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Groundwater Level Distribution in Bonny Local Government Area, Rivers State, Nigeria

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Abstract— This research involves the analysis of the spatial distribution of groundwater Level within the Bonny Metropolis, in Rivers State, Nigeria. The study area is located between latitudes 4˚28N and longitude 7˚10E. The GPS (global positioning system) was used to take the various coordinates of the site location. Ten Vertical Electrical Sounding was carried out with an ABEM Terrameter 300 SAS B in order to determine the groundwater level distribution using Schlumberger configuration. The data acquired was analyzed and interpreted with the aid of IP2Win and surfer 8 software. Topsoil, clay and sandy formations were encountered and the result from the geoelectric section reveals three to five layers with HKH, QK, HQQ, H, KH, HAA, QHA and QAA curve types. The resistivity values for the first layer ranges from 1.73Ωm to 863.6Ωm, the second layer ranges from 0.89Ωm to 788.3Ωm, the highest resistivity value was observed in the third layer with resistivity ranging from 0.5 to 1,222,355Ωm, the fourth layer ranges from 1.84 to 9,203Ωm and the fifth layer ranges from 62.9 to 12,464Ωm with an infinite thickness. The overburden thickness across the area falls between 5m to 100m. The water level depth distribution of the area varies between 0.2m to 2.6m and the direction of the water flow is towards the central part of the study area while the highest value of the borehole depth distribution was observed at North-Eastern part and North-Western part with a range of 40 to 57ft. The study will provide information on the variation of water table depths for proper water resources management across the study area.

Keywords— Groundwater Level, Vertical Electrical Sounding, Aquifer, Niger Delta, Nigeria

INTRODUCTION

The importance of water as a useful natural resource goes beyond the fact of being essential for the survival of mankind but also for the survival of the natural environment [1]. More than two billion people worldwide depend on groundwater for their daily water supply, and a large proportion of the world's agricultural and industrial water requirements are supplied by groundwater [2, 3]. Due to an increasing demand for groundwater in response to rapidly growing urban, industrial, and agricultural water requirements, several countries, especially those in arid and semi-arid zones, are experiencing water shortages resulting from the imbalance between demand and supply [4].

Groundwater resources are influenced by both climate change and human activities [5, 6, 7, 8, 9, 10]. The combination of climate change and indiscriminate groundwater development has caused a general decline in groundwater levels, resulting in the depletion of groundwater, land subsidence, and saltwater intrusion in deltaic areas [11]. Lower groundwater levels are a threat to the environment and hinder economic development. Excessive groundwater depletion has affected vast regions, including Northwest India, North China, and the Central USA [12].

The Niger Delta region is blessed with large quantity of groundwater from shallow aquifer, but the region is still challenged by water inadequacy due to the commercialization of available potable water, making it unavailable to indigent people. Many communities in Bonny local government are facing an acute shortage of potable water due to the problem of high iron-water, saltwater intrusion and tidal influence [13]. Urbanization in Bonny Town has resulted to increase in groundwater exploitation but in the villages ground water is underutilized and not even available since there is lack of power supply in the villages and access to use motorized rig to sink a deep well is very difficult, the nearby streams or surface runoffs that could have supplemented the groundwater are heavily polluted by the various human activities in the area such as oil spillage and poor sanitation habits [14].

The study area Bonny Local Government is is an island located in southern part of the Niger Delta (Figure1.1). It is bounded by the Atlantic Ocean in the south , the Andonies and Ogonis in the east and the Kalabaries at the west and finally the Okirikas by the North, the study area is only accessible by sea.

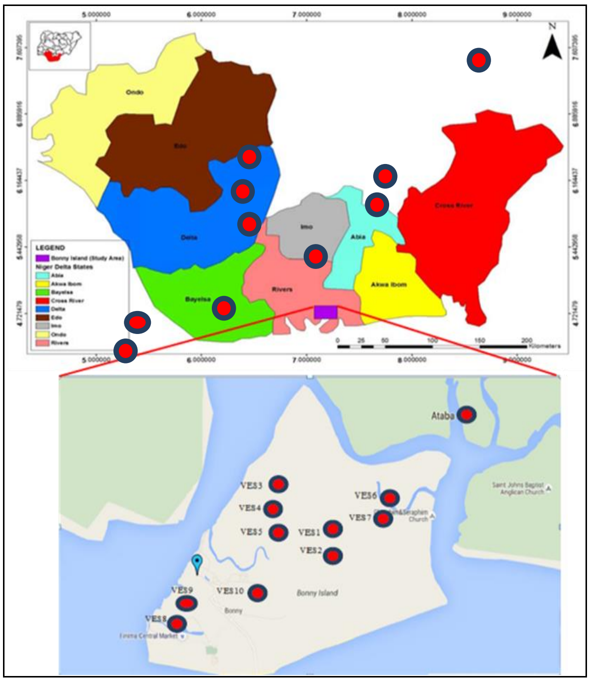

Figure 1: *Map of Bonny Showing the VES Points*

The physiography conforms to the geomorphic features of the Niger Delta governed by several factors which influence transport and ultimate deposition of the sediment load, shape and growth of the delta. The Niger Delta lies between latitudes 4°N and 6°N and longitudes 3°E and 9°E [15]. The Delta ranks as one of the major oil and gas provinces globally, with an estimated ultimate recovery of 40 billion barrels of oil and 40 trillion cubic feet of gas [16]. The coastal sedimentary basin of Nigeria has been the scene of three depositional cycles [17]. The first began with a marine incursion in the middle Cretaceous and was terminated by a mild folding phase in Santonian time. The second included the growth of a proto-Niger Delta during the Late Cretaceous and ended in a major Paleocene marine transgression. The third depositional cycle from Eocene to Recent, marked the continuous growth of the main Niger Delta. A new threefold lithostratigraphic subdivision is introduced for the Niger delta subsurface, comprising an upper sandy Benin Formation, an intervening unit of alternating sandstone and shale named the Agbada Formation, and a lower shaly Akata Formation. These three units extend across the whole delta and each ranges in age from early Tertiary to Recent. They are related to the present outcrops and environments of deposition. A separate member of the Benin Formation is recognized in the Port Harcourt area. It is Miocene-Recent in age with a minimum thickness of more than 6,000ft (1829m) and made up of continental sands and sandstones (>90%) with few shale intercalations [18]. Subsurface structures are described as resulting from movement under the influence of gravity and their distribution is related to growth stages of the delta [19]. Rollover anticlines in front of growth faults form the main objectives of oil exploration, the hydrocarbons being found in sandstone reservoirs of the Agbada Formation.

The Benin Formation (coastal plain sands) forms the major aquifer in the study area and is exploited for groundwater supply. Although a depth of about 7m is most exploited, about 400m depth has been exploited for water supply in Bonny Local Government Area drilled by Nigeria Liquefied Natural Gas (NLNG) but contains iron and is treated for iron before use by the public. It consists essentially of massive and highly porous sands and gravels with few clay intercalations. [20] utilized Vertical Electrical Soundings (VES) using surface Schlumberger array with a Terrameter to discover the ground water possibilities, while earth and underground water sections were gathered and evaluated for important geochemical considerations in Bonny island. The geoelectrical curve indicated a salty (30– 90 m) and iron content (90– 180 m) clean water that is less saline salt and iron substance can be seen at profundities amongst 180– 300 m. The study of groundwater occurrence in Bonny metropolis is one way of understanding and mitigating the water resource problem facing the people of the area. This study therefore focuses on the need for accurate characterization of the subsurface for a better understanding of the groundwater architecture of the area to aid plan for the future development of boreholes and wells in this region.

Rest of the paper is organized as follows, Section I contains the introduction of groundwater level distribution in Bonny local government area, Rivers state, Nigeria. Section II contains the related work of groundwater level distribution in Bonny local government area, Rivers state, Nigeria. Section III contains the materials and methods employed in determining the groundwater level distribution in Bonny local government area, Rivers state, Nigeria. Section IV contains the important findings of the study and section V concludes the research work with future directions.

II. Related Work

In "Groundwater Level Distribution and Evaluation of Physicochemical Characteristics in North-Eastern Bayelsa State, Nigeria," [21] the analysis of the spatial distribution of groundwater level and the evaluation of its physicochemical characteristics in the north-eastern Bayelsa State in Nigeria was done. The study area is located between latitudes 4°12' and 5°23'N and longitudes 5°22' and 6°45'E. The samples locations were geo-referenced and the elevations of the locations also determined using global positioning system (GPS). 12 randomly-selected groundwater sample borehole locations were used from where the water samples were collected for the physicochemical analysis. The evaluation of water quality was in accordance with regulatory standard. The water samples from boreholes were subjected to physicochemical analysis and results were compared to the World Health Organization Standard (WHO) to determine its suitability for domestic and industrial uses. The surface atmospheric temperature in the area of of study ranged between 26.2 and 28.6°C. The groundwater level (depth to groundwater surface) ranges between 0.4 and 2.6m with an average of 1.60m. The depth to groundwater was observed to increase with increase in elevation, being shallower southwards towards the sea. Elevation varies between 6.0 and 16.0m with an average of 10.8m. Elevations are greatest in the upland recharge areas where groundwater levels are deepest. Groundwater-levels at lower elevations are near valley bottoms, which are groundwater discharge areas. pH value ranged between and 5.80 and 7.20 with an average value of 6.70. However all the samples met the WHO standard for drinking water which is between 6.5 and 8.5. In this investigation, the mean total dissolved solid (TDS) was 357.25mg/l. In water, total dissolved solids are composed mainly of carbonates, bicarbonates, chlorides, phosphates and nitrates of calcium, magnesium, sodium, potassium and manganese, organic matter, salt and other particles. Electrical conductivity (EC), a measure of water's capacity to convey an electric current, has values ranging from 260µs/cm to 1357 µs/cm with an average value of 697.0 µs/cm. Biochemical Oxygen Demand (BOD) is the amount of dissolved oxygen required for the biochemical decomposition of organic compounds and the oxidation of certain inorganic materials; which shows an average concentration of 3.96mg/l. Bicarbonate shows an average concentration of 48.03gm/l. Carbonate also shows an average concentration of 3.93mg/l. Nitrate average concentration was 0.298mg/l. Sulphate mean concentration value was 14.05mg/l. Chloride shows a mean concentration value of 34.18mg/l. From the results, the mean concentration values of Sodium, Potassium, Magnesium, Calcium and Iron are well within the permissive and tolerable range of the international (WHO) standard.

Also, in "Aspects of Geophysical Survey Using Vertical Electrical Sounding (VES) for Groundwater Exploration in Parts of Ahoada West LGA of Rivers State, Southern Nigeria," [22] an aspect of geophysical study using the Vertical Electrical Sounding (VES) technique was applied in Ishiayi community in Ahoada west Local Government Area of Rivers State to delineate geo-electric stratigraphy and to access hydro-geological conditions. Six (6) VES points with an electrode spacing's of AB/2 147M and AB/2 294M were occupied along the traverses. Surface data were acquired with an ABEM SAS 1000 terrameter set. The data were interpreted using IP2 win computer software. The results of the interpreted VES data and the drilled borehole logs confirms the following stratigraphy top moist soil (86-319Ωm), lateritic sand (44-631Ωm), silty clay layer (44-335Ωm), and saturated brownish sand (999-1056Ωm) as aquifer. Geophysical VES reports and borehole logs confirms that the area is a homogeneous formation consisting of consistent lithology of sand with intercalation of silty clay layer. Borehole logs further envisaged that the groundwater distribution network is uniform. Geo-electric sections further reveal that depth to groundwater is relatively shallow reflecting less than 5m virtually in all the locations. Water level generally reflects consistency within the surveyed area. Furthermore, the results of the interpretation of the VES data indicate that the thickness values of the aquifer vary from 8.16m to 30.91m. VES 1 and 2 reflect little thickness of aquifer within a depth ranges of 50-65ft and 30-35ft. However, VES 3, 4, 5 and 6 showed relatively thick column of the aquifers. Although, all the mapped aquifers in the investigated area are prolific but the thickness of the aquifer is a reflection of the hydraulic properties, such as water retention capacity and transmissivity. Hence, VES 3, 4, 5 and 6 show better hydraulic properties as a result, water abstractions wells were sited within depth range of (115.5-132ft). Thus, four (4) boreholes were drilled in aforementioned locations confirming the water to be good and free of iron concentration.

In addition, in "Assessment of Economically Accessible Groundwater Reserve and its Protective Capacity in Eastern Obolo Local Government Area of Akwa Ibom State, Nigeria Using Electrical Resistivity Method," [23] the application of geophysical method employing vertical electrical sounding (VES) method in combination with laboratory analysis of aquifer sediments was used to access the economically accessible groundwater reserve and its protective capacity in some parts of Eastern Obolo Local Government area, the eastern region of the Nigerian Niger Delta. Schlumberger electrode configuration was used to sound twelve VES to occupy the areas that have borehole locations and accessibility for the spread of current electrodes to at least 1000 m. Based on the results, the safe and economic aquifer potential has groundwater reserve of about 168480558+18532861m3. The desired aquifer thickness and its depth of burial have average value of 52.02 m and 73.14 m, respectively. The area has a fair protective capacity. This is indicated by 58.33% weak, 16.67% moderate, and 25% good protective capacity for the area. This study was done in one of the oil cities, where contaminated Salt River water is used as the major source of water for domestic uses and it is believed that the settlers will appropriate this result and sue for safe groundwater at the indicated depths.

III. Materials and Methods

The basic resistivity Equipment used in the study is an ABEM Terrameter SAS 300 B, a 12 volts battery, four stainless steel electrodes , calibrate tapes, four reels of cables, a hammer and Global Positioning System (GPS). These instruments are rugged and are built to adapt to any field work manipulation. They are equally portable assessable and can be moved above with case.

The ABEM Terrameter SAS 300 B is powered internally by a 12 volts battery which supplies the external power source by means of a cable, inbuilt in the instrument. This transmits the power source to the ground through the electrons by means of reams of cables. The four stainless electrons are round with pointed ends for easy drive to the earth. The tapes are used in making out the electrodes spacing along a straight traverse line. With the hammer, it becomes easier to drive into the ground the electrodes and the GPS is used to get the geographical coordinate of the sounding points and the direction of the spread.

The method used in this research is the Schlumberger Array (as shown in figure 2) and a total of 10 VES station points were taken in different communities in Bonny Local Government Area with minimum and maximum electrode spread length of 300m and 500m respectively. The procedure involved in measuring VES is, first to confirm the functionality of the instrument ABEM Terrameter 300B and battery voltage, then the current electrodes C_1& C_2 is connected to the instrument and the potential electrode P_1 and P_2 is also connected to the instrument as indicated on the instrument. The two electrodes C_1 and C_2 called the current electrodes on the opposite side of the VES station point were marked and noted and the driven to the ground with the aid of a sledge hammer for better contact to the ground. Similarly, the two other electrodes P_1P_2 called the potential electrodes of equal distance between the current electrodes were equally measured and driven to the ground for proper contact. The current and potential electrodes were both placed so as to maintain a straight line. The potential Electrodes P_1 & P_2 were placed with varying spacing which was not more than one fifth of the half current C1 & C_2 Electrode spacing. The current Electrode spacing was placed at progressively large distances.

The separation of the potential electrodes was increased in accordance with the corresponding increase in distance between the current electrodes. Measurement continued and the potential electrodes separation increased again as necessary until the Vertical Electrical Sounding (VES) was complete. At every corresponding interval between the current Electrode and the potential Electrode, the resistivity value was obtained.

FIELD WORK PROCEDURE

Vertical electrical sounding (VES) survey using Schlumberger configuration was conducted at ten (10) sites distributed along different transverse locations in the study area. With the Schlumberger array, the potential electrodes separation is kept constant while the current electrodes separation is increased in steps. A maximum current electrodes separation (AB) of 200 meters was marked out in this work. In each measurement, the digital averaging instrument ABEM Terrameter measure the resistance when the current is more than 10.0 µA otherwise apparent resistivity ρ_a is computed using the relation:

$$\rho_a = \pi L^2 / I\,(\Delta R) \qquad (1)$$

therefore,

$$\rho_a = (RK) \qquad (2)$$

where R = resistance (R), K = geometric factor and ρ_a= apparent resistivity (Ωm) These results are made possible as the four electrodes driven into the ground are connected to the ABMN terminals of the ABEM Terrameter through the reeds of cables.

This procedure is repeated for each location along the marked profile as the depth of penetration of current into the ground is increased with an increase in the electrodes separation.

Results are presented on a log-log graph by plotting apparent resistivity along the ordinate and AB/2 along the abscissa, using the IP12 win software. The GPS was used to take the various coordinates of the site location.

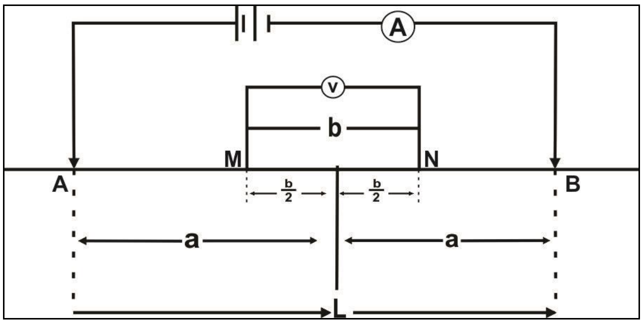

Figure 2 : Schematic Diagram for Schlumberger Array

INTERPRETATION OF FIELD DATA

The acquired data obtained was interpreted using IP2Win software. The result from the software were then analyzed based on the number of layers, the resistivity, the depth of aquifer and the thickness observed. The result was then compared to the type of resistivity sounding curve observed in the study area in order to delineate areas of low and high resistivity values in order to demarcate areas of thick aquifer and ground water potential.

The process was made possible to estimate the resistivities of the various geo-electric layers, while sulfer8 software was used to generate Iso-pach and iso-resistivity of the various locations which gives details of the overburden thickness and resistivity of the various sub surface formations.

IV. RESULTS AND DISCUSSION

The results of the work are presented in Figures 3 – 14 and in Tables 1 – 3.

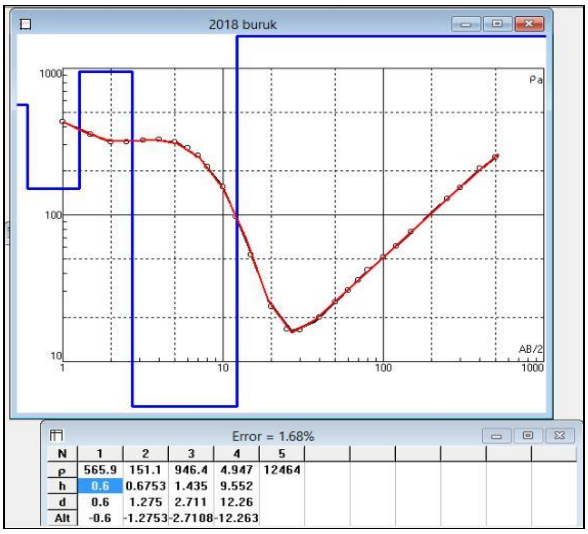

Figure 3 : *Geoelectric Curve for Aru-agbalama Community*

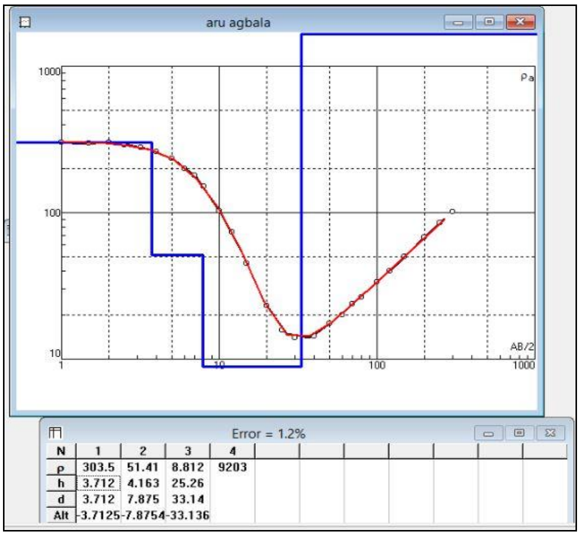

Figure 4: *Geoelectric Curve for Burukiri Community*

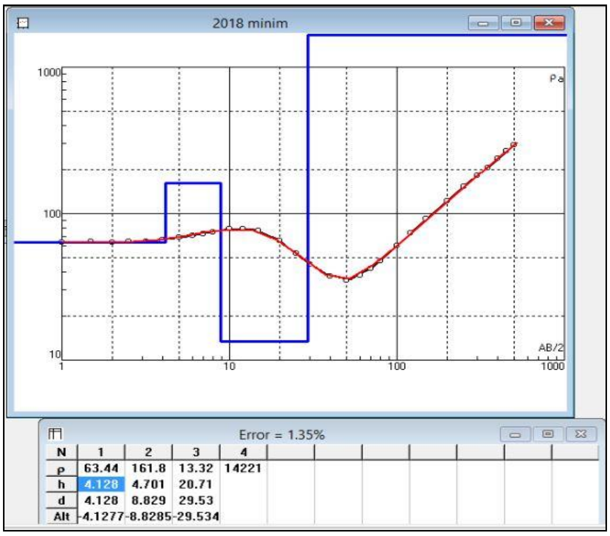

Figure 7: *Geoelectric Curve for Minima Community*

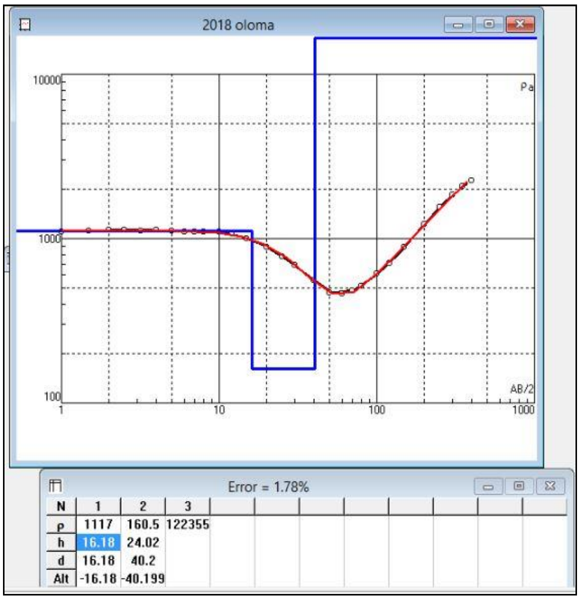

Figure 5: *Geoelectric Curve for Oloma Community*

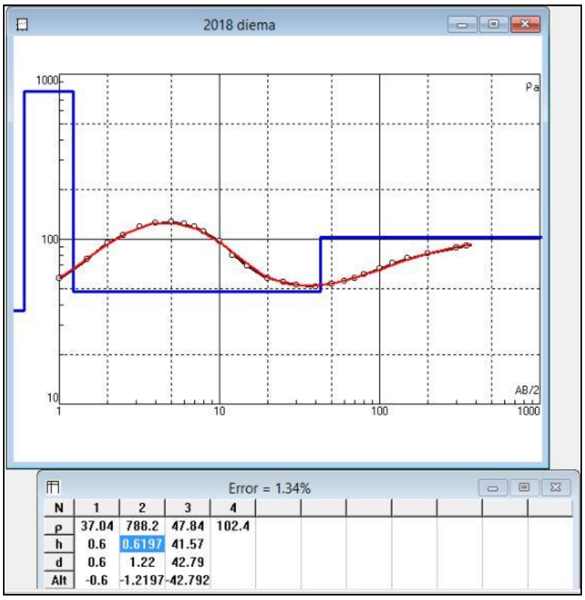

Figure 8: *Geoelectric Curve for Diema Community*

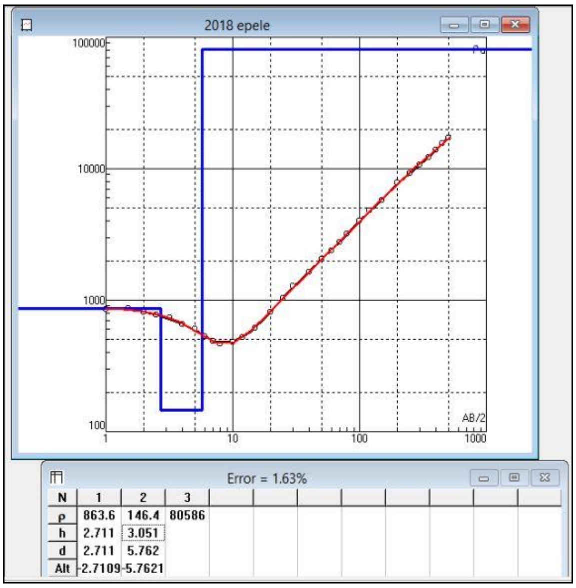

Figure 6: *Geoelectric Curve for Epelema Community*

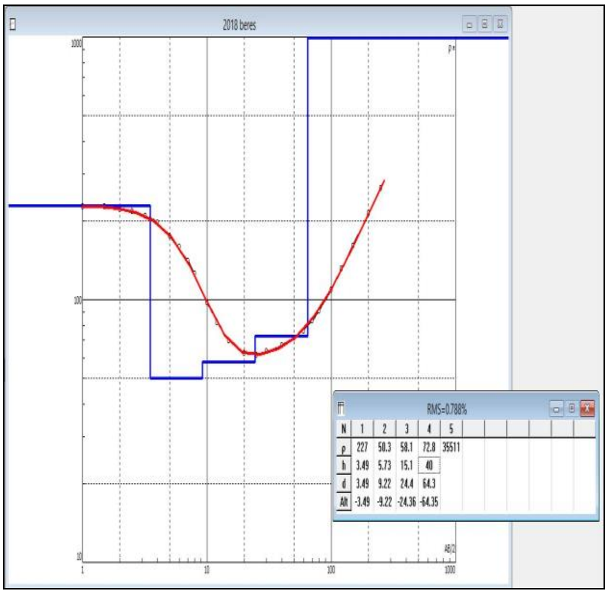

Figure 9: *Geoelectric Curve for Beresiri Community*

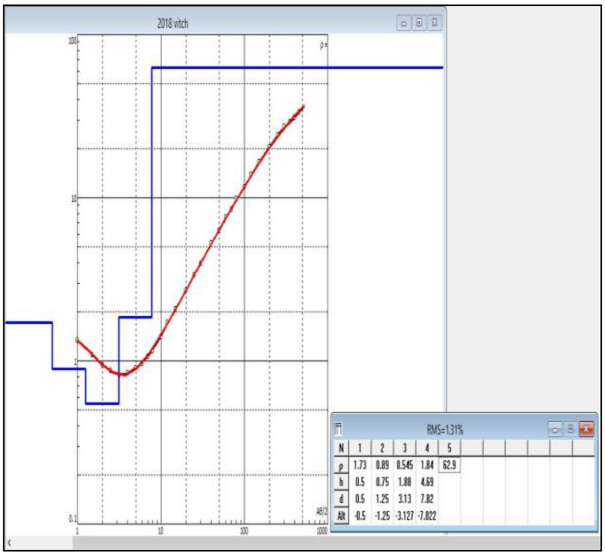

Figure 10: *Geoelectric Curve for Victoria Street Government School*

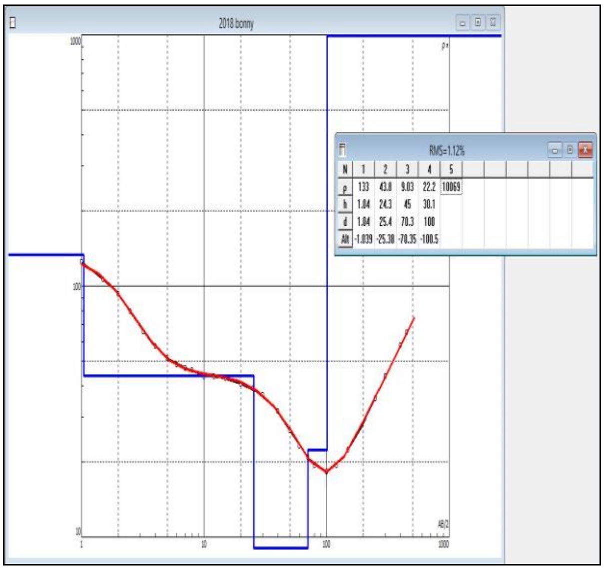

Figure 11: *Geoelectric Curve for Berger Road*

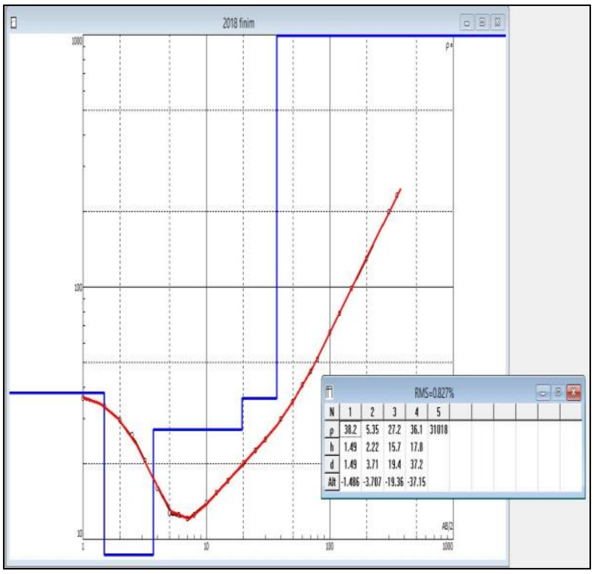

Figure 12: *Geoelectric Curve for Light House Finima*

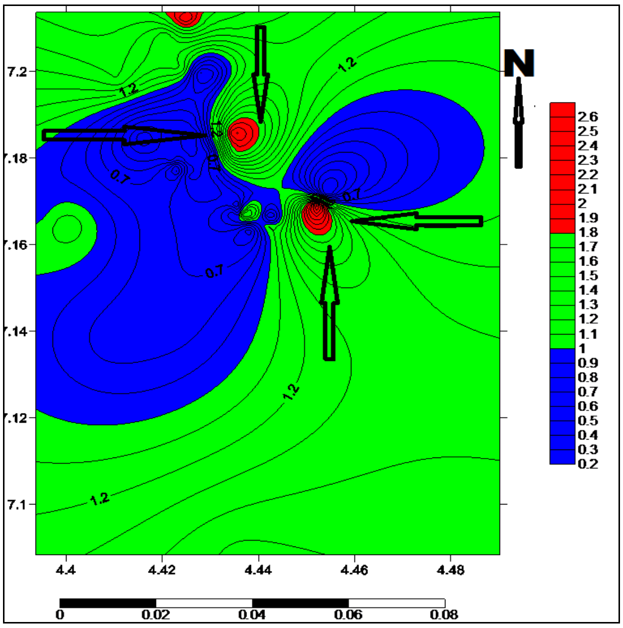

Figure 13: Water Level Depth

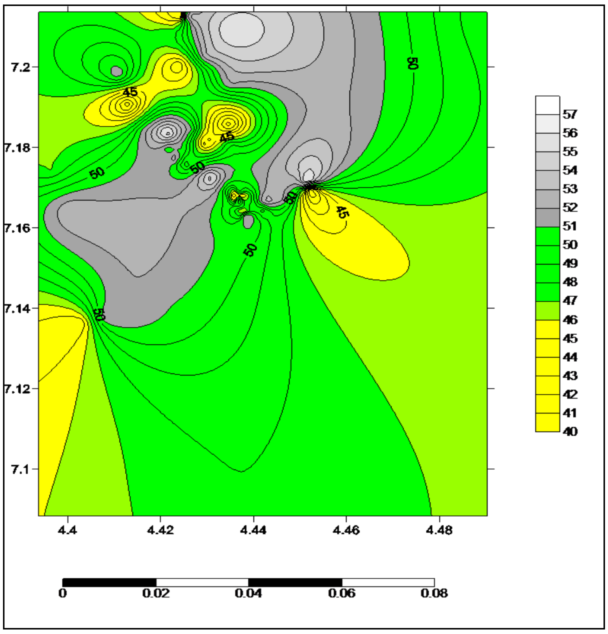

Figure 14: *Borehole Depth*

VERTICAL ELECTRICAL SOUNDING RESULTS

The result from the VES was used to produce the Geo-electric sections of the various curves. Figure 3 - 12 represent the result of the Vertical Electrical Sounding curves. The curve shows characteristics of HKH-curve for Burukiri (Figure 3), QH-Curve for Aru-Aghalama community (Figure 4). H-Curve type for Oloma and Epelema Community (Figure 5 and 6), HK-Curve type for Minima and Deima-Abbey Community (Figure 7 and 8), HAA-Curve type for Beresiri and back of Government school (Figure 9 and 10), AHA-Curve type for Berger Road (Figure 11) and QA-Curve type for Finima Settlement (Figure 12). The summary of the geoelectric section are presented in Table 1 while the summary of the curve type and their characteristics are shown in Table 2.

RESULT OF GEO-ELECTRIC SECTION OF VES 1 (ARU-AGBALAMA COMMUNITY)

In this location, five geoelectric layers were delineated (Figure 3 and Table 1) the resistivity of the area vary between 4.94Ωm and 12646m with thickness range of 0.6m to 33.14m. The uppermost layer is interpreted as clayey sandstone which is 0.6m thick, having a low resistivity value of 565.9Ωm. The second layer is 0.6753m thick consists of clay with low resistivity value of 115.1Ωm. The third layer of 1.434m thick has a high resistivity value of 946.4Ωm. The high resistivity indicates low conductivity and was interpreted as water saturated sandstone layer and as well the prospective aquifer unit. The fourth formation having resistivity value of 4.947Ωm which is 9.552m is clayey in nature. Underneath this formation consist of dry with infinite depth but has a high resistivity value of 12,464Ωm.

RESULT OF GEO-ELECTRIC SECTION OF VES 2 (BURUKIRI COMMUNITY)

Four Geo-electric units were observed in VES 2 curve (Figure 4) the area consist of varying resistivity value of 8.82Ωm to 9,203Ωm. The uppermost layer is mostly yellowish brown clay sandstone Earth material. It has a resistivity value of 303.5Ωm and is 3.712m thick. The underlying layer has a drastic fall resistivity value of 51.41Ωm and 7.875m thick. The resistivity indicates conductivity. It is interpreted as water saturated sandstone which is the prospective aquifer unit of interest containing iron or saline water. The third layer which has resistivity value 8.812Ωm with thickness 25.26m is interpreted as clay. The last layer whose bottom was not reached has with infinite depth and resistivity of 9,203Ωm which is interpreted as dry sandstone.

RESULT OF GEO-ELECTRIC SECTION OF VES 3 (OLOMA COMMUNITY)

The sounding encountered three geo-electric units (Figure 5 and Table 1). The sounding has a resistivity range of 160.5Ωm to 122,355Ω with average thickness range of 16.18m to 24.02m. The first layer is about 16.18m thick, which is the top soil that is made up of blackish earth of sandstone origin with resistivity of 1,117Ωm. The second layer is 24.02m thick with lower resistivity of about 160.5Ωm is interpreted to contain water saturated sandstone which is the prospective aquifer unit. The third layer whose base could not be reached has a very higher resistivity 122,355Ωm.

RESULT OF GEO-ELECTRIC SECTION OF VES 4 (EPELEMA COMMUNITY)

Three Geo-electric units were delineated at this location (Figure 6 and Table 1). The survey is distinguished with resistivity range of 146.4Ωm to 80586Ωm with varying thickness of 2.711m to 3.051m. The first layer with 2.711m thick is the top soil made up of Shaly Sandstone earth material. The second layer is 3.051m thick with low resistivity value of146.4Ωm and is interpreted as water saturated sandstone layer which is the target aquifer unit. The third layer whose base could not be reached has a very high resistivity of 80586Ωm interpreted as dry Sandstone.

RESULT OF GEO-ELECTRIC SECTION OF VES 5 (MINIMA COMMUNITY)

Four Geo-electric units were delineated in VES 5 curve (Figure 7) and its interpretation is shown in Table 1. The survey is characterized with varying resistivity of 13.32Ωm to 161.8Ωm and thickness range of 4.128m to 20.71m.The uppermost layer which is mostly yellowish brown clay sandstone Earth material and has a resistivity value of 63.44Ωm and 4.128m thick. The underlying layer has a higher resistivity value of 161.8Ωm and 0.6197m thick. The high resistivity indicates low conductivity. It is interpreted as water saturated sandstone which is the prospective aquifer unit of interest. The third layer which has resistivity value 13.32Ωm with thickness $13.32m$ is interpreted as clay. The last layer with infinite depth has a resistivity value of 14,221Ωm which is interpreted as dry sandstone.

RESULT OF GEO-ELECTRIC SECTION OF VES 6 (DEIMA ABBEY)

In this section, four geo-electric units were revealed (Figure 8 and Table 1). The first layer which is top soil of clayey sandstone origin and has resistivity value of 37.04Ωm and 0.6m thick. The underlying layer has a higher resistivity value of about788.2Ωm and about 0.54m thick. The high resistivity indicates low conductivity. It is interpreted as sandstone. The third layer which has resistivity value 47.84Ωm with thickness of 0.6197m. It is interpreted as shale. The forth layer with a depth of 41.57m and resistivity value of 102.4Ωm is interpreted as water saturated sandstone which is the prospective aquifer unit of interest. .

RESULT OF GEO-ELECTRIC SECTION OF VES 7 (BERESIRI COMMUNITY)

In this location, five geo-electric layers were delineated (Figure 9 and Table1). The uppermost layer is interpreted as clayey sandstone which is the top soil which is 3.49m thick, having a low resistivity value of 22.7Ωm. The second layer of 5.73m thick consists of clay with low resistivity value of 50.3Ωm. The third layer is 15.1m thick has a high resistivity value of 58.1Ωm. The high resistivity indicates low conductivity and was inferred as water filled sandstone formation which serves and as the prospective aquifer unit. The fourth stratum which is 40m thick having resistivity value of 72.8Ωm which is clayey in nature. Underneath the layer comprise of dry sandstone with infinite depth but has a reasonable resistivity of 35,311Ωm.

RESULT OF GEO-ELECTRIC SECTION OF VES 8 (BEHIND GOVERNMENT, BONNY TOWN)

In this location, five geo-electric layers were delineated (Figure 10 and Table 1). The uppermost formation is inferred as topmost soil of clayey sandstone origin with a thickness of 0.5m and a resistivity value of 1.73Ωm. The second layer is 0.75m thick consists of resistivity value of 0.89Ωm. The third layer is 0.545m thick has a resistivity value of 1.88Ωm. The fall in resistivity indicates high conductivity and is interpreted as water saturated sandstone layer and as well the prospective aquifer unit and possibly containing water. The fourth layer with a thickness of about 4.6m and resistivity value of 1.84Ω-m is deduced as clay. Beneath the fourth layer comprises of dry sandstone depth is infinite but has a resistivity of 62.9Ωm and the high resistivity signifies presence of salt water.

RESULT OF GEO-ELECTRIC SECTION OF VES 9 (BERGER ROAD)

In this location, five geo-electric layers were delineated (Figure 11 and Table 1). The section consists of varying resistivity between 9.03Ωm to 10,069Ωm with thickness range of 1.04m to 30.1m. The first layer is interpreted as clayey sandstone which is the topmost formation been 1.04m a thick with resistivity value of 133Ωm. The second layer of about 24.3m thick consists of clay with low resistivity value of about 43.8Ωm. The next stratum is 45m thick has a high resistivity value of 9.03Ωm inferred as area made up of clay. The fourth layer with a thickness of 22.2m and resistivity value of 30Ωm. The high resistivity indicates high conductivity and is inferred a sandstone saturated layer the prospective aquifer unit. Beneath this layer consist of dry sandstone that is infinite in depth but has a good resistivity of 10,069Ωm.

RESULT OF GEO-ELECTRIC SECTION OF VES 10 (FINIMA LIGHT HOUSE ROAD)

In this section, five geo-electric units were delineated (Figure 12 and Table 1). The resistivity value falls between 5.35Ωm and 38.2Ωm. The first layer which is top soil of clayey sandstone origin has a resistivity value of about 38.2Ωm and 1.49m thick. The underlying layer has a lower resistivity value of about 5.35Ωm and about 2.22m thick. The low resistivity indicates high conductivity. It is inferred as clay. Third formation which has resistivity value of 15.7Ωm with thickness of 27.2m. It is inferred as water saturated sandstone which is the prospective aquifer unit of interest. The forth stratum has resistivity value of 36.1Ωm with thickness of 17.8m. The infinite layer has resistivity of 31,018Ωm, which is interpreted as dry sandstone.

WATER LEVEL DISTRIBUTION AND BOREHOLE DEPTH MAPS

The subsurface maps of water level distribution and borehole depths of the study area were generated from Table 3 with the aid of surfer8 software and presented as Figures 13 and 14 which depict the results of the water level distribution and borehole depths of the aquifer encountered. The water level distribution varies from 0.2m to 2.6m. The area colour coded red is observed to be the steepest in the central part of the study area, while the area colour coded with green indicates area that is the shallowest. The other area colour coded blue indicates area that has intermediate water level values. The direction of the water flow is indicated by the arrow pointing towards the steepest areas. From the map it can be suggested that the direction of underground water in the study area is towards the central parts of the study area (Figure 12). Figure 13 shows how borehole depth is spread within the study area. The highest value of the depth distribution is seen at North-Eastern parts and North-Western part with a range of 40 to 57m. The area coded with yellow indicates areas that has the lowest borehole depths (40-46m). The areas colour coded with colour green are areas of intermediate borehole depths (47 – 51m) while the areas colour coded with ash indicates the areas that has the highest borehole depths.

V. Conclusion and Future Scope

The passage of current into the ground by adopting VES techniques in the area has immensely helped in knowing the overburden depths and potential zones of the study area. Ten Vertical Electrical Sounding was carried out with an AbamTerrameter 300 SAS in order to determine the groundwater level distribution using Schlumberger configuration. The data acquired was analyzed and interpreted with the aid of IP2Win and surfer 8 Software. Topsoil, clay and sandy formations were encountered and the result from the ten Geoelectric section reveals three geo-electric units in two, four geo-electric units in three and five geo-electric units in five of them with HKH, QK, HQQ, H, KH, HAA, QHA and QAA curve types. The resistivity values for the first layer ranges from 1.73Ωm to 863.6Ωm, the second layer ranges from 0.89Ωm to 788.3Ωm, the highest resistivity value was observed in the third layer with resistivity ranging from 0.5 to 1,222,355Ωm, the fourth layer ranges from 1.84 to 9,203Ωm, the fifth layer ranges from 62.9 to 12,464Ωm with an infinite thickness. The overburden thickness across the area falls between 5m to 100m. The water level depth distribution of the area varies between 0.2m to 2.6m and the direction of the water flow is towards the central part of the study area while the highest value of the borehole depth distribution was observed at North-Eastern part and North-Western part with a range of 40 to 57ft. This study recommends the following for further studies (i) Groundwater potential in Parts of Bonny Local Government Area. (ii) Evaluation of physiochemical characteristics in Bonny Local Government Area.

Table 1: ***Summary of Result of Geo-electric Section***

Location	**Layers**	**ρ1**	**ρ2**	**ρ3**	**ρ4**	**ρ5**	**h1**	**h2**	**h3**	**h4**	**d1**	**d2**	**d3**	**d4**
Aru-gbalama	4	303.5	51.41	8.81	9203	_	3.712	4.162	25.26	_	3.712	7.875	33.14	_
Burukiri	5	565.9	115.1	946.4	4.974	12464	0.6	0.6753	1.434	9.552	0.6	1.275	2.711	12.26
Epelema	3	863.6	146.4	80586	_	_	2.711	3.051	_	_	2.711	5.762	_	_
Oloma	3	1117	160.5	122355	_	_	16.18	24.02	_	_	16.18	40.2	_	_
Minima	4	63.44	161.8	13.32	_	_	4.128	4.701	20.71	_	4.128	8.829	29.53	_
Diema Abbey	4	37.04	788.3	47.84	102.4	_	0.6	0.6197	41.57	_	0.6	1.22	42.79	_
Beresiri	5	227	50.3	58.1	72.8	35311	3.49	5.73	115.1	40	3.49	24.4	64.3	_
GovtSch	5	1.73	0.89	0.5444	1.84	62.9	0.5	0.75	1.88	4.69	0.5	1.25	3.13	7.82
Berger Road	5	133	43.8	9.03	22.2	10069	1.04	24.3	45	30.1	1.04	25.4	70.3	100
Finima Light House Road	5	38.2	5.35	27.2	36.1	31018	1.49	2.22	15.7	17.8	1.49	3.71	19.4	37.2

Table 2: ***Curve Types Characteristics (Showing Curve types & Layers)***

VES	Curve Type Table	Curve Characteristics	Geo- Electric Layers
1	HKH	$\rho_1 > \rho_2 < \rho_3 > \rho_4 < \rho_5$	5
2	QH	$\rho_1 > \rho_2 < \rho_3 > \rho_4$	4
3	H	$\rho_1 > \rho_2 < \rho_3$	3
4	H	$\rho_1 > \rho_2 < \rho_3$	3
5	KH	$\rho_1 < \rho_2 > \rho_3 < \rho_4$	4
6	KH	$\rho_1 < \rho_2 > \rho_3 < \rho_4$	4
7	HAA	$\rho_1 > \rho_2 < \rho_3 < \rho_4 < \rho_5$	5
8	HAA	$\rho_1 > \rho_2 < \rho_3 < \rho_4 < \rho_5$	5
9	QHA	$\rho_1 > \rho_2 > \rho_3 < \rho_4 < \rho_5$	5
10	QA	$\rho_1 > \rho_2 < \rho < 3\ \rho_4 < \rho_5$	5

Table 3: *Water Level and Borehole Depth Distribution*

S/N	Northings	Eastings	water Level	Borehole Depth
1	4.43584	7.1673433	0.64	41
2	4.43652	7.166435	1.25	52
3	4.4365733	7.166995	1.39	53
4	4.4374433	7.16778283	1.2	43
5	4.4384367	7.16312	0.46	53
6	4.43784	7.1637567	0.44	44
7	4.43848	7.16759	1.47	46
8	4.4368233	7.1688517	0.96	50
9	4.4356467	7.16897	0.47	45
10	4.4347633	7.167505	1.04	49
11	4.4307567	7.17259	0.54	56
12	4.425145	7.1759967	0.5	47
13	4.4254983	7.179525	0.41	50
14	4.4231417	7.1775283	1.11	53
15	4.4160817	7.1847217	0.19	51
16	4.4129017	7.1906083	0.78	40
17	4.4108983	7.198095	1.5	52
18	4.3963917	7.17434	0.92	47
19	4.39377883	7.1678183	0.92	50
20	4.4003283	7.1645867	1.2	53
21	4.422333	7.1408333	0.73	51
22	4.4029533	7.1363417	0.84	44
23	4.4080967	7.1376817	0.74	52

24	4.421815	7.179635	0.46	50
25	4.4214217	7.1836	0.51	57
26	4.42637	7.18083	0.4	49
27	4.426765	7.1847533	0.35	51
28	4.4269283	7.1896517	0.61	48
29	4.4239483	7.2005183	1.32	43
30	4.4207717	7.2084467	1.32	48

Table 3: Water Level and Borehole Depth Distribution continued

S/N	Northings	Eastings	water Level	Borehole Depth
31	4.42787	7.1994	0.45	47
32	4.4296567	7.202855	0.82	53
33	4.4249467	7.2128367	2.27	44
34	4.4254033	7.2129233	2.1	54
35	4.4245817	7.2136883	1.96	44
36	4.42867	7.2129717	1.75	53
37	4.4902	7,2127367	1.2	47
38	4.4309433	7.1994817	0.6	50
39	4.4354617	7.2098183	1.5	56
40	4.4356633	7.08835	1.54	48
41	4.434735	7.1957183	1.29	52
42	4.4348567	7.1858133	2.15	40
43	4.4294667	7.181185	0.48	43
44	4.4348967	7.1809433	1.75	49
45	4.4385267	7.171285	0.88	50
46	4.4421633	7.1649867	1.16	47
47	4.442445	7.1660683	0.44	54
48	4.4465	7.167085	1.3	52
49	4.452455	7.1694967	2.71	40
50	4.4514883	7.1712833	0.98	57
51	4.4497033	7.1724317	0.92	53
52	4.45392	7.171165	0.2	52
53	4.4569117	7.1719617	0.68	48

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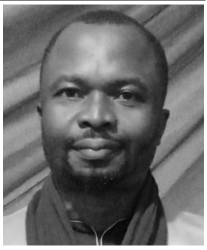

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