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Investigation of the Groundwater Resources and Aquifer Characteristics in Utagba-Uno Area, Delta State, Nigeria Using Surface Geoelectric Sounding

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Abstract

A study was carried out in Utagba-uno to obtain the type and distribution of near surface aquifers and also to determine the flow direction, transmissivity and conductivity of the aquifer using the Schlumberger electrode configuration of Vertical electrical sounding, the global positioning system (GPS) and a measuring tape.

The results of vertical electrical soundings revealed that boreholes for sustainable water supply should be drilled to the fourth layer (medium grained sand) at a depth of between 20m - 30m in Utagba-uno road Ndemili, Umusam Onicha-Ukwuani road, Eke market road Umusedeli, Umusadege Ekilibi road, Adofi road Ekilibi and Adofi road Etua,. This is the best aquifer in Utagba-uno area; however, in locations within Umuseti major road and Odas road Isumpe, boreholes could be drilled to the third layer (fine grained sand) to a depth of about 10m – 15m. While in the locations at Market road Ndemili and along Etua major road, boreholes could also be drilled to the third layer (fine grained sand) to a depth of about 10m – 12m, but they are not encouraging formation for groundwater exploitation.

The Dar Zarrouk parameters were used in estimating the transmissivity which ranged between 54m^2/day-245m^2/day with an average of 122.3m^2/day. Umusam Onicha Ukwuani road having the highest transmissivity value of 245m^2/day and a reasonable aquifer thickness should be the location for any concentrated ground water project in Utagba-uno. Based on the hydraulic gradient obtained from the different wells, ground water flows from Ndemili down to Isumpe with an average hydraulic gradient of 0.0439.

. The contour of map of the static water level at Utagba-uno revealed that the ground water flows toward the southern part of the region. It is therefore recommended that dumpsites should be sited within the Southern part of Utagba-uno and none in the north, west and eastern part of Utagba-uno in order to minimize contamination. Boreholes therefore should be sited within the north, east and western part of Utagba-uno for potable and sustainable water supply.

***Keywords*:** Groundwater Potential, Vertical electrical sounding, Aquifer, contour map, driller's log, geoelectric section, transmissivity, hydraulic gradient, meter tape, longitude, latitude, dumpsite and flow direction.

1.0 Introduction

One of the major problems faced by most communities in Utagba-uno is the acute shortage of water. Water therefore is not only a basic necessity to life but essential for human existence on earth; its proximity has a great influence on human activities such as domestic, agriculture and recreation. Potable water is not only commonly found but its provision limits the setting up of villages and towns to places where there is an existence of supply [1]. To obtain a potable water supply, surface geoelectric soundings were necessary in the study are. Hence the study was carried out to establish a baseline geophysical data and hydrological characteristics using the vertical electrical sounding of schlumberger arrangement and the lithologic log from a nearby borehole in Olieogo Umuseti quarters of Utagba-uno.

The vertical electrical sounding method was chosen for this study because the instrumentation is simple: field logistics are easy and straight forward and the analysis of data is less tedious and economical [2 - 6].

The resistivity method has been used successfully in the investigation of groundwater potential in different geological settings. The method has been used to investigate the aquifer characteristics and groundwater potential in Kwale [7], Obiaruku and environs [8], sedimentary environment [9], and Obudu basement area [10].

The resistivity of water may vary from 0.20 Ωm to over 100.00 Ωm depending on its ionic concentration and the amount of dissolved solids [11, 12].

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Resistivity of natural water without clay varies from 1.00 Ωm to 1000 Ωm while that of clay only varies from 1.0 Ωm to 120 Ωm [3]. The type of curve [13], the modified table of resistivity and sediments [14], the drillers log from a nearby borehole and the knowledge of the local geology of the area were used as guides in the interpretation of resistivity data in terms of probable aquifer.

In a sedimentary environment, high resistivity may broadly be associated with the presence of fresh groundwater in aquifer, but low resistivity may result from brackish water and/or clay formation.

The combination of thickness and resistivity into single variables, other words known as Dar Zarrouk parameters are used as a basis for the evaluation of aquifer properties [15]. The concept of Dar Zarrouk parameters were first introduced in [16] to explain the problem of non-uniqueness in the interpretation of resistivity depth sounding curves. Analytical relations between aquifer transmissivity and Dar Zarrouk parameters have been developed and various data sets tested [17]. The Dar Zarrouk parameters consist of the transverse resistance (R_T) and longitudinal conductance (Lc). For a horizontal, homogeneous, and isotropic layer, the transverse resistance R_T (Ωm^2) is defined as

$$R_T = \rho h \tag{1}$$

And the longitudinal conductance Lc (mho) is defined as:

$$L_C = h/\rho \tag{2}$$

where h is the thickness of the layer (in meters) and ρ is the electrical resistivity of the layer in ohm-meters. In such a simple horizontal layer model, Niwas and Singhal [15] established an analytical relationship between transmissivity and the Dar Zarrouk parameters based on the analogy between Darcy's law of groundwater flow and Ohm's law of current flow as follows:

$$T = K/\rho(R_T) \tag{3}$$

$$T = K\rho L_C \tag{4}$$

where T is the transmissivity (m^2/d) defined as the product of aquifer hydraulic conductivity (K) and thickness (h), *i.e.*

$$T = Kh \tag{5}$$

R_T and Lc are the transverse resistance and longitudinal conductance, respectively. It has been observed that hydraulic conductivity of clayey sediment could be linked to electrical resistivity through the concept of clay content and that high clay contents generally correspond with low resistivity and hydraulic conductivity [18]. In other words, in a clay-rich aquifer, a linear relationship exists between hydraulic conductivity and resistivity [19].

Therefore, $K/\rho = C_1$ (6)

MacDonald et al [20] reported that in an unconsolidated, sandy, clay-free aquifer, a direct relationship exists between hydraulic conductivity and porosity ($K\ \alpha\ \Phi$); while an inverse relationship exists between porosity and resistivity ($\Phi\ \alpha\ 1/\rho$). Therefore,

$$K\rho = C_2 \tag{7}$$

where C_1 and C_2 are constants

Substituting Equation (6) into (3) and Equation (7) into (4) gives

$$T = R_T C_1 \tag{8}$$

$$T = L_C C_2 \tag{9}$$

The hydraulic gradient is a vector gradient between two or more hydraulic head measurement over the length of the flow path. Although no known work on hydraulic gradient has been carried out in the study area, different works have been carried out in other parts of the country. The hydraulic gradient is also called the Darcy slope; since it determines the quantity of Darcy flux or discharge. A dimensionless hydraulic gradient can be calculated between two piezometers as;

$$i = \frac{dh}{dL} = \frac{h_2 - h_1}{length}$$

where

i → is the hydraulic gradient (dimensionless).

dh → is the difference between two hydraulic heads (length usually in m or ft).

dL → is the flow path length between the two piezometers (length, usually m or ft).

The above is put into a simple statement that hydraulic gradient is defined as the vertical change in groundwater elevation over horizontal distance, in the direction of groundwater flow. It can be determined, for example using the following equation,

$$\text{Hydraulic Gradient} = \frac{\text{Water table elevation change (in direction of flow)}}{\text{Horizontal distance between measured points}}$$

Hydraulic gradient can be expressed in vector notation using the del-operator. This hydraulic head field can only be obtained practically from a numerical model, such as mode of flow.

The hydraulic grade line is a line whose height above a flowing fluid is equal to the height water raises in piezometers at that point. The slope of the hydraulic grade line is $\frac{h_L}{L}$ but $h_L = hw_2 - hw_1$

where hw_2 stands for water table elevation of $well_2$ and hw_1 water table elevation of $well_1$ and L is the distance in ft between the wells.

Hydraulic gradient is very important in the following ways; it helps the researcher to know the direction of flow of ground water within an area. It helps also in drilling of boreholes in order to avoid contaminate which may come as a result of erosion. It also indicates the flow rate of ground water and direction for proper sitting boreholes and dump sites.

2.0 Location of the Area

Utagba-uno region is in Delta state located in the South-southern geographical Zone of Nigeria, it lies within latitudes 5^0 09^1 N and 6^0 00^0 N and longitude 6^0 01^1 E and 6^0 04^1 E. It consists of seven (7) major quarters namely; Umusadege, Umuseti, Umusam, Umusedeli, Isumpe, Etua and Ekilibi. However, Ndemili and Olieogo are farm settlements of Umusadege and Umuseti respectively. It is bounded in the East by Ossissa, North by Nsukwa, West by Onicha-Ukwuani and south by Obiaruku and falls within Niger-Delta Sedimentary basin in Nigeria. The area is accessible by a network of roads. The Ossissa – Obiaruku and the Umutu-Nsukwa Express-ways are the major road into the town and the quarters are linked together by a network of roads that are not tarred (Figure 1).

3.0 Climate, Vegetation and Drainage

Vegetation refers to the plant coverage of an area. Utagba-uno is in an area of low-lying sedimentary terrain, generally flat and has gentle slope. The vegetation is that of the tropical rainforest belt characterized by dense vegetation cover consisting of evergreen forest of tall trees with undergrowth of climbing plants that are closed together along the streams and creek channels and this normally typifies primary vegetation while the presence of grassland with sparse trees and shrubs typified the secondary vegetation pattern within the vegetation belt.

Generally, two major wind systems influence the climate of Utagba-uno. They are the Northeast trade wind blowing cold dry air from the Sahara and the Southwest trade wind blowing cold moist air from the Atlantic. The South-west wind prevails almost throughout the year that is from March – October, while the North-east trade wind is responsible for the cold dry period (Harmattan) which influences the area for about four months (November – February). This brings about two types of seasons within a year; the raining and dry seasons, respectively. During the raining season, the area experiences double rainfall maximal with a period of short break around August popularly called "August break". The dry season usually known as Harmattan period is cold, dry, and dusty with no rain. This is usually very severe in the months of December and January. The major factor that is responsible for the change in the climate of Utagba-uno includes the falling of trees (deforestation) and farming thereby causing the climate prevailing in the area to be quite distinct from that of the surrounding. The surface elevations at different points vary due to topographic variations.

4.0 Geology of the Study Area

Utagba-uno is within the sedimentary region of the Niger Delta basin of Delta state situated in the South-Southern part of Nigeria. The Niger-Delta in this project applies to the entire 3-Dimensional bodies of continental, transitional and marine deposits formed by sediments from Rivers Niger and Benue. The continental deposits from the land area otherwise called the sub aerial regions. The marine deposits are the water filled region otherwise called the sub aqueous region. While the transitional deposits forms the swampy (mangrove) regions [21 – 22]. The structure of the continental geologic framework directed River Niger and Benue towards the present site of the Delta. Hence the geology of Niger-Delta, like other parts of the earth has undergone different changes right from the tectonic setting through the paleogeographic evolution to the present day. This development of the Delta has been dependent on the balance between the rate of sedimentation and subsidence. The balance and the resulting sedimentary patterns appear to have been influenced by the structural configuration of tectonics of the basement [23, 24]. Physical observations within the study area include; lateritic soil, clay soil and sandy soil.

5.0 Materials and Methods

Detailed investigation of the aquifer potential in Utagba-uno was carried out using surface geophysical measurements. The materials used includes the following: terrameter, cables/wires, and electrodes, measuring tape, cutlass, car battery, sledge hammer, clips, umbrella, the Global Positioning System (GPS) and the meter tape. Electrical resistivity method using Vertical Electrical Sounding (Schlumberger array) is adopted in this investigation. A detailed account of the use of this method can be found elsewhere [2 – 5, 7, 25 - 28]

The basic method employed in this work, is the surface resistivity sounding. In this method, current is introduced artificially into the earth through a pair of electrode pinned to the ground (current electrode) and the resulting potential difference due to the current is measured through another pair of electrode (potential electrode) that is also pinned to the ground, any subsurface variation in conductivity alters the current flow; which in turn affects the distribution of electric potential at the surface [29 – 36].

The location and geology of the area were noted and a map of the area was sketched out. The vertical electrical sounding technique using the schlumberger array method was used in the field. A spot was marked out as the base station where the terrameter and the battery were placed to serve as the centre of the array and the reference point is marked using an electrode. Two current electrodes were placed 1m away from the terrameter at opposite sides of the terrameter, the same thing was done with the potential electrodes but these are placed at 0.5m away from the terrameter. The electrodes were driven fast into the ground with the help of a sledge hammer. The cables/wires were connected from the terrameter to the electrodes and clipped to the electrodes in order to make sure that the wire is in contact with the electrode while reading is taken.

The terrameter was switched on and current passed from the terrameter through the electrodes into the ground. The current and voltage readings were recorded after which the terrameter was switched off in order to avoid electric shock while handling the electrodes and cable wires. The current electrode distance was increased to 2m then the same procedures were repeated at 2m, 3m, 4m and 6m.

The procedures were repeated at specified current electrode spacing while the potential electrode separations were increased after every four current electrodes spacing. When suitable quantities of data were recorded, the array was disconnected and the equipments were moved to another VES point. A total of 10 (ten) VES (vertical electrical soundings) were obtained from different locations evenly distributed within Utagba-uno using the schlumberger electrode configuration array. The field data acquired was plotted on a log-log graph with electrode spacing (AB/2) on the x-axis and the apparent resistivity (ℓ_a) on the y-axis. The field curves were curve-matched using a conventional curve matching technique. The resulting curves were interpreted both qualitatively and quantitatively. The resistivities and thickness obtained from the partial curve matching were improved upon by employing an iterative computer program to obtain the layer parameters (Figures 2 - 9). The type of curves, the resistivity of the sediments and the local geology of Utagba-uno-Uno were used in the interpreting the near surface aquifers. In Utagba-uno, four-five layers were revealed within the probed zone. In general the sedimentary lithologies of the area were lateritic, fine-sand and medium grained sand. The results obtained from Utagba-uno were correlated with driller's logs from Olieogo Umuseti and were found to be consistent.

At each well, the global positioning system was powered on and allowed to boot after which, the elevation at that well, the longitude and latitude were measured with the aid of the GPS while the depth to the surface of the water in that well was measured with a meter tape and recorded. This process was repeated for another well close to the first well, at each time the distance between the wells were also recorded. This was repeated for ten different wells which include; well 1, and well 2 in Ndemili, well 3 in Umusadege, well 4 in Umusam, well 5 Umusedeli, well 6 Umuseti, well 7 Ekilibi, well 8 and 9 in Etua and well 10 Isumpe and the results are shown in tables 1 and 2 in meters and feet.

. The static water level of the different locations were obtained by subtracting the elevation with respect to the mean sea level from the depth to the water level in the hand-dug well [37].

Let *Dwl* = depth from the surface of the earth to the water level in the hand dug wells. E = surface elevation with respect to the mean sea level

Therefore, $Swl = E - Dwl$

Swl is the static water level otherwise known as the true or uniform water level.

The values of the static water levels were contoured using the longitudes and latitude in mapping out the locations within Utagba-uno area of Ndokwa land. Groundwater flows from the highest values of the contour lines to the lowest values in the direction perpendicular to the contour lines [37].

6.0 Results and Discussion

From the geoelectric section shown in fig 10, it is observed that the lithology sequence of Utagba-uno consist of alternate fine and medium grained sand.

The first location (Utagba-uno road Ndemili) consists mainly of five layers; the first layer correspond to the topsoil with thickness of 0.15m and resistivity values that ranged from 100 Ωm - 200 Ωm. The second layer consist of lateritic soil with resistivity value ranging from $200\ \Omega m - 500 \Omega m$, and thickness of about 3m. The third layer corresponds to fine grained sand with resistivity value ranging from $500\ \Omega m - 2000 \Omega m$, and thickness of about 4m. This is the first aquifer in this location but not a good one for groundwater development; this is because fine grained sand is not porous enough and as a result does not have the capacity to hold water for a very long time. The fourth layer corresponds to medium grained sand with resistivity value ranging from $2000\ \Omega m - 5000 \Omega m$ and thickness of about 30m. This is the second and the best aquifer in this location; this is because it is more porous than the fine grained sand. The fifth layer correspond to very fine grained sand with resistivity value ranging from $1000\ \Omega m - 2000 \Omega m$ and thickness of about 10m. This is also another aquifer in this location but has little thickness.

The locations at Umusam Onicha-Ukwuani road, Eke market road Umusedeli, Umusadege Ekilibi road, Adofi road Ekilibi and Adofi road Etua have similar geologic formation (five layers) to that Utagba-uno road Ndemili with medium grained sand as the best aquifer and this is mainly within the fourth layer.

The location at market road Ndemili consists mainly of four layers. Here a hidden layer exist which is supposed to be lateritic soil as evidenced from the drillers log, however, the first layer consist of topsoil with a thickness of 1m. The second layer consists of fine grained sand with resistivity value ranging from 200 $\Omega\mathrm{m} - 1000\Omega\mathrm{m}$ and thickness of about 4m. This is the first aquifer in this location but not an encouraging site for groundwater development following the reason given in the first location. The third layer corresponds to medium grained sand with resistivity value ranging from 1000 $\Omega\mathrm{m} - 5000\Omega\mathrm{m}$ and thickness of about 50m. This is also the best aquifer in this location but is a shallow one. The fourth layer consist of very fine grained sand with resistivity value ranging from 1000 $\Omega\mathrm{m} - 2000\Omega\mathrm{m}$ and thickness of about 5m. This is also another aquifer. The location Along Etua major road is similar to that of the Market road Ndemili with four layers of geologic formation. Here a hidden layer exist which is supposed to be lateritic soil.

Furthermore, the locations at Umuseti road and Odas street Isumpe have similar geologic formation (four layers). Here, a hidden layer exist which is supposed to be medium grained sand. The first layer corresponds to top soil with thickness of 0.15m. The second layer corresponds to lateritic soil with resistivity value ranging from 100 $\Omega\mathrm{m} - 300\Omega\mathrm{m}$ and thickness of about 4m. The third layer consists of fine grained sand with resistivity value ranging from 500 $\Omega\mathrm{m} - 1000\Omega\mathrm{m}$ and thickness of about 10m. This is the first aquifer and the best aquifer in this location. The fourth layer correspond to very fine grained sand with resistivity value ranging from 1000 $\Omega\mathrm{m} - 2000\Omega\mathrm{m}$ and thickness of about 5m. This is another aquifer

The values of the static water levels were contoured on the map of Utagba-uno. Equal values of static water levels were joined together very carefully such that none of the lines overlapped or cut across each other. This was improved upon by using surfer 8 software as shown in Fig. 11. The contour map of Utagba-uno using colour to represents the static water levels is shown in Fig. 12, while the wire frame of Utagba-uno in three dimensions is also shown in Fig. 13. Flow pattern of the aquifer system in Utagba-uno revealed that groundwater flow direction was toward the southern part of the region. It is therefore recommended that dumpsite should be sited within Southern part of Utagba-uno kingdom and none in the north, east and western region of the land in order to minimize contamination. The research went further to recommend that boreholes for potable water should be sited within the north, east and western part of Utagba-uno kingdom.

From tables 1 and 2, the distance between wells "L" is as stated below:

1. Distance between well 2 and well 3 at Ndemili and Ekilibi =180m =590ft.
2. Distance between well 3 and well 4 at Umusadege and umusam =135m =442ft.
3. Distance between well 5 and well 6 at Umusedeli and Umuseti = 90m =295ft.
4. Distance between well 7 and well 8 at Ekilibi and Etua = 225m= 738ft.
5. Distance between well 9 and well 10 at Etua and Isumpe= 180m=590ft.

The hydraulic gradients along Ndemili, Umusedege, Umusam, Umuseti, Ekilibi, Etua and Isumpe are calculated as shown below:

1. Hydraulic gradient between wells at Ndemili and Umusedege.

h_2= 111ft, h_3=80ft and L= 180m=590ft i.e. $i = \frac{h_2 - h_3}{L} = \frac{111-80}{590}$ = <u>0.05254</u>

2. Hydraulic gradient between well in Umusadege and Umusam.

h_3 =80ft, h_4=54ft and L = 442 ft ie $i = \frac{80-54}{442}$ = 0.05882

3. Hydraulic gradient between well in Umusedeli and Umuseti

h_6 =73ft, h_5=56ft and L = 295ft ie $i = \frac{73-56}{295}$ = 0.05763

4. Hydraulic gradient between well in Ekilibi and Etua.

h_8 =62ft, h_7=61ft and L= 738ft ie $i = \frac{62-61}{738}$ = 0.00136

5. Hydraulic gradient between well in Etua and Isumpe.

h_9 =62 ft, h_{10}= 33ft L = 590ft ie $i = \frac{62-33}{590}$ = 0.04915

From the above the average hydraulic gradient is

$$i = \frac{0.05245 + 0.5882 + 0.05763 + 0.00136 + 0.04915}{5} = 0.0439$$

This revealed that the ground water flow direction is from Ndemili down to Isumpe with an average hydraulic gradient of 0.0439. Therefore dumpsite should be situated at Isumpe to prevent contamination of ground water, since contamination is always along the direction flow of ground water.

Furthermore, Ground water flows from a higher head to a lower head; meaning ground water direction is from higher water table elevation to lower water table elevation. The hydraulic head of the well in Ndemili is (216ft) with depth to the water inside the well at 105ft. From these two values, the water table elevation is 111ft. This value gradually reduces across the well at Umusadege, Umusam, Umusedeli, Umuseti, Ekilibi, Etua and finally to 33ft at Isumpe. This shows that the ground water flow direction is from Ndemili down to Isumpe with an average hydraulic gradient of 0.0439. Since the rate of flow or discharge rate between two or more wells depend on the hydraulic gradient

Tables 3 and 4 revealed that Utagba-uno road, Ndemili is an AK- type curve ($\ell_1<\ell_2<\ell_3<\ell_4>\ell_5$) with resistivity varying from 241.5Ωm to 2022.8Ωm and layer thickness ranging from 0.6m to 53.0m with root mean square percentage error of 2.9. The second layer is taken as the aquiferous layer having very low resistivity value. The transmissivity is computed as $105m^2$/day.

Market road, Ndemili is an AK- type curve ($\ell_1<\ell_2<\ell_3>\ell_4$) with resistivity varying from 279.9Ωm to 2486.6Ωm and layers thickness ranging from 3.5m to 86.6m with root mean square percentage error of 2.5. The second layer is taken as the aquiferous layer having very low resistivity value. The transmissivity is computed as $54m^2$/day.

Umusadege Ekilibi road is a KHK- type curve ($\ell_1<\ell_2>\ell_3<\ell_4>\ell_5$) with resistivity varying from 139.7Ωm to 1646.0Ωm and layers thickness ranging from 0.9m to 18.8m with root mean square percentage error of 4.2. The third layer is taken as the aquiferous layer having very low resistivity value. The transmissivity is computed as $96m^2$/day.

Umusam Onicha Ukwuani road is a HKH- type curve ($\ell_1>\ell_2<\ell_3<\ell_4<\ell_5$) with resistivity varying from 579.2Ωm to 5672.3Ωm and layer thickness ranging from 0.8m to 24.5 with root mean square percentage error of 2.7. The fourth layer is taken as the aquiferous layer having very low resistivity value. The transmissivity is computed as $245m^2$/day.

Eke market road Umusedeli is an A- type curve ($\ell_1<\ell_2<\ell_3<\ell_4<\ell_5$) with resistivity varying from 284.0Ωm to 4036.4Ωm and layers thickness ranging from 0.8m to 44.3m with root mean square percentage error of 2.5. The second layer is taken as the aquiferous layer having very low resistivity value. The transmissivity is computed as $85m^2$/day.

Umuseti road Utagba-uno is an A- type curve ($\ell_1<\ell_2<\ell_3<\ell_4$) with resistivity varying from 152.2Ωm to 1186.9Ωm and layers thickness ranging from 1.6m to 17.6m with root mean square percentage error of 2.4. The second layer is taken as the aquiferous layer having very low resistivity value. The transmissivity is computed as $97m^2$/day.

Adofi road, Ekilibi is a QHK- type curve ($\ell_1>\ell_2>\ell_3<\ell_4>\ell_5$) with resistivity varying from 197.4Ωm to 143.4Ωm and layers thickness ranging from 1.0m to 20.5m with root mean square percentage error of 3.5. The second layer is taken as the aquiferous layer having very low resistivity value. The transmissivity is computed as $80m^2$/day.

Along Etua major road and Adofi road Etua are A- type curve ($\ell_1<\ell_2<\ell_3<\ell_4<\ell_5$) with resistivity varying from 50.5Ωm to 8853.8Ωm and 79.6Ωm to 3553.3 Ωm layers thickness ranging from 2.3m to 19.6m and 2.1m to 20.2m with root mean square percentage error of 3.0 and 3.4. The third layer is taken as the aquiferous layer having very low resistivity value. The transmissivity is computed as $196m^2$/day and $193m^2$/day.

Odas street Isumpe is an AK- type curve ($\ell_1<\ell_2<\ell_3<\ell_4$) with resistivity varying from 136.5Ωm to 1851.4Ωm and layers thickness ranging from 1.0m to 20.8m with root mean square percentage error of 2.4. The second layer is taken as the aquiferous layer having very low resistivity value. The transmissivity is computed as $72m^2$/day.

In general we have an average transmissivity of $122.3m^2$/day. Umusam Onicha Ukwuani road has the highest transmissivity value of $245m^2$/day while Market road, Ndemili have the least transmissivity value of $36m^2$/day. Hence Umusam Onicha Ukwuani road has been distinct, having good ground water potential.

7.0 Conclusion

Geophysical investigation was conducted at Utagba-uno with the aim of providing useful information on the Hydrogeological nature of the aquifer potential in the area, so as to aid borehole drillers in particular and the government official in general involved in borehole drilling. It is very proper to determine the viability of drilling boreholes in any given location once the surface geophysical survey result has been interpreted. From the results it is save conclude that in locations such as; Utagba-uno road Ndemili, Umusam Onicha-Ukwuani road, Eke market road Umusedeli, Umusadege Ekilibi road, Adofi road Ekilibi and Adofi road Etua, boreholes for sustainable water supply should be drilled to the fourth layer (medium grained sand) to a depth of about 20m & 30m. This is the best aquifer in Utagba-uno area; however, in locations within Umuseti major road and Odas road Isumpe, boreholes could be drilled to the third layer (fine grained sand) to a depth of about 10m – 15m. While in the locations at Market road Ndemili and Along Etua major road, boreholes could also be drilled to the third layer (fine grained sand) to a depth of about 10m – 12m, but they are not encouraging formation for groundwater exploitation.

It is advisable to recommend that boreholes within Utagba-uno should be drilled to a depth of between 10m – 30 m. In general all aquifers in Utagba-uno are unconfined due to the absence of clay formation in the region and as a result, groundwater is not protected, it is prone to contamination. From the above discussion, it could be conveniently recommended that the best ground water location should be in Umusam Onicha Ukwuani road, since it has the highest transmissivity value and a reasonable aquifer thickness which are favorable condition for drilling of productive water wells.

Table 1: Depths to water in the hand-dug wells, latitude, longitude and water elevation in Utagba-uno in feet

Ves/Name Of Location	Depth To Water Level In The Hand Dug Well	Height Above Sea Level Elevation	Latitude	Longitude	Water Table Elevation (H)
Ves 1 utagba-uno road, Ndemili	105 ft	216ft	O6^0, 1.9’	006^o,17.03’	111ft
Ves 2 market road Ndemili, utagba-uno	105ft	216ft	06^o,1.9’	006^o,17.03’	111ft
Ves 3 Umusedege Ekilibi road, utagba-uno	7ft	87ft	05^o,53.09’	006^o,23.4’	80ft
Ves 4 Umusam onicha ukwani road utagba-uno	6ft	60ft	05^o,52.97’	006^o,23.5’	54ft
Ves 5 Umusedeli eke market road utagba-uno	4ft	60ft	05^o,52.9’	006^o,23.08’	56ft
Ves 6 Umuseti road utagba-uno	7ft	80ft	05^o,52.9’	006^o,23.3’	73ft
Ves 7 Adofi road, Ekilibi utagba-uno	9ft	70ft	05^o’52.426’	006,23.295’	61ft
Ves 8 Etua major road utagba-uno	10ft	72ft	05^o,53.427’	006^o,24.294’	62ft
Ves 9 Adofi road utagba-uno	10ft	72ft	05^o,53.427’	006^o,24.294’	62ft
Ves 10 Odas street Isumpe utagba-uno	9ft	42.3ft	05^o,53.584’	006^o,24.392’	33ft

Table 2: Depths to water in the hand-dug wells, latitude, longitude and water elevation in Utagba-uno in meters

Location	VES	Longitude	Latitude	Elevation E (M)	Depth To The Water Level In The Hand DUG Well D_HD_W(M)	Static Water Level (SWL) =E-DwL (M)
Utagba-uno road, Ndemili	1	6^0 01’404”N	6^{0}17’234”E	65.84	32	33.84
Market road, Ndemili	2	6^0 01’806”N	6^{0}16’989”E	65.84	32	33.84
Umusadege Ekilibi road	3	5^0 53’165”N	6^{0}23’358”E	26.52	2.0	24.52
Umusam Onicha –Ukwuani road	4	5^{0}53’909”N	6^{0}23’472”E	18.29	1.7	16.59
Eke market road Umusedeli	5	5^{0}52’974”N	6^{0}23’144”E	18.29	1.2	17.09
Umuseti major road	6	5^0 52’907”N	6^{0}23’250”E	24.38	2.0	22.38
Adofi road Ekilibi	7	5^{0}54’158”N	6^{0}23’522”E	21.34	2.4	18.54
Along Etua major road	8	5^0 53’433”N	6^{0}24’285”E	21.95	3.0	18.95
Adofi road Etua	9	5^0 53’84”N	6 24’342”E	21.95	3.0	18.95
Odas street Isumpe	10	5^{0}53’255”N	6^{0}23’762”E	12.95	2.6	10.35

Table 3: Summary of the Result of the Smoothed Curve

LOCATIONS	LAYER	RESISTIVITY	THICKNESS	DEPTH	CURVE TYPE
Utagba-uno road, Ndemili	1	241.5	0.6	0.6	
	2	560.7	10.5	11.1	
	3	2740.3	11.0	22.1	Ak
	4	5901.2	53.0	75.1	
	5	2022.8	- - - -	- - - -	
Market road, Ndemili	1	279.8	3.5	3.5	
	2	1015.6	5.4	8.9	
	3	4697.1	86.6	95.5	Ak
	4	2486.6	- - - -	- - - -	
Umusadege Ekilibi road	1	139.7	0.9	0.9	
	2	1490.2	3.2	4.1	
	3	154.3	9.6	13.7	KHK

	4	1936.2	18.8	32.6	
	5	1646.0	- - - -	- - - -	
	1	579.2	0.8	0.8	
Umusam Onicha Ukwani road	2	234.5	4.1	4.9	
	3	392.6	15.5	20.4	HA
	4	282.6	24.5	44.9	
	5	5672.3	- - - -	- - - -	
	1	284.0	0.8	0.8	
Eke market road Umusedeli	2	746.4	8.5	9.3	
	3	1599.4	12.0	21.3	A
	4	3605.9	23.0	44.3	
	5	4036.4	- - - -	- - - -	
	1	152.2	1.6	1.6	
Umuseti major road	2	360.6	9.7	11.3	
	3	530.5	17.6	28.9	A
	4	1186.9	- - - -	- - - -	
	1	197.4	1.0	1.0	
Adofi road Ekilibi	2	192.8	3.6	4.6	
	3	81.1	8.0	12.6	QH
	4	1075.5	20.5	33.1	
	5	143.4	- - - -	- - - -	
	1	50.5	2.3	2.3	
Along Etua major road	2	341.8	9.1	11.4	
	3	355.0	19.6	31.1	A
	4	8853.8	- - - -	- - - -	
	1	79.6	2.1	2.1	
Adofi road Etua	2	287.2	3.6	5.7	
	3	544.3	19.3	25.0	A
	4	760.0	20.2	45.2	
	5	3553.3	- - - -	- - - -	
	1	136.5	1.0	1.0	
Odas street Isumpe	2	165.3	7.2	8.2	
	3	1607.9	20.8	29.0	A
	4	1851.4	- - - -	- - - -	

Table 4: Geoelctric Parameters With Transmissivity Values

Location	**Resistivity (Ωm)**	**Thickness (m)**	**Conductivity $(\Omega m)^{-1}$**	**Longitudinal Conductance $(\Omega^{-1}.m^{-1})$**	**Transmissivity T=kh (m^2/day)**	**Transmissivity $Tr=k\rho L_C$ (m^2/day)**
1	560.7	10.5	0.001783	0.018727	105	105
2	1015.6	5.4	0.000985	0.005317	54	54
3	1543	9.6	0.006481	0.062222	96	96
4	282.6	24.5	0.003539	0.086695	245	245
5	746.4	8.5	0.001340	0.011390	85	85
6	360.6	9.7	0.02773	0.026900	97	97
7	81.1	8.0	0.012330	0.098644	80	80
8	355.0	19.6	0.002817	0.055211	196	196
9	544.3	19.3	0.001837	0.035458	193	193
10	165.3	7.2	0.006050	0.043557	72	72

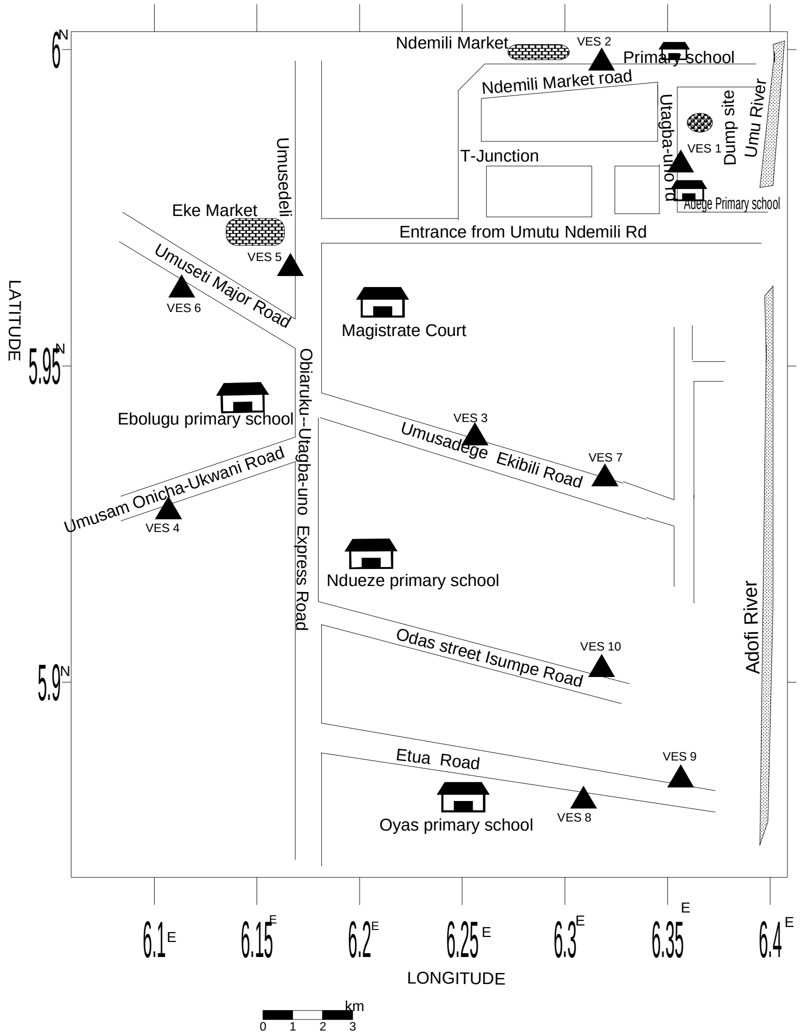

Figure 1: Base map of the study area.

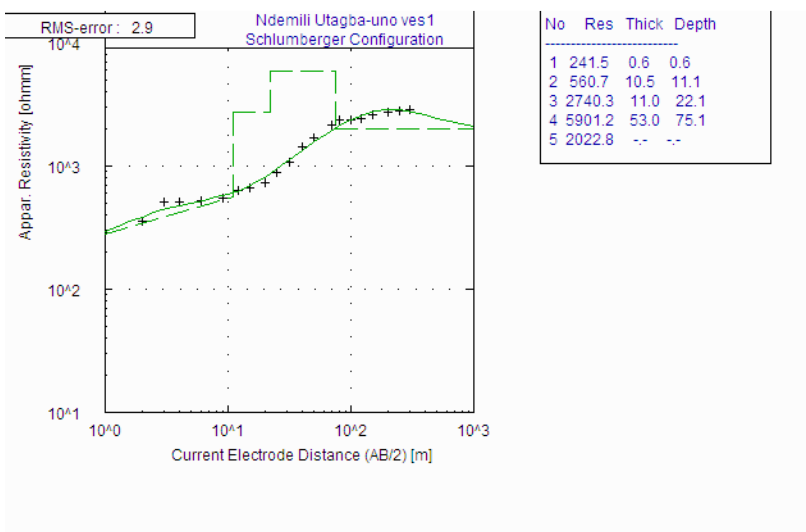

Figure 2: Resistivity Sounding Interpretation for VES 1 (Ndemili Utagba-Uno) and VES 2 (Ndemili market Road, Utagba-Uno) Showing Observed (Field) and Computed Resistivity Data and Curves; and Interpreted layer model Parameters.

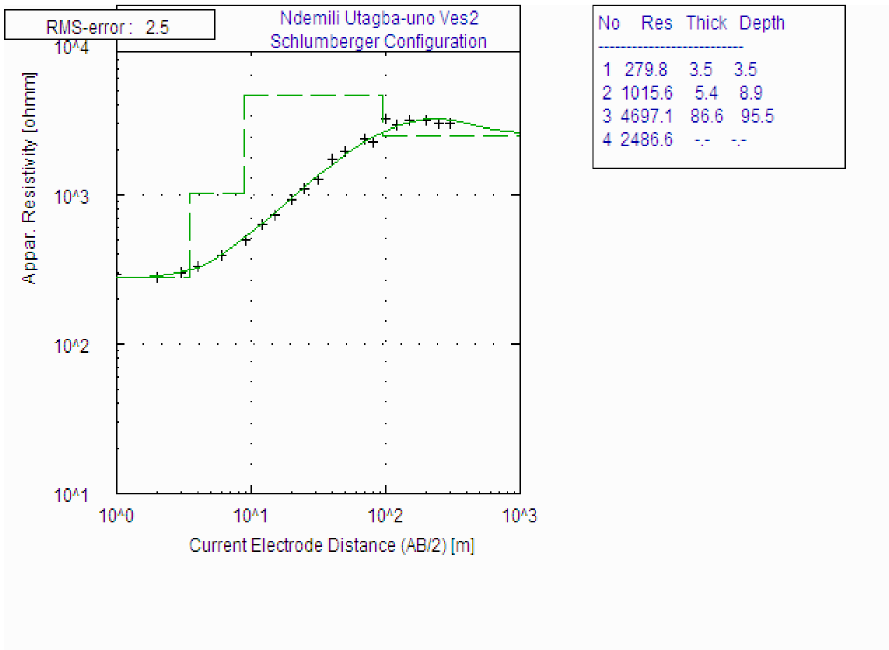

Figure 3: Resistivity Sounding Interpretation for VES 3 (Umusedege Ekilibi, Utagba- Uno) Showing Observed (Field) and Computed Resistivity Data and Curves; and Interpreted layer model Parameters.

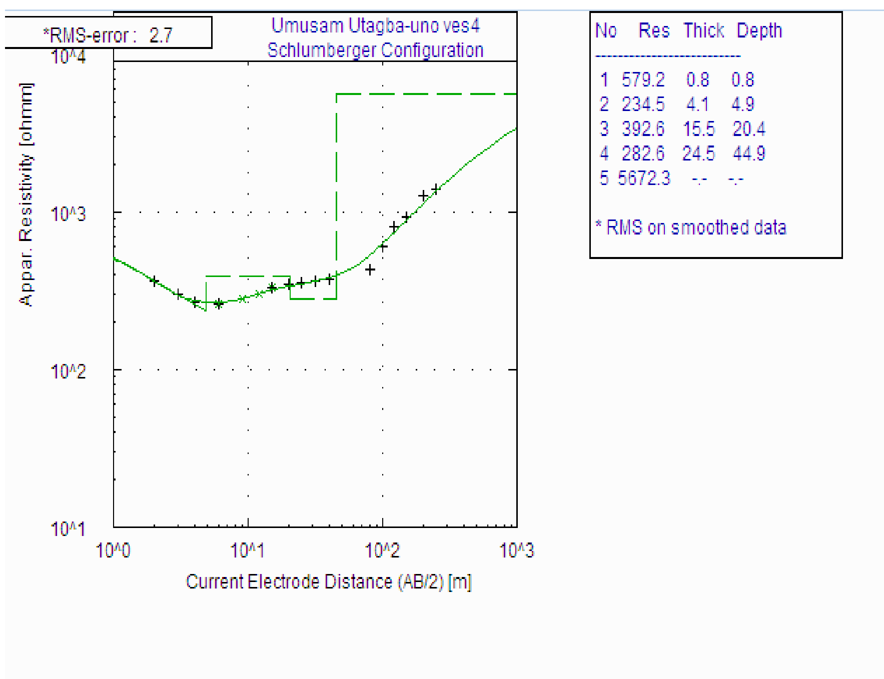

Figure 4: Resistivity Sounding Interpretation for VES 4 (Umusam Utagba-Uno) Showing Observed (Field) and Computed Resistivity Data and Curves; and Interpreted layer model Parameters.

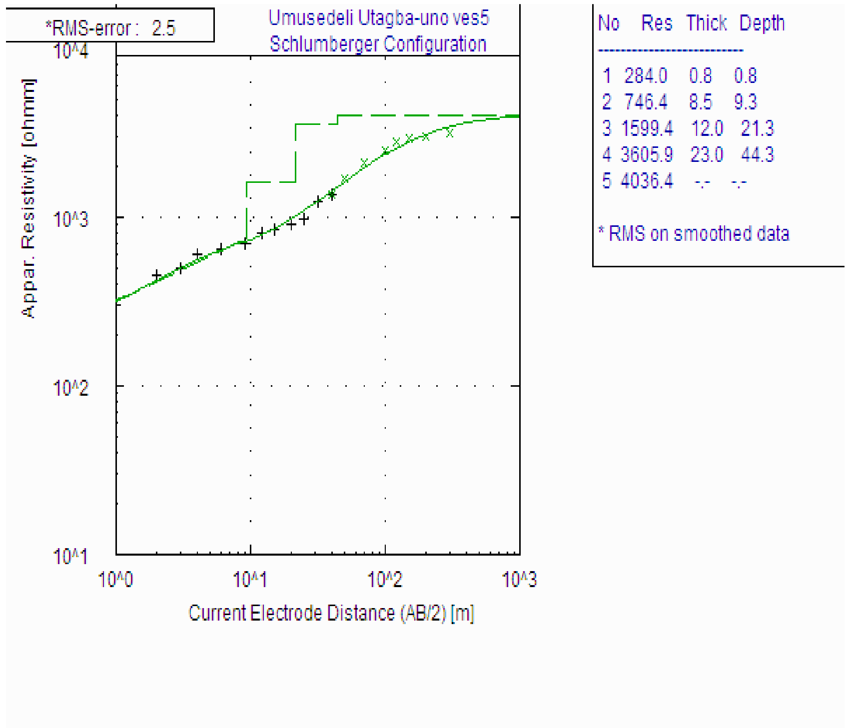

Figure 5: Resistivity Sounding Interpretation for VES 5 (Umusedeli Utagba-Uno) Showing Observed (Field) and Computed Resistivity Data and Curves; and Interpreted layer model Parameters.

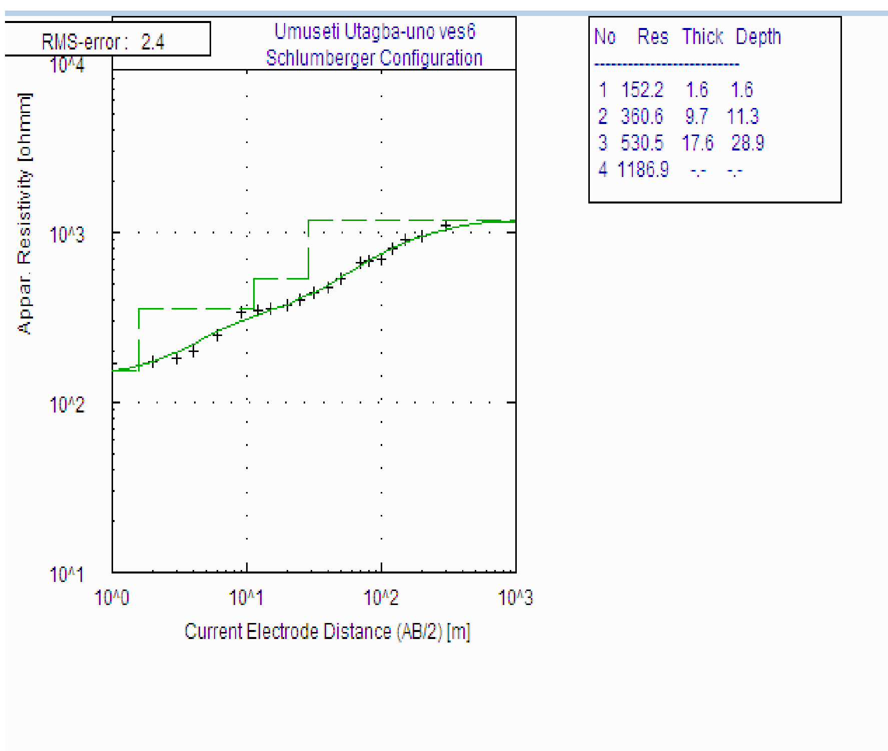

Figure 6: Resistivity Sounding Interpretation for VES 6 (Umuseti Utagba-Uno) Showing Observed (Field) and Computed Resistivity Data and Curves; and Interpreted layer model Parameters.

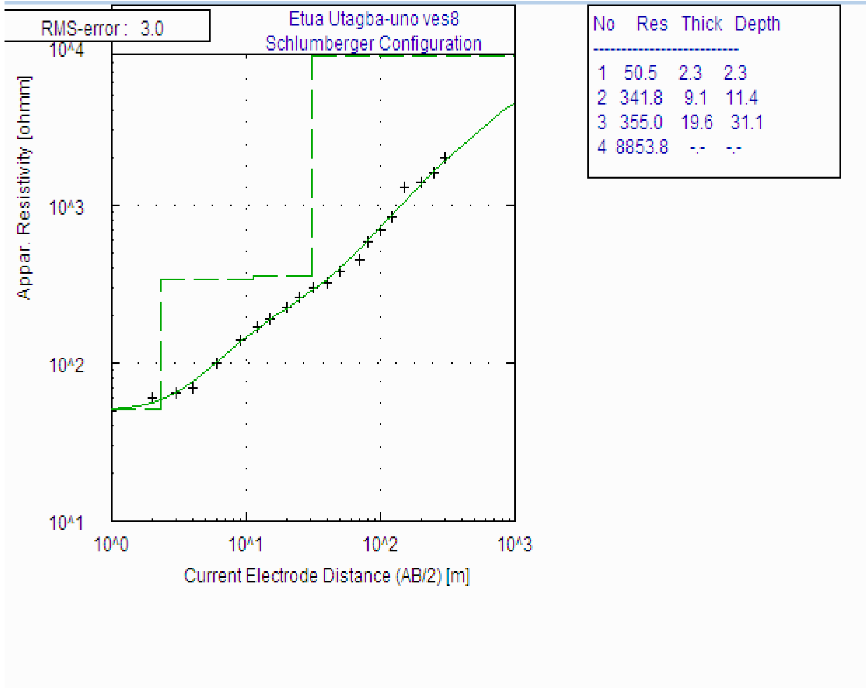

Figure 7: Resistivity Sounding Interpretation for VES 7 (Adofi Road Ekilibi, Utagba-Uno) Showing Observed (Field) and Computed Resistivity Data and Curves; and Interpreted layer model Parameters.

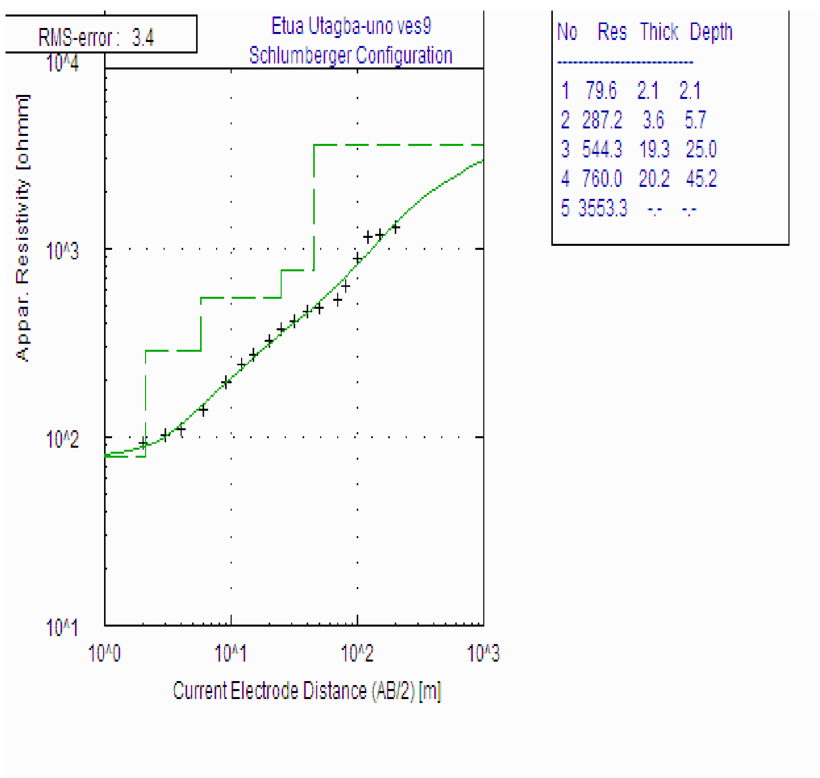

Figure 8: Resistivity Sounding Interpretation for VES 8 (Etua Major Road, Utagba-Uno) and VES 9 (Adofi Road, Utagba-Uno) Showing Observed (Field) and Computed Resistivity Data and Curves; and Interpreted layer model Parameters.

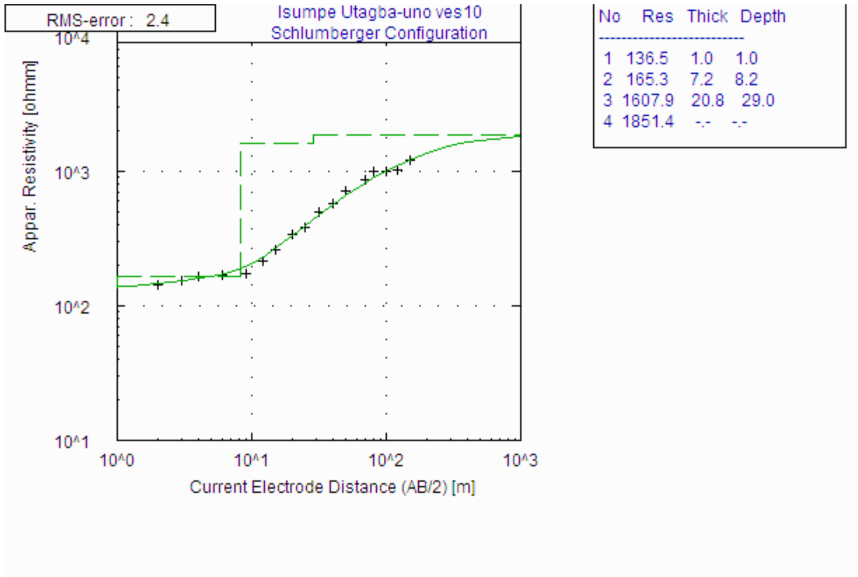

Figure 9: Resistivity Sounding Interpretation for VES 10 (Isumpe Utagba-Uno) Showing Observed (Field) and Computed Resistivity Data and Curves; and Interpreted layer model Parameters.

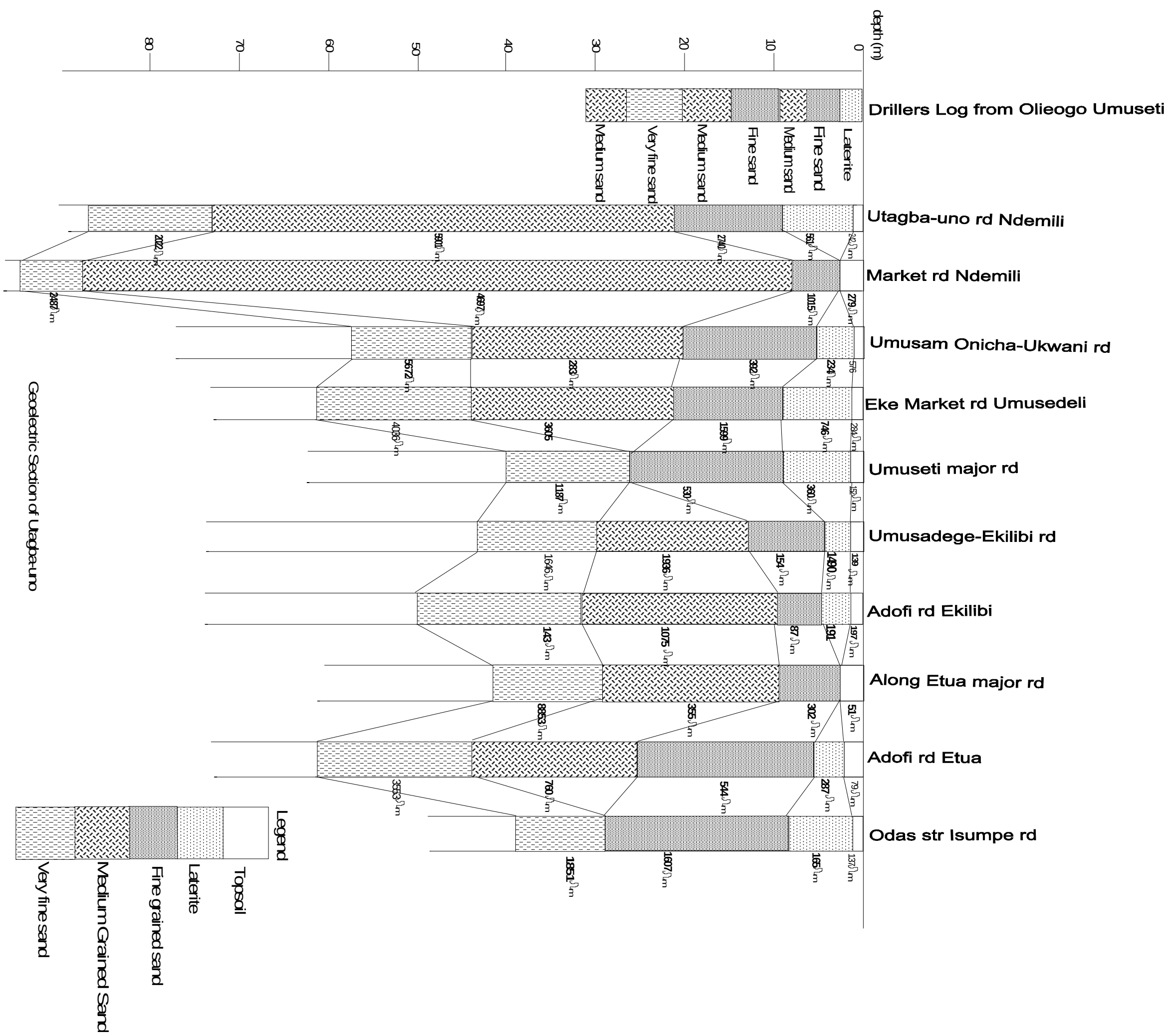

Figure 10: The geoelectric Section of Utagba-Uno

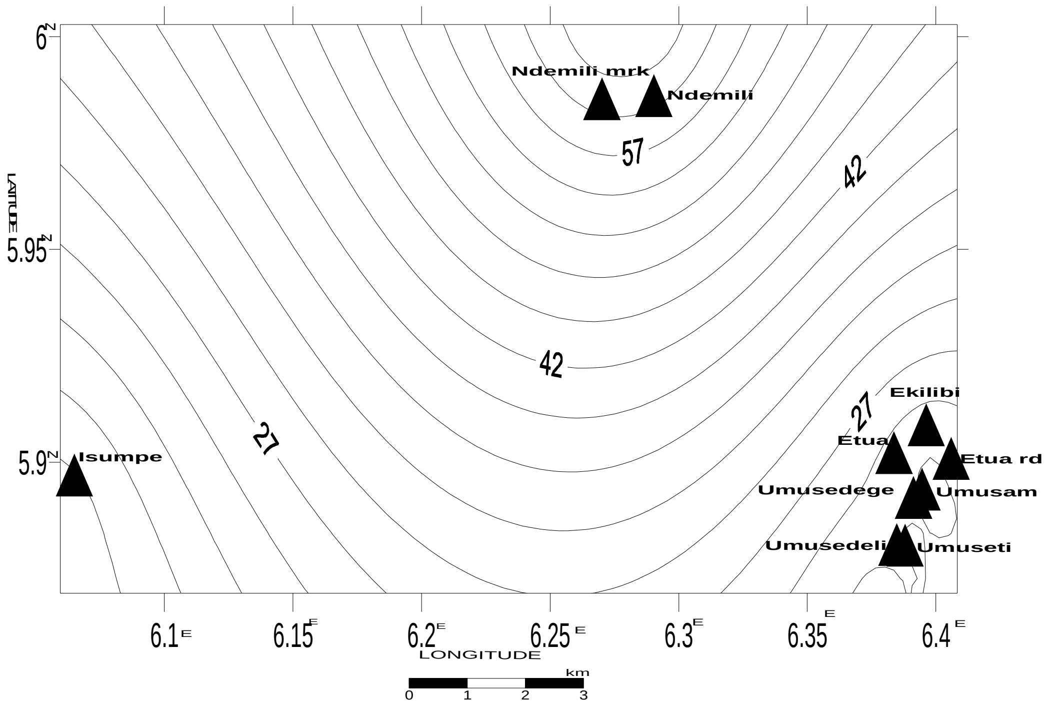

Fig 11: Contour Map of Utagba-uno showing Groundwater flow direction in two dimensions using Suffer 8 Software

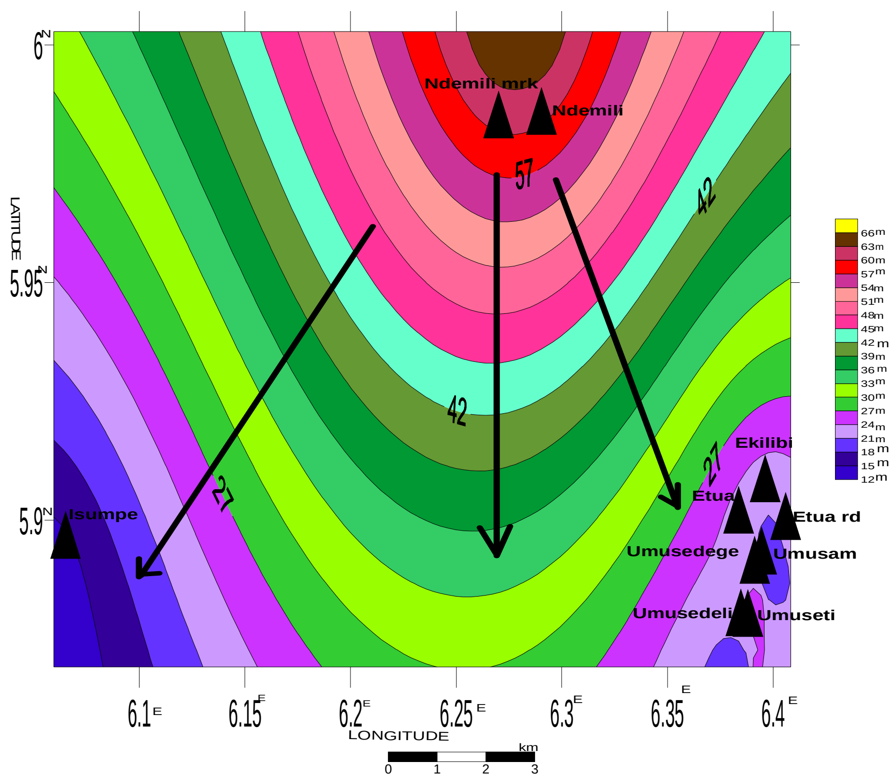

Figure 12: Color Contour Map of Utagba-uno showing Groundwater Flow Direction in Two dimensions with contour intensity of 0.50

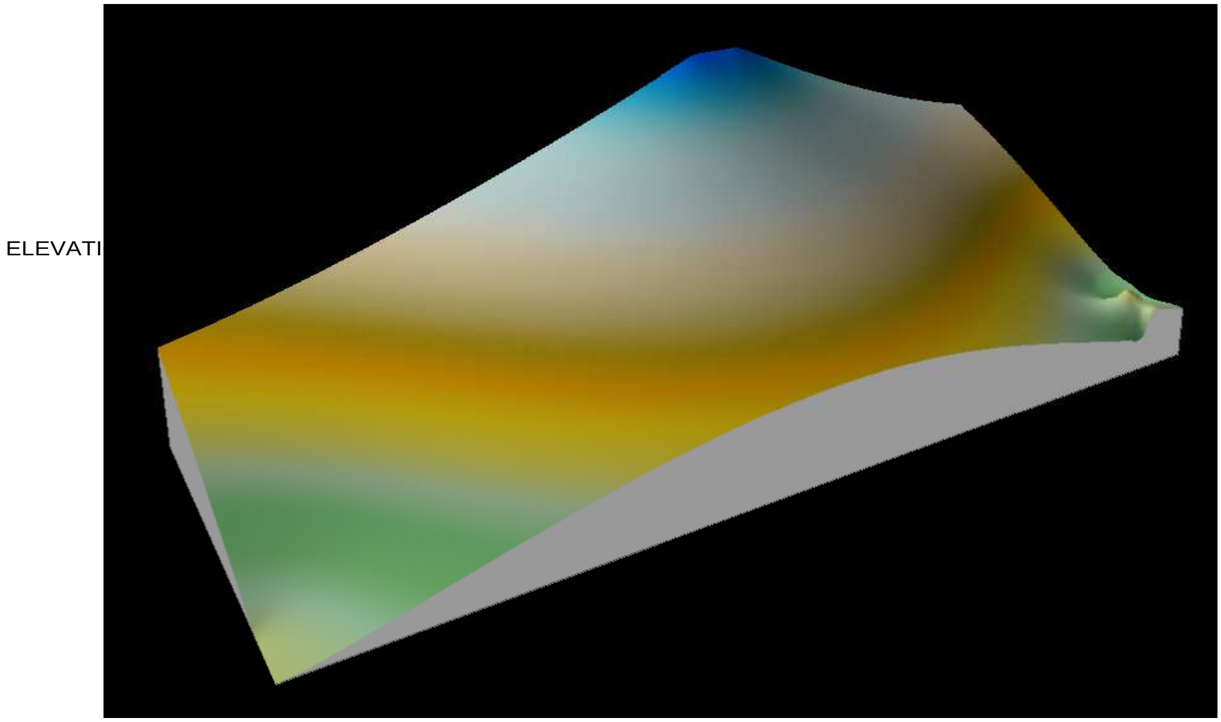

Fig. 13: The Contour Map of Utagba-uno showing Groundwater Flow Direction in Three Dimensions with contour intensity of 0.50

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