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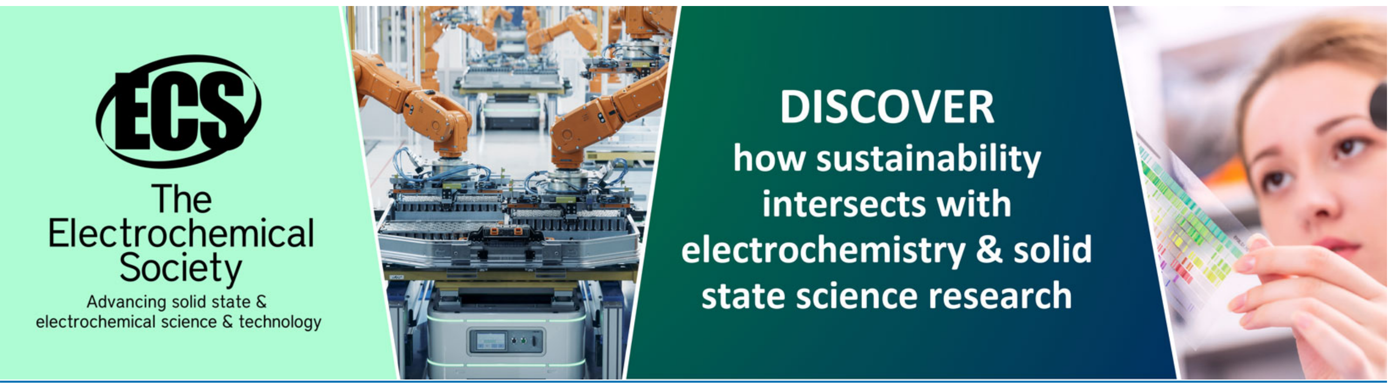

Integration of Magnetic Data and Geo-Spatial Analysis for Characterising Aquiferious Yields in New Estate, Covenant University, Ota, Ogun State

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Abstract This study was conducted to understand the possible causes of abortive boreholes along the New Estate in Covenant University. The conceptual model predicted the two groundwater characteristics of weathered and the unweathered zones. The V-shape curve revealed two groundwater anomalies with high and low curves. The peak anomaly indicates the higher resistivity, presumed to be the geological structures of unsaturated features in the area. The sink V-shape curve indicate an anomaly with groundwater features, presenting low resistivity values attributed to be water bearing formation that will be viable for groundwater potential. The Iso-resistivity contour map identified possible groundwater features. The first Iso-resistivity column is a region of aquitard with a semipervious in nature that could transmit water in a slower rate. The second groundwater feature in column 2 is a perch aquifer that could enhance the main aquifer due to interconnectivity and pore pressure of downward-upward migration in confined hydrogeological aquifer setting. Column 3 depicts a complete impermeable feature of aquifuge or aquiclude of subsurface structure with rich in clay sediments or stratum of sediments found at the depth range of 30 m to 270 m. The forth groundwater column indicates a promising water bearing formation, probably sandy in nature with a depth range of 210 to 300 m and thickness of about 90 m. The spatial analysis identified the two locations along the survey areas to be suitable for productive boreholes as well as the trending of the groundwater in the area to be Northwestern Southeast direction. Consequently, the model could be a guide to organize site data, understand site processes and screen for applicability of drilling. These multiple methods of geophysical, spatial analysis and conceptual model could be used a tool for mapping hydrocarbon bearing formation.
Keywords: Groundwater, GIS, Electromagnetic Method, Conceptual Model

1. Introduction

An Aquifer is a body of permeable rock that can contain and transmit groundwater. It is a geologic formation that bequests significant quantities of water. Groundwater is a source of fresh water, and it is the primary storage reservoir of freshwater. Groundwater is not just water under the ground; it is water held in rocks by specific forces, replenished by nature according to the climate and the local geology, and consequently variable in both amount and quality (Molle et al., 2017). Aquifers are essential to all life and beings (Omole et al., 2017). Aquifer behavior is related to many factors in the hydrological system. One of the essential ideas in hydrology, and in any water resource management, is the hydrologic cycle (also called the water cycle), this ideology has been stipulated on since ancient times (Maidment, 1993). The hydrological cycle gives a detailed description of water production and transportation in different ways from place to place (Rushton and Kruseman, 2004). Groundwater, a renewable and finite natural resource, vital for human life, for social and economic development and a valuable component of the ecosystem, is vulnerable to natural and human impacts (Vrba 2002). In Nigeria today, the unmanaged digging of wells and its utilization is also a source of hydrological stress (Ufoegbuna, 2016). The lack of proper laws on how people in residential areas dig wells, and even as they use these wells can cause severe damage to the aquifer. Lack of knowledge of how improper management of groundwater resources would continue to lead people to dig up wells in any available area continually. This study is aimed at using integrated geophysical, conceptual models and geospatial analysis to identifying the subsurface features that could cause the abortive boreholes along New Estate in Covenant University

2.0 Geology of the Study Area

Ogun State with other south-western Nigerian states including Oyo and Lagos States lies in the eastern Dahomey Basin. Its geology is composed of sedimentary and basement complex rocks that are Late Cretaceous to Early Tertiary (Olabode, 2006). Stratigraphically, the sedimentary rock of Ogun State consists of the Abeokuta group, Imo group, Ewekoro, Oshosun, Ilaro and Benin formations (Olabode, 2006; Omole, 2006). The Geology of the study area is shown in Figure 1 and the Google Earth map indicating the location is shown in Figure 2.

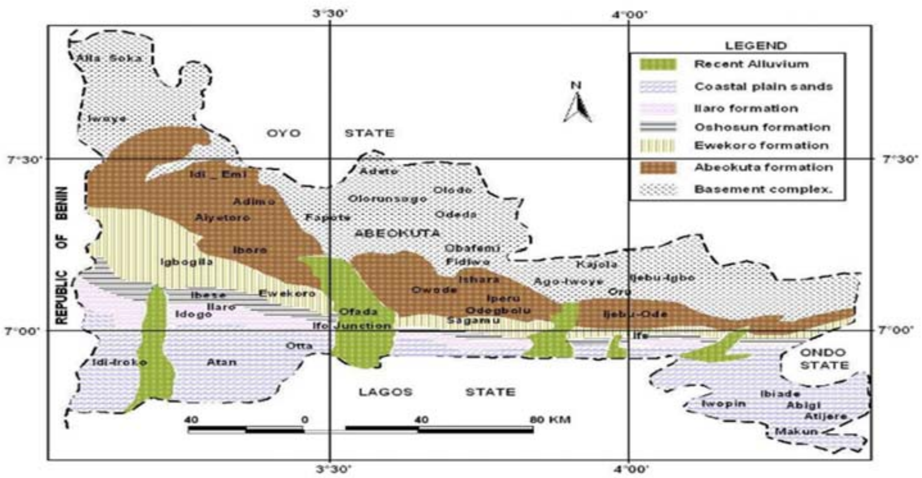

Figure 1: Geological Map of Ogun State (Olowofela et al., 2012)

3.0 Materials and Methods

TC-300 Series is a Hunan Puqi Geologic Exploration Equipment (Model No: PQWT-TC300) is an electromagnetic method used to study the subsurface geological features geological ore / mass bodies, groundwater and its abnormalities. These variations are useful in interpreting and solving the subsurface characteristics of the geological, geoengineering, environmental and disaster problems. The basic principle of the instrument is measuring the existing natural electric field of subsurface water / minerals /geological structures / ore bodies. The natural electric field geophysical instrument is one of the geophysical instruments, working with the source of natural electric field, measuring the subsurface rock / ore / groundwater, natural electric fields and variations at different frequencies and different depths. It detects the abnormality changes in the subsurface with a coupled 3 methods integrated and developed, consisting more and more data filters for analyzing data and filtering errors etc. It is easy operation, high quality touch screen and highly standard. The instrument profile map gives accurate mean depth, quantity, quality, shape of subsurface features and the geological structure. The instrument gives 100% results subsurface investigation and detection of bed rocks etc. The measurement is done by using tape to measure 10 meters distance and mark the starting point to be 0 meter. The configuration of M N two electrode bar equidistance is 10 meters, and subsequently both M N moved 1meter after measuring the first point placed at the position of 1.

3.1 Data Acquisition Using Magnetic Methods

Figure 2 presents the sampling points in the study area where the magnetic measurements and electromagnetic measurements were taken using Hand-held GEM Magnetometer. At each point, four different magnetic anomalous values in nano-tesla (nT) were measured and the average was taken to ensure accuracy. The measurements were carried out at an interval of 50 m from each other which was maintaianed all through the forthy nine (49) station points mapped. All the data were treated to ensure accuracy in georeferencing, capturing the subsurface geological structures that could be of interest for groundwater features according to Emenike et al., 2020 and Mama et al., 2020.

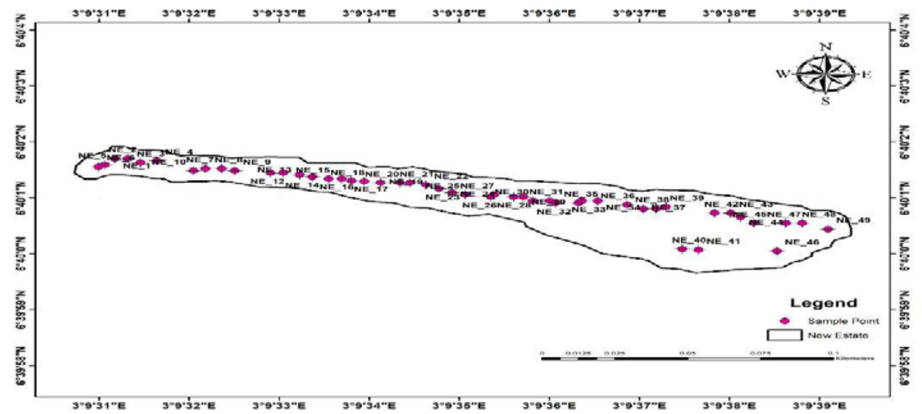

Figure 2: The Base Map of the Study Area Showing the Points Where the Magnetic Measurements were Carried Out

3.2. GIS Spatial Analysis of Magnetic Data from the Study Area

The magnetic data acquired from the study area were used to map the possible potential zones for water bearing formation. The acquired values were in nano-tesla (nT) with stations 10 and 48 identified to be the locations of water bearing zones as shown in Figure 6. The georeferencing and groundwater attributes pointed the area with magnetic values of 34331 to 34507 as the possible weathered or fractured zone that could trap large scale of groundwater. This permeable zones are within range of stations 10 – 11 and 48 – 49, respectively. The fissures and weathered zone picked from the magnetic values was used to justify the promising locations that form the leaky aquifers in New Estate.

3.3 Conceptual Model for Groundwater Flow in the Study Area

This conceptual model was developed to review the relationship between the hydraulic head, hydraulic gradient, hydraulic conductivity of productive and the unproductive boreholes in New Estate using two boreholes as a case study. This conceptual model is shown in Figure 3.

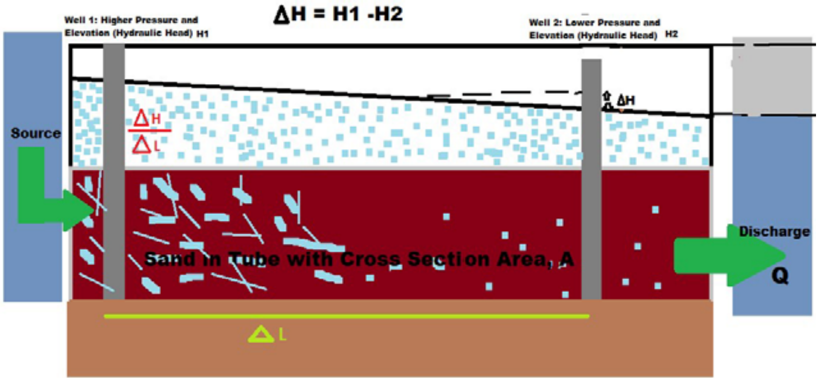

Figure 3: Conceptual Model for Prediction of Groundwater Flow in New Estate, Canaanland

3.4 GIS Spatial Analysis of Magnetic Data from the Study Area

The magnetic data acquired from the study area were used to map the possible potential zones for water bearing formation. The acquired values were in nano-tesla (nT) with stations 10 and 48 identified to be the locations of water bearing zones as shown in Figure 6. The georeferencing and groundwater attributes pointed the area with magnetic values of 34331 to 34507 as the possible weathered or fractured zone that could trap large scale of groundwater. This permeable zones are within range of stations 10 – 11 and 48 – 49, respectively. The fissures and weathered zone picked from the magnetic values was used to justify the promising locations that form the leaky aquifers in New Estate.

4.0 Results and Discussion

4.1 Interpretation of the Groundwater Conceptual Model of New Estate

The conceptual model developed in Figure 4 is an interpreted version of Figure 3 using selected values of the electromagnetic method acquired in the area. This model is used to infer the groundwater condition in New Estate, Covenant University. The prediction has revealed that any borehole sited within the left hand site of the model will be productive due to the possible large grain sizes, large pore spaces, less frictional resistance of flow and as well as higher hydraulic conductivity and hydraulic gradient which is geologically termed as the thick overburden. This region will be a suitable aquiferous zone with good yield of groundwater since the layers are weathered, hence presumed to be the saturated zone or water bearing formation. On the right hand side of the model, siting a borehole may constitute low to dry aquifer due to the smaller grain sizes, smaller pore spaces, more frictional resistance of the groundwater flow, lower hydraulic conductivity, and is termed as the unsaturated zone. Borehole 1 will give good yield in the study area whereas boreholes 1, 2, 3, and 4 will be highly unproductive due to the unweathered formation that may constitute clay and silt stone. The weathered zone is possibly interbedding of sandy-clay formation presumed to be perch aquifer was noticed at the depth of 150 m at the left hand side of the model. The main water bearing formation from the model ranged from 190 m to 300 m deep along the saturated/water bearing zone. This prediction may not be precise but a tool to help understand the site processes and screen for groundwater flow. The validation of this model will be the field measurements along the zones of where both successful and unsuccessful boreholes were drilled in the study area.

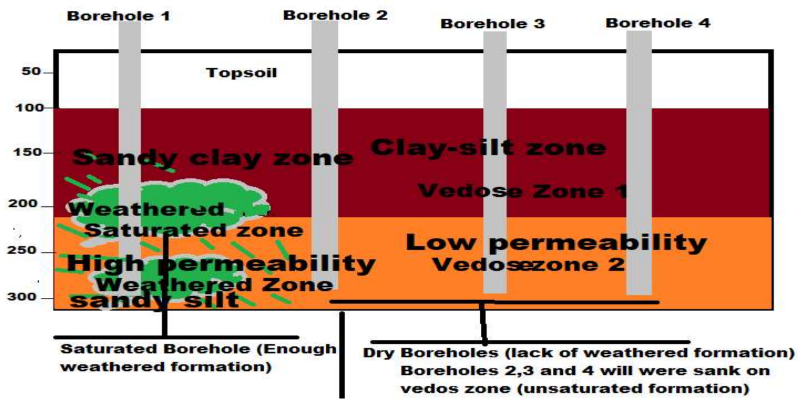

Figure 4: Conceptual Model for Prediction of Groundwater Flow in New Estate, Canaanland

4.2 The V-Shape Curve of the Measured Electromagnetic Methods for Groundwater Detection

The V-shape curve of the measured electromagnetic values were plotted in Figure 5 with several colour bands showing different frequency levels. The curve presented two different groundwater anomalies with high and low curves. The peak anomaly indicates the higher resistivity, presumed to be the geological structures of unsaturated features in the area. The sink V-shape curve indicate an anomaly with groundwater features, presenting low resistivity values pointing down. This sinking zone is termed the water bearing formation that will be viable for groundwater potential. At the same time, it could be a prone zone for groundwater contamination in the area.

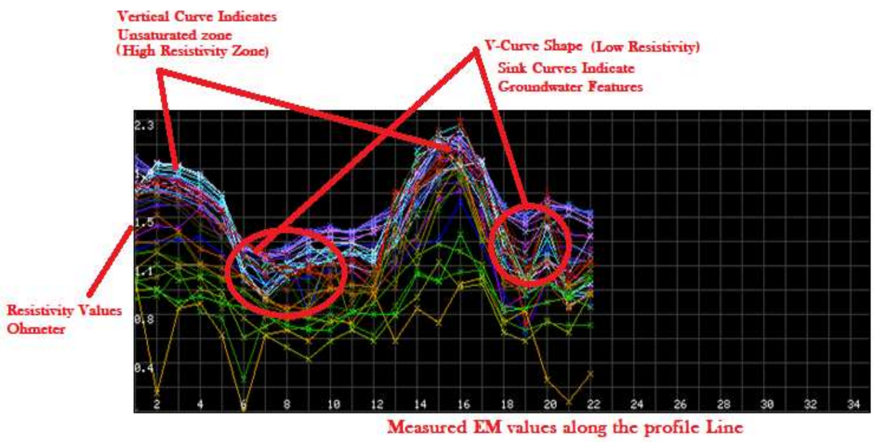

Figure 5: V-Curve Shape Profile Plot of Measured EM values and the Colour Band Frequencies in the Area

4.3 Iso-Contour Profile Map of the Measured Electromagnetic Method Values in New Estate

This Iso-resistivity profile map shows several variations in groundwater characteristics in the area. The region possesses 4 possible groundwater features. The first Iso-resistivity column which is labeled 1 is a region of aquitard that is semipervious in nature that could transmit water in a slower rate and possibly low hydraulic conductivity. The layers are compacted with probably clay or silt that retard groundwater flow; that is they act are groundwater barrier in Iso-resistivity column 1. The second groundwater feature in column 2 is the region of perch aquifer that could enhance the main aquifer due to interconnectivity and pore pressure of downward-upward migration experience in the aquifer hydrogeological setting. In the Iso-resistivity zone of column 3, it depicts a complete impermeable aquifuge or aquiclude of groundwater features with rich in clay sediments. This impermeable feature in column 3 may be attributed to the stratum of sediments found at the depth range of 30 m to 270 m. The forth groundwater column labeled column 4 indicates a promising water bearing formation, probably sandy in nature. This geological formation of groundwater potential found at this depth range between 210 and 300 m is inferred to be the aquiferous zone with a thickness of about 90 m. This layer seems to be made of denser geological materials that are completely weathered with fissures in alluvium aquifer which constitute high hydraulic conductivity.

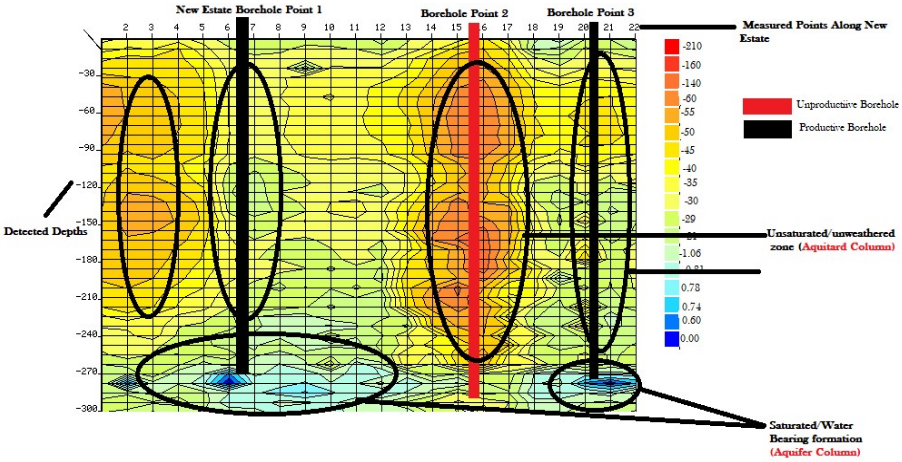

Figure 6: Iso-Resistivity Profile Map of the Study Area Showing 4 Different Groundwater Characteristics

4.4 GIS Spatial Analysis of Magnetic Data from the Study Area

The magnetic data acquired from the study area were used to map the possible potential zones for water bearing formation. The acquired values were in nano-tesla (nT) with stations 10 and 48 identified to be the locations of water bearing zones as shown in Figure 6. The georeferencing and groundwater attributes pointed the area with magnetic values of 34331 to 34507 as the possible weathered or fractured zone that could trap large scale of groundwater. This permeable zones are within range of stations 10 – 11 and 48 – 49, respectively. The fissures and weathered zone picked from the magnetic values was used to justify the promising locations that form the leaky aquifers in New Estate.

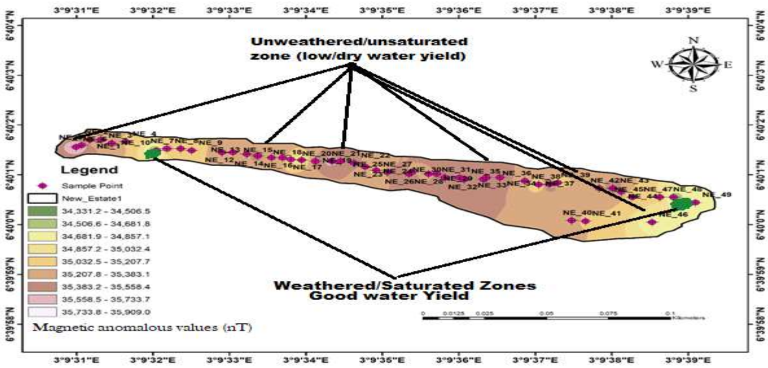

Figure 7: GIS Spatial Analysis of Magnetic Data Showing the Weathered and the Unweathered zones in the Study Area

4.5. Locating the Suitable Sites for Productive and Unproductive Boreholes along New Estate from Spatial Analysis Map

The successful siting of boreholes within the leaky aquifers was geologically inferred to be on dark green location of the spatial analysis map. This integrated map only identified two viable locations for successful boreholes, pointing to the extreme Northwestern part of the region and the other suitable site is trending towards the Eastern part of the region as shown in Figure 7. This spatial map revealed the trending of groundwater flow, with the source from NW trending towards SE direction.

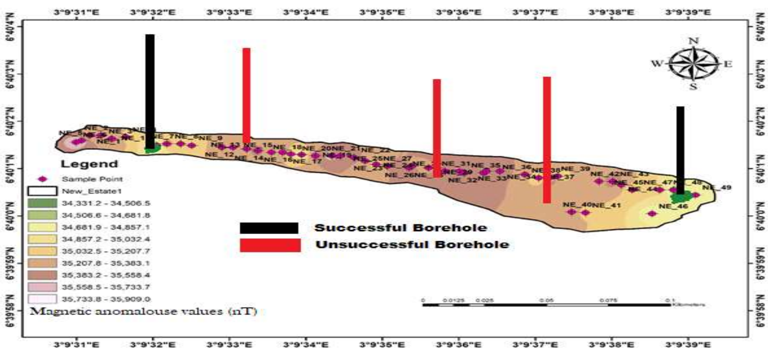

Figure 8: Spatial Analysis Map Showing the Successful and the Unsuccessful Zones for Borehole Siting or Drilling

5.0 Conclusion

This present study integrated conceptual model, geophysical methods and GIS spatial analysis to understand the subsurface structural formation that controls the groundwater yield at New Estate in Covenant University. The subsurface geology from the conceptual model identified the possible hydraulic head, hydraulic gradient and hydraulic conductivity. The V-shape curve from electromagnetic method revealed two groundwater potential points with low resistivity values at profile lines ranges between 6 – 8 and 18 – 20, respectively. The Iso-resistivity map of EM indicates the range of water bearing formation in the study area to be from 210 to 300 m with an aquifer thickness of about 90 m. The spatial analysis map identified measured points of 10 -11 and 48 -49, respectively as the viable zones for accessing productive boreholes in the area. The conceptual model could be a guide for organize site data, understand site processes and screen for applicability of drilling. These multiple methods of integrating groundwater Conceptual model, electromagnetic methods, magnetic methods and GIS spatial analysis for viable mapping of groundwater potential could serve as a tool for hydrocarbon mapping.

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