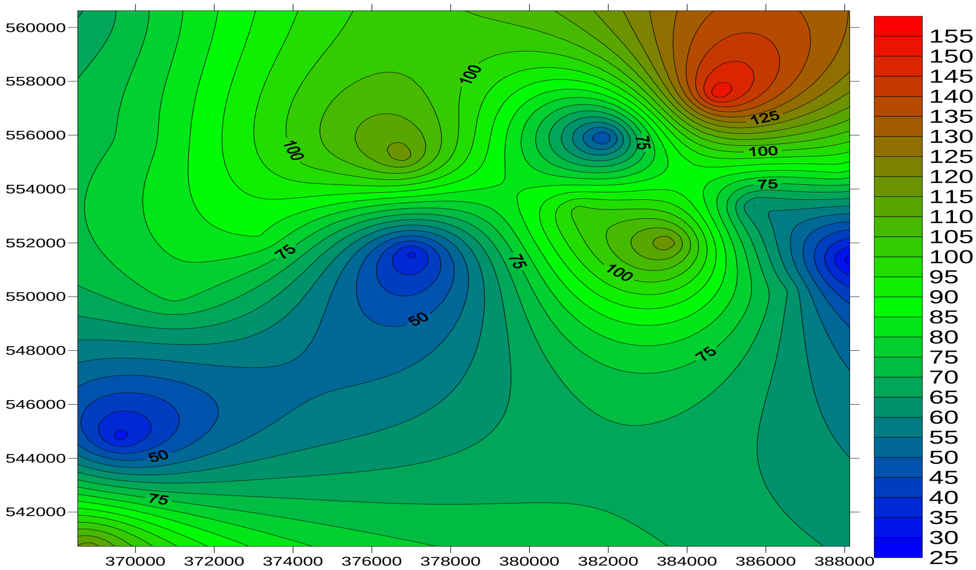

Fig3.5. Aquifer Thickness Map of the Study Area

3.5 Coefficient of Anisotropy Map Layer

Fig 3.6 shows the overburden's coefficient of anisotropy, which is a function of transverse resistance and longitudinal resistance. Transverse resistance and longitudinal transverse resistance are correlated with aquifer transmissivity and is one of the parameters used to define target areas of good groundwater potential. Higher values of transverse resistance indicate aquiferous zones with high transmissivity. From fig 4.6, the northern zone shows higher anisotropy coefficient and decreases towards the Southern zone.

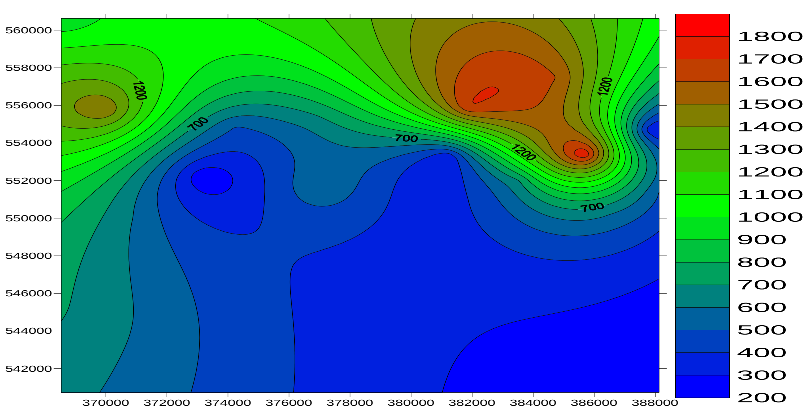

Fig.3.6 Coefficient of Anisotropy Map of the Study Area

3.6 Hydraulic Conductivity

From equation 3.3 the calculated hydraulic conductivity (K_c) values estimated from the VES results ranges from 0.0556 to 0.4545 cm/s. The hydraulic conductivity map (Fig 3.7) of the study area shows a prolific aquifer that could be tapped and developed for groundwater infrastructure.

The blue colour shows a low hydraulic conductivity while the green colour shows a medium hydraulic conductivity and the red shows a high level of hydraulic conductivity within the study.

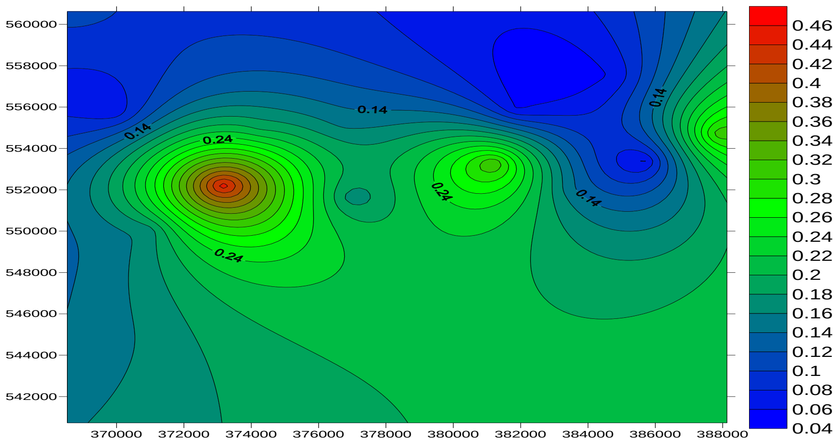

Fig.3.7 Hydraulic Conductivity Map of the Study Area

3.7 Transmissivity

Fig 3.8 shows the transmissivity map of the study area. From equation 2.1 &2.2 the calculated transmissivity (T_c) values of the study area range from 2.5754 to 38.6325cm^2/s. Thus, suggesting a reasonable quality of reservoir as an aquifer. The fundamental knowledge of transmissivity is a fundamental source of information for establishing a hydrogeological model for the delineation of potential groundwater zones. From the map the blue regions tend to have lower transmissivity value while the green and red region tend to have a higher transmissivity value which shows a prolific zone for groundwater development.

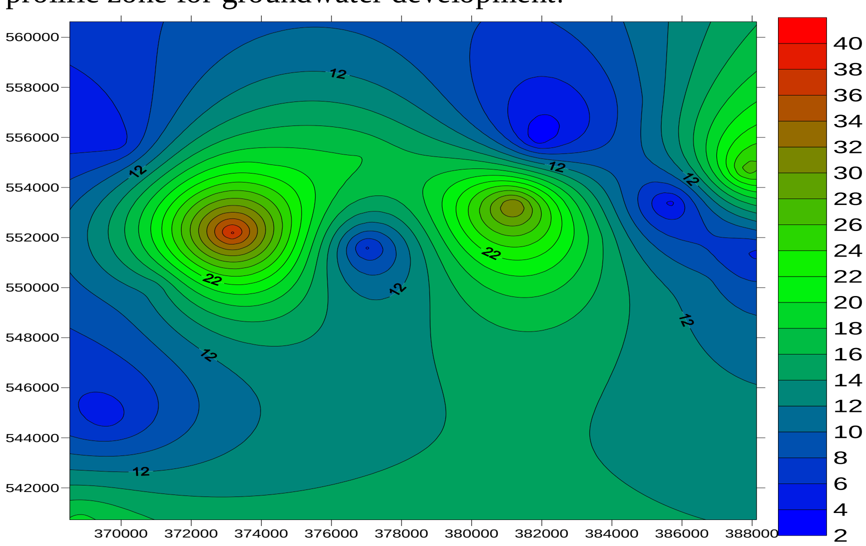

Fig.3.8 Transmissivity Map of the Study Area

3.8. Final Groundwater Potential Map of the Study Area

Final groundwater potential map of the study area was produced by overlaying the concerned maps in order to draw the final conclusion from the individual maps. The map (Fig. 3.9) presents local groundwater prospects of the study area which is zoned into high, medium and low groundwater potentials. Areas with blue colour on the map constitute the low groundwater potential zone while areas with green colour constitute the medium groundwater potential zone. Red colour represents the high groundwater potential zone. High groundwater potential zone is made up of VES 8 and 12, while VES 2, 4, 7, 10, 11, 14 and 16 are made up of medium groundwater potential zone and VES 1, 3, 5, 6, 9. 13, 15 and 17 make up the low groundwater zone of the study area. From the geologic formation of the study area, it shows that the study area is prolific for groundwater development; this is in accordance with the resistivities of 500ohm-m to 700ohms-m for fresh freshwater exploration except for case where there is change in the anomaly as a result of the bed rock materials.

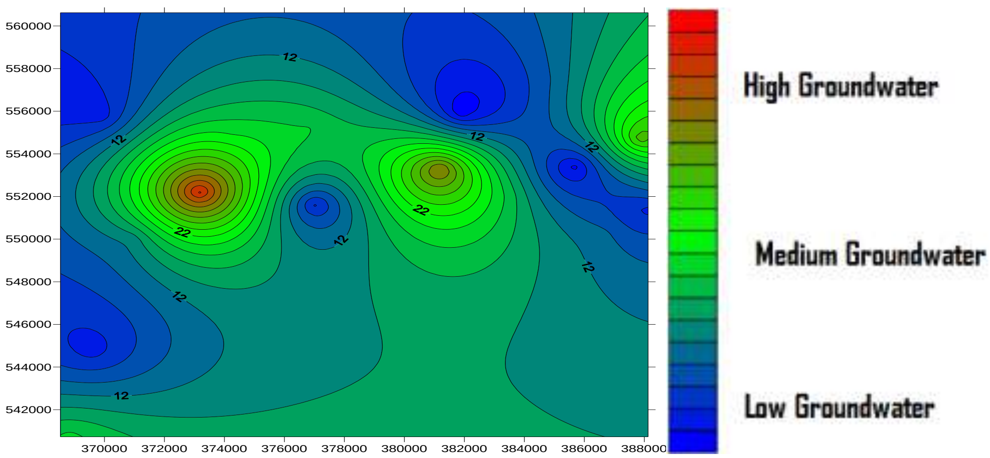

Fig3.9 Groundwater Potential Map of the Study Area

4.0. Conclusion

In conclusion, a total of seventeen (17) vertical electrical soundings (VES) were carried out and interpreted. The field data were obtained from Schlumberger electrode configuration from which the apparent resistivities were obtained. The low range of resistivity has proven to be a major success in ensuring the availability of fresh water for potable water supply, while the various thicknesses of the aquifers show that the aquifers within the study area are prolific for groundwater infrastructural development. From the interpretation of the curves, it shows that the VES curve types identified in the study area includes K, A and H type. 52.94% of all the sounding curve belong to the K-type whereas the remaining 47.05% belongs to A and H curves. Therefore, K is the most dominant sounding curve type in the study area. The hydrogeological studies have helped to delineate the aquiferous zones into their groundwater bearing potentials within the area through the help of the transmissivity and thickness of each of the sounding zones. The geologic formations of the study area shows that the aquifers are mainly sandy which is a function of the local geologic condition (Benin formation) of the study area, which exhibits a moderately low to high groundwater potentials, which reflects the geological setting of a typical sandy formation. Based on the results obtained after analyzing and interpreting the data obtained, potential aquifer has been identified for sustainable groundwater infrastructural development. The aquifers within the study area were delineated into high, medium and low groundwater potentials.

5.0 Recommendation

This research presents the hydro-geological knowledge of Uyo in order to create awareness on the productive aquifer for sustainable groundwater development within the study area. The depth to top of aquifer in the study area varies between 42m and 160m with an average depth of 103.4m for groundwater abstraction. Therefore, to avoid excessive drilling, wastage of resources and reduce pumping cost, the above depths should be targeted for groundwater infrastructural development.

References

1. Alile, M.O., Jegede, S. I. and Ehigiato, O. M. (2008). Underground water Exploration Using Electrical Method in Edo State. Asian Journal of Earth Sciences, 1(1): 38-42.
2. Akpabio, I. O., Ejedawe, J. E., Ebeniro, J. O. and Uko, E. D. (2003). Geothermal gradient in the Niger Delta from continuous temperature logs. Global Journal of Pure and Applied Sciences; Vol. 9 (No. 2): 265-271.
3. Anizoba, D., Orakwe, L., Chukwuma, E. and Nwoke O. (2015). Delineation of potential groundwater zones using geo- electrical sounding data at Awka in Anambra State, South-eastern Nigeria. European Journal of Biotechnology and Bioscience, 3(1):01-05.
4. Asawa, G. L. (2009). Irrigation and Water Resources Engineering. New Delhi, New Age International Limited Publishers.
5. Jha, M. K., Kumar, S. and Chowdhury, A. (2008). Vertical electrical sounding survey and resistivity inversion using genetic algorithm optimization technique. Journal of Hydrology, 359, 71– 87.
6. Ekpo, A. E., Orakwe, L. C., Ekpo, F.E. and Eyeneka, F. D. (2016). Evaluating the Protective Capacity of Aquifers at Uyo in Akwa Ibom State, Southern Nigeria, using the Vertical Electrical Sounding (VES) Technique.International Advanced Research Journal in Science, Engineering and Technology, Vol. 3(1): 34-39.
7. Ekwere, S. J., Esu, E. O., Okereke, C. S. and Akpan, E. B. (1994). Evaluation of Limestone in Obotme Area, Southeastern Nigeria. for Potland Cement Manufacture. Journal of Mining and Geology. 30(2):145-150
8. Ishola K, Ogunsanya S, Adiat K, Abdulrahman A. (2013). Assessing Groundwater Potential Zones in Basement Complex Terrain Using Resistivity Depth Soundings: A Case of Challenge and Oluyole in Ibadan, Southwestern. Nigeria Journal of Science; 1(1)11-32
9. Mbipom, E. N., Okwueze, E. E. and Onwegbuche, A. A. (1996). Estimation of transmissivity using VES data from the Mbaise area of Nigeria. Nigeria Journal of Physics, V. 85, pp 28-32
10. Michael A.M. (1978). Irrigation Theory and Practice. New Delhi; Vikas Publishing House.
11. Niwas, S. and Singhal, D. C. (1981). Estimation of Aquifer Transmissivity from Dar Zarrouk Parameters in Porous Media. Hydrology 50: 393-399
12. Ozegin, K. O. and Oseghale, A. O. (2012).Geophysical Characterization of Shallow Aquifers in a Sedimentary Area: A Case Study. Advances in Applied Science Research, 3 (1):469-474.
13. Short, K. C. and Stauble, A. J. (1967). Outline Geology of Niger-Delta. 51(5): 761-779.