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GEOPHYSICAL SURVEY ON GROUNDWATER PREDRILL FOR THE CONSTRUCTION OF WATER BOREHOLE IN OBIO/AKPOR LOCAL GOVERNMENT AREA, RIVERS STATE, NIGERIA

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ABSTRACT

Predrilling groundwater geophysical survey for the construction of water borehole in Obio/Akpor Local Government Area, Rivers State, Nigeria, was conducted using a detailed Vertical Electrical Sounding (VES) with the Schlumberger configuration, Spontaneous Potential (SP) and Resistivity (Short and Long Lateral) geophysical methods to ascertain the groundwater potential in the study area. The sounding curves show three layers to four layers earth models. It could be suggested that the low resistivity and significantly thick weathered rock/clay constitute the aquifer in the study area. The north central, northeastern, eastern, southeastern, south central and southwestern part from the maps of weathered layer thickness and groundwater potential, signify that groundwater potential is moderate in these areas. The western part of the study area showed a very thin weathered layer which indicates low groundwater potential area, while the northeastern, central, and southeastern axes of the study area are of high groundwater potential. Results from the study has revealed that 9 VES stations are most viable locations for the development of groundwater in the study area. However, about 11 VES stations could be considered as fair for borehole development while the remaining 10 VES stations could be considered to exhibit low prospects. The study has established the fact that some parts of Obio/Akpor LGA contain reasonable amount of groundwater which if well tapped will go far to reducing the water problem in the Local Government Area. Further studies using integrated geophysical investigation for subsurface characterization which will aid community planning in terms of water works construction should be carried out and areas of high ground water potential as indicated from the findings of this work should be noted and earmark for borehole establishment.

Key Words: Geophysical Survey, Groundwater, Predrill, Potential, Borehole, Obio/Akpor

INTRODUCTION

Groundwater is a vital resource for meeting global water demands, and water boreholes serve as essential infrastructure for accessing this resource. Predrilling groundwater geophysical surveys have gained prominence as a crucial step in the planning and construction of water boreholes. Access to clean and sustainable water sources is a critical issue in many regions, including Obio/ Akpor Local Government Area in Rivers State. There are benefits of predrilling geophysical surveys such as enhancement of success rate, resource allocation optimization, and environmental impact reduction. The construction of water boreholes in Obio/Akpor Local Government Area faces challenges related to uncertainty in subsurface conditions. Blind-drilling often results in dry or low-yielding boreholes, wasting resources and causing delays in providing access to clean water. Insufficient information about the hydrogeological characteristics of the area leads to suboptimal borehole placement and potential failure of water supply systems. Water boreholes play a significant role in meeting the water needs of the community. However, the construction of successful boreholes relies on accurate subsurface information. Predrilling groundwater geophysical surveys have emerged as a valuable tool for optimizing borehole construction by assessing subsurface conditions. (Shaibu, 2020).

Groundwater is one of the precious resources that are most widely distributed within the earth, subsurface within sediments, rocks, ice, and snow. Groundwater occurrence, its flow, and storage properties are determined by the geological structure, geomorphology and rainfall pattern (Coker, 2012). The groundwater is a natural renewable water resource obtained from beneath the earth surface, which gets replenished after every rainfall. However, this renewable resource is getting depleted due to its significant exploitation worldwide. Over time, the groundwater has gone deep below the surface (Michael and Solomon, 2015).

Geophysical surveys enable targeted drilling, reducing the need for extensive drilling campaigns. By delineating favorable drilling sites and estimating aquifer depth, thickness, and productivity, predrilling surveys optimize resource allocation, saving time, effort, and costs (Ochuko, 2015). Conducting geophysical surveys prior to drilling minimizes the environmental impact associated with blind drilling. By avoiding unnecessary drilling attempts and reducing the overall number of boreholes required, predrilling surveys contribute to the sustainable management of groundwater resources (Lenkey, 2005). There could be limitations and challenges to geophysical surveys including geological heterogeneity, data interpretation and integration, survey techniques and equipment, etc. (Michael and Solomon, 2015).

The effectiveness of geophysical surveys is influenced by the geological complexity of the study area. Heterogeneous subsurface conditions, such as variations in lithology, fault zones, or fractures, can pose challenges in accurately delineating aquifers and estimating their properties (Schwartz, 2017). The choice of geophysical techniques and equipment significantly impacts the quality and reliability of survey results.

Predrilling ground water geophysical survey is a method typically conducted prior to drilling a well to investigate subsurface structures, identify potential aquifers, determine best location for well and to assess the potential yield of an aquifer. The survey involves the use of geophysical methods such as seismic, electrical, and electromagnetic methods. These methods measure the physical properties of the subsurface, including electrical resistivity, magnetic susceptibility, seismic velocity, and other properties. Data obtained from the measurements are then used to create a subsurface map that can help identify potential aquifers and other subsurface features (Ochuko, 2015). Predrilling ground water geophysical surveys save time and money and help to identify the best location for a well and provide an estimate of the potential yield of an aquifer prior to drilling (Omosuyi, 2010). This study aims to investigate the application of predrilling geophysical surveys in Obio/Akpor Local Government Area for the construction of water boreholes with the objectives to conduct predrilling geophysical surveys in selected locations within the study area, analyze and interpret the geophysical data to identify favorable

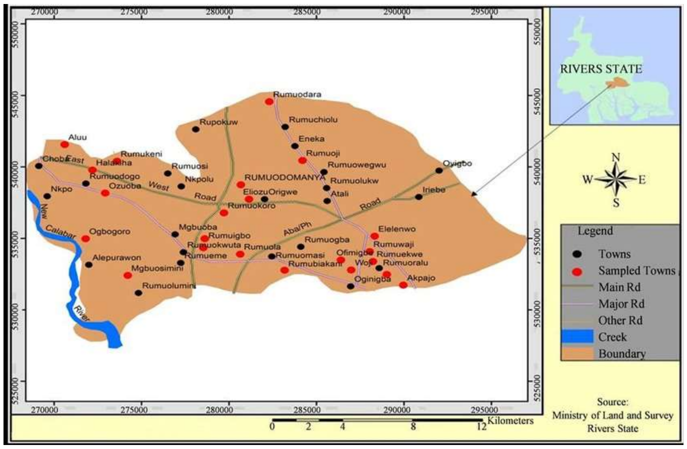
drilling sites and estimate aquifer properties. Hence, there is a need to explore the use of predrilling geophysical surveys as a solution to these challenges.
(Schwartz, 2017).

The Study Area

Obio/Akpor Local Government Area is located between latitudes 4°45'N and 4°60'N and longitudes 6°50'E and 8°00'E. The Local Government Area covers 260 km^2 and it is generally a lowland area with average elevation below 30 m above sea level. Its geology comprises basically of alluvial sedimentary basin and basement complex (Weli et al., 2016). The thick mangrove forest, raffia palms and light rainforest are the major types of vegetation.

Obio/Akpor is located within the Niger Delta region which is characterized by its beaches, mangrove swamps and barrier bars. The Niger Delta Basin is also referred to as the Niger Delta province. The basin comprises several types of geologic formations, indicative of how the basin could have formed. At the beginning of the Paleocene there was a tremendous shoreline transgression. During the Paleocene, the Akata Formation had been deposited, before the Agbada Formation during the Eocene. (Ibim and Nwinka, 2023). The Akata Formation is 7,000 m thick.

The Agbada Formation is marine facies defined by both freshwater and deep-sea characteristics. This is the main oil and natural gas-bearing facies in the basin. The hydrocarbons in this layer were formed when this layer of rock became subaerial and was covered in a marsh-type environment that is very rich in organic content. It is about 3,700 meters thick (Tuttle *et al*., 2015). Agbada Formation which is generally fluviatile and fluviomarine is primarily of interest to the hydrocarbon industry. The depositional pattern which accompanied sedimentation during the formation of the delta, gave rise to structural traps (growth faults and roll-over anticlines) in the Agbada Formation, which facilitated the accumulation of petroleum in the reservoirs of the Niger Delta. The Agbada Formation while suitable for petroleum accumulation is considered too deep to be of interest for groundwater abstraction (Nwankwoala and Omunguye, 2013).



Source:
Ministry of Land and Survey
Rivers State

Figure 1: Map of Obio/Akpor Local Government Area, River State

The Benin Formation is Oligocene and is the youngest in age. It comprises continental flood plain sands and alluvial deposits and it is estimated to be about 2,000m thick. Also, the Benin formation is still being deposited today (Ibim and Nwinka, 2023). The Benin Formation on the other hand which occurs at shallower horizons consists of continental deposit of sand and gravel and is therefore of greater significance to the groundwater and civil construction sectors. It is now well known that the Benin Formation (Miocene to Recent) possesses excellent water yielding properties even at great depths. Well cuttings from the logs of oil wells spread across the Niger delta, reveal that the Benin Formation is laterally extensive and extends to depths of 2000 m in places (Ezemokwe et al., 2018).

The Deltaic plains (upper and lower) and Benin Formation are the main aquifer formations. The area is dominated by both confined and unconfined aquifers at different depths and they contain highly saline groundwater. Because of high permeability, high recharge potential and the enormous thickness of the aquifers, groundwater is found to be very high. Water table distribution within the area is in the range of about 1.6 to 9.0 m (Ochuko, 2015).

Materials and Methods

There are two basic procedures in resistivity work. The procedure to be used depends on whether we are interested in lateral or vertical variations in resistivity. Resistivity surveys are made to satisfy the needs of two distinctly different kinds of interpretation problems: the variation of resistivity with depth, reflecting more or less horizontal stratification of earth materials; and lateral variations in resistivity that may indicate soil lenses, isolated ore bodies, faults, or cavities. For the first kind of problem, measurements of apparent resistivity are made at a single location (or around a single center point) with systematically varying electrode spacing. This procedure is sometimes called vertical electrical sounding (VES), or vertical profiling. The first is called horizontal or trenching profiling.

An enormous number of electrode spreads has been used in resistivity at various time particularly, however the electrodes are almost always in line, otherwise interpretation of result becomes difficult and then field work is complicated.

The materials used for the study include groundwater flow meter to measure the rate and direction of groundwater flow, hydrogeological maps to study existing groundwater conditions and identify potential drilling locations, resistivity meter (ABEM Terrameter) to measure the electrical resistivity of the subsurface materials which helps identify the presence of groundwater, conductivity meter to measure the electrical conductivity of the groundwater indicating the presence of dissolved ions, global positioning system (GPS) and Survey Equipment to accurately mark and measure drilling locations. Other accessory tools used for the surveys include four stainless steel metal rods electrodes (2 current, 2 potential) that are pegged into the ground, cables comprising of one pair of current cable and another pair of potential cable which serves as points of contacts between the terrameter and the electrodes, and hammer for hitting the electrodes into the ground.

Thirty Vertical Electrical Soundings (VES) data were acquired in different locations of the study area. The logging was carried out on 6th June, 2023, geographically located at latitude $4^0\ 52'$, longitude $7^0\ 25'$ and Ordinance Datum (O.D) elevation of 64 meters. The materials used for the predrilling groundwater geophysical survey for the construction of a water borehole include groundwater flow meter to measure the rate and direction of groundwater flow, hydrogeological maps to study existing groundwater conditions and identify potential drilling locations, resistivity meter (ABEM Terrameter) to measure the electrical resistivity of subsurface materials, which helps identify the presence of groundwater, conductivity meter to measure the electrical conductivity of groundwater indicating the presence of dissolved ions, global positioning system (GPS) and Survey Equipment to accurately mark and measure drilling locations.The other accessory tools used for the surveys include electrodes which four stainless steel metal rods (2 current, 2 potential) that are pegged into the ground, the cables comprising of one pair of current cable and another pair of potential cable which serves as points of contacts between the terrameter and the electrodes, the hammer for hitting the electrodes into the ground.

The observed field data which is the ratio of the resulting voltage to the imposed current is only a measure of resistance of the subsurface (ground resistance). This is read off directly from the terrameter and is used to compute the corresponding apparent resistivity in Ωm by multiplying with the geometric factor 'values as functions of electrode spacing', which then gives the required apparent resistivity results as functions of depths of individual layers:

$$\rho_a = \pi R \left[\frac{a^2}{b} - \frac{b}{4}\right] \tag{1}$$

where ρ_a= apparent resistivity, R = resistance in ohm, $a = AB/2$ = half current electrode spacing (m), $b = MN$ = potential electrode spacing (m) $\pi\left[\frac{a^2}{b} - \frac{b}{4}\right]$ = geometric factor (K).

The apparent resistivity values computed were plotted against half of the current electrode spacing (AB /2) on a log-log graph scale. The sounding curves obtained were subjected to conventional partial curve matching using the Rijks Waterstaat (1988) master curves to obtain the initial model parameters (resistivities and thickness) of the various geoelectric layers. The results obtained from the exercise were used as the input-model for the eventual computer aided iteration using the WINRESIST software.

The Spontaneous Potential (SP) and Resistivity (Short and Long Lateral) geophysical methods were adopted. The short spacing of the resistivity log was useful in locating strata interface while the long one provides better information on the formation lithology (grain sizes) as well as fluids in permeable strata. The procedure involved lowering of the multi-electrode probe manually to the bottom of the logged hole below ground level while readings were then taken at intervals of 3 m as the cable was pulled out of the hole. The depth of the logged hole was 156 m against the drilled depth of 180 m.

Results

From the interpretation of the VES data acquired, the resistivities associated with each layer were derived together with corresponding thicknesses and the lithologic interpretation. The typical representatives of the thirty (30) curves as obtained from the computer iteration processes are as shown in Figure 2. The sounding curves show three layers to four layers earth models. The three layer curves characterized by H and A types represent 54% of the curve types in the study while the four layer models are characterized by KH, KQ, QH and AH which covers 46% of the curve types in the study area. Figure 3 shows the location of the curve type on a map to determine which curve type falls within the range of high, moderate and low groundwater potential.

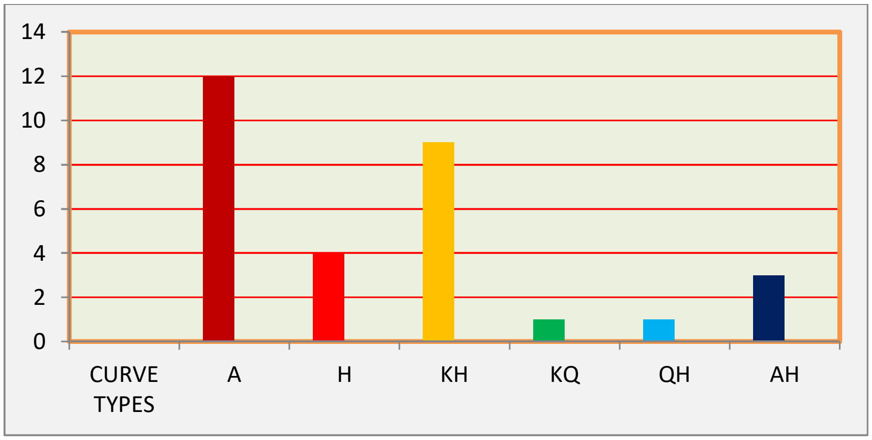


Figure 2: Bar chart showing the frequency of curve types obtained from the study area

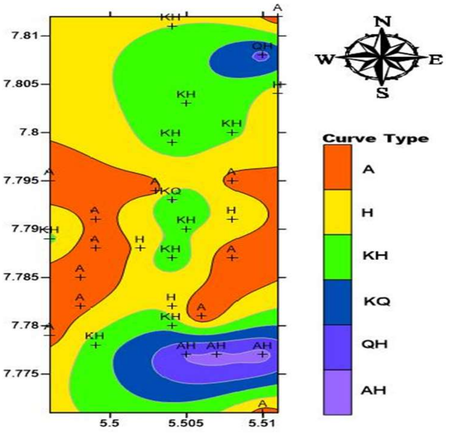


Figure 3: Map showing the distribution of the curve types

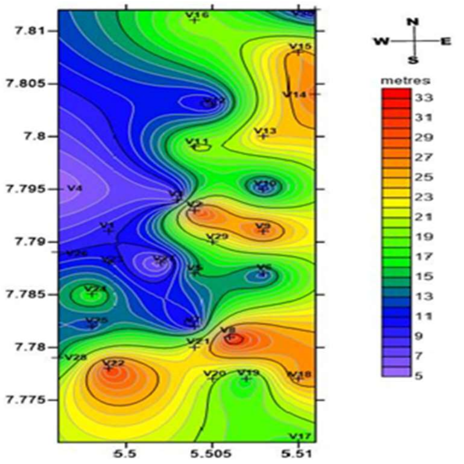


Figure 4: Overburden thickness isopach map

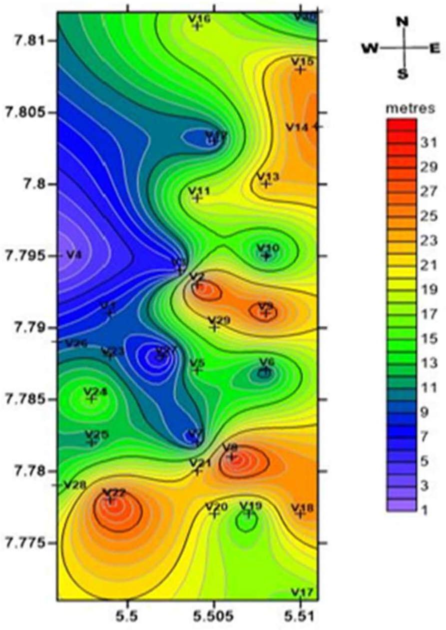


Figure 5: Weathered layer thickness map

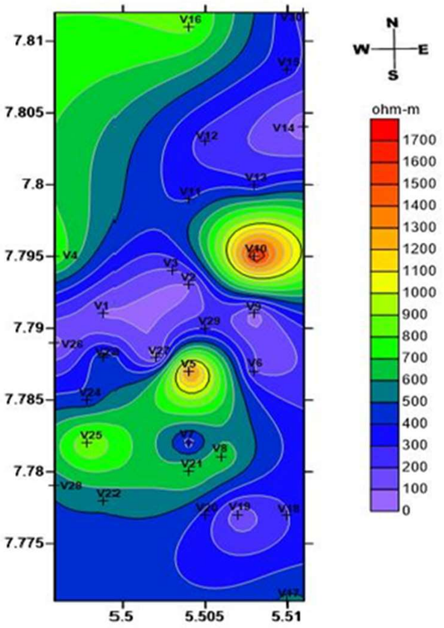
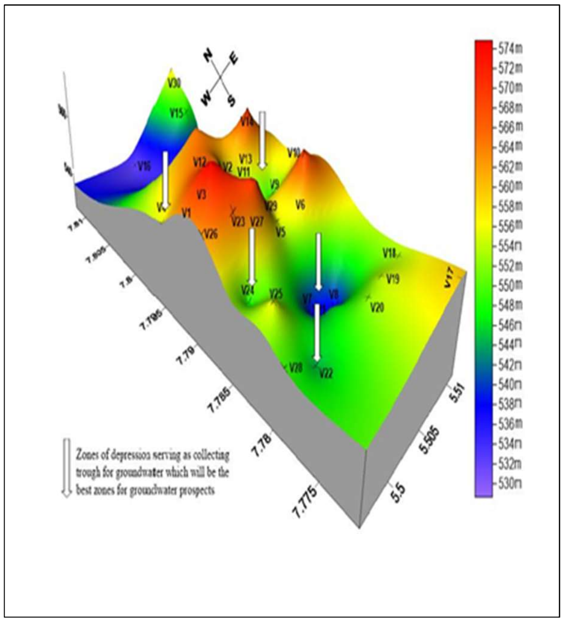


Figure 6: Weathered layer iso-resistivity



Zones of depression serving as collecting trough for groundwater which will be the best zones for groundwater prospects

Figure 7: Bedrock Relief Map

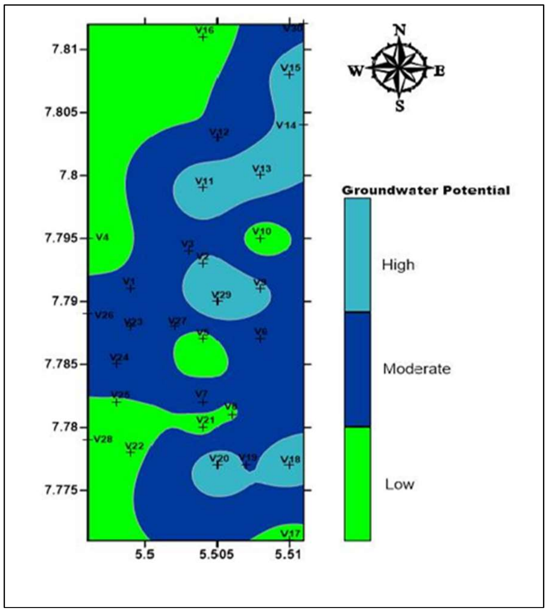


Figure 8: Groundwater Potential Map

DISCUSSION

Groundwater Potential Evaluation

The groundwater potential of a Basement Complex area can be determined by a complex inter-relationship between the geology, post emplacement tectonic history (fractures), weathering processes and depth, nature of the weathered layer, groundwater flow pattern, recharge and discharge processes (Olorunfemi et al., 1999). The groundwater potential of the study area was evaluated from overburden thickness, weathered layer thickness, weathered layer resistivity, and bedrock relief. The characteristic geo-electric parameters enabled the groundwater potential rating at each VES location. These maps are as presented above and discussed below.

Overburden Thickness Isopach Map

The depth to the basement (overburden thickness) beneath the sounding locations were plotted and contoured at 1m interval as shown in Figure 4. This was done to enable a general overview of the aquifer geometry of the surveyed area. The overburden was assumed to include the topsoil, upper and lower saprolite, saprock, andweathered basement. The values range from 5.1 m and 32.5 m. Areas with thick overburdenand not clayey in materials are corresponding to basement depression which are known to have high groundwater potential particularly in the basement complex area. Areas with thick overburden which favours occurrence of groundwater resources in an area particularly underlain by weathered rock are observed across the north central, northeastern, eastern, southeastern, south central and southwestern part of the map while thewestern and northwestern flank of the study area showed thin overburden thickness as shown in Figure 4.

Weathered Layer Thickness Map

The weathered layers as defined in this work are materials constituting the regolith, straddled in between the topsoil and fresh bedrock. The thickness of these lithological materials varies between 1.8 m and 31.1 m. This was determined from the layer interpretation of the sounding results. The weathered layer isopach map was produced using a contour interval of 1 m (Figure 5). The map was produced with a view to observing how the weathered basement layer considered which is the major component of the aquifer in the study area varied from place to place. The weathered layer was seen to be thickest at north central, northeastern, eastern, southeastern, south central and southwestern part of the map signifying that groundwater potential is moderate in these areas. The western part of the study area showed a very thin weathered layer which indicates low groundwater potential area.

Weathered Layer Resistivity Map

To have an insight to the groundwater potentials of the study area, there is a need for an aquifer resistivity map (Figure 6) to be produced from the interpreted VES data results. The resistivity value of the aquifers at each VES site location was plotted and contoured at 100 Ω-m interval. The map was produced in order to determine areas favorable for groundwater, and to find out whether or not the degree of weathering/saturation varies frompoint to point in the study area. As shown on the map, the resistivity value of the aquifer is highest at a small portion of the eastern part and southern part while portion of thesouthwestern, north central and northwestern part of the study area falls within moderately high values. However, the northeastern, small portion of western, southeastern, southwest and south central part of the study area showed moderate resistivity values. The northeastern and south-central part could be the most promising location for groundwater prospect because of its thick overburden and moderate resistivity values. Some portion of the western part could also be considered as another promising areafor ground water prospect but due to its thin over burden, the water present in the aquifer might not be able to serve the industrial purposes in the time of prolonged dry season.

Bedrock Relief Map

The bedrock relief map (figure 7) is a contoured map of the bedrock elevations beneath all the VES stations. These bedrock elevations were obtained by subtracting the overburden thicknesses from the surface elevations at the VES stations. The bedrock relief map generated for the locations shows the subsurface topography of the bedrock across the surveyed area in order to view clearly the suspected areas for groundwater prospects. Areas with basement depressions on the map serve as collecting trough for groundwater which will be the best zones for groundwater prospects. The map shows series of basement depressions and basement ridges. Southern, eastern, western and northeastern parts are the designated areas for the depressions while northern, northwestern, and small portion of the southeastern are ridges zones. The depression zones are noted for thick overburden cover while the basement ridge zones are noted for thin overburden. Geologically, depressions zone in basement terrain could serve as groundwater collecting trough especially water dispersed from the bedrock crests. Thus, the zones with basement depressions are priority areas for groundwater development in the study locations.

Groundwater Potential Map

Groundwater potential evaluation of the area was derived from the synthesis of the curve type analyses as well as the composite maps of the isopach map of weathered layer, resistivity map of weathered layer, overburden isopach map and bedrock relief map, hence, groundwater potential map was produced in order to draw the final conclusion from the evaluated maps (Figure 8). The map presents local groundwater prospects of the study area which is zoned into low, moderate and high groundwater potentials. Area with color green on the map constitute the low groundwater potential zone, moderate groundwater potential zone covers area with color navy blue while areas with color sky blue constitute the high groundwater potential zone. Regions seen to have low groundwater potential in the study area will be good for engineering purposes (i.e. construction of high rise buildings).

CONCLUSIONS

As long as water still remains one of our essential amenities in life, the groundwater potential evaluation of an area cannot be overlooked. Ignorantly without carrying out geophysical survey, the building contractors might have decided to build on the promising areas for groundwater exploration which will lead to more scarcity of groundwater in the society. Also, building of factories on promising areas for groundwater exploration is even disastrous to the users in the future. The study has been able to highlight the importance of geophysical survey for effective hydrogeologic characterization and town planning. The presence of weathered layer is a key component of aquifer system and zone of groundwater accumulation.

Results from this study have revealed that 9 VES stations are most viable locations for the development of groundwater in the study area. However, about 11 VES stations can also be considered as fair for borehole development while the remaining 10 VES stations are considered to exhibit low prospects.

The north central, northeastern, eastern, southeastern, south central and southwestern part from the maps of weathered layer thickness and groundwater potential signify that groundwater potential is moderate in these areas. The western part of the study area showed a very thin weathered layer which indicates low groundwater potential area, while the northeastern, central, and southeastern axes of the study area are of high groundwater potential. It can be concluded that the low resistivity and significantly thick weathered rock/clay constitute the aquifer in this area.

The findings of this study is capable of contributing to the knowledge and understanding of the use of predrilling geophysical surveys for water borehole construction in Obio/Akpor Local Government Area and providing insights into the hydrogeological conditions of the area, identify potential aquifers, and offer guidelines for optimizing borehole placement and also help in improving the success rate of borehole construction, minimize drilling costs, and ensure the availability of clean and sustainable water sources for the community. Additionally, the study may serve as a reference for future research and inform decision-making processes related to groundwater exploration and development in similar regions. The study has established the fact that some parts of Obio/Akpor LGA contain reasonable amount of groundwater which if well tapped will go far to reducing the water problem in the Local Government Area.

Further studies using integrated geophysical investigation for subsurface characterization which will aid community planning in terms of water works construction should be carried out and areas of high ground water potential as indicated from the findings of this work should be noted and earmark for borehole establishment.

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