GEOPHYSICAL INVESTIGATION FOR GROUNDWATER POTENTIAL EVALUATION OF A REGOLITH AQUIFER IN A TYPICAL BASEMENT COMPLEX TERRAIN; A CASE STUDY OF IKOLE EKITI, SOUTHWESTERN, NIGERIA

BY

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CERTIFICATION

This is to certify that the project research was carried out by Mr. ADEBAYO OLAMILEKAN SODIQ with Matriculation Number (GPY/14/2266) of the Department of Geophysics, Federal University Oye-Ekiti, Ekiti State, Nigeria. Under my supervision, the report has been approved as meeting part of the requirement for the award of (B.Sc.) degree in Geophysics of Federal University Oye-Ekiti, Ekiti State.

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DEDICATION

I dedicate this report to Almighty God the creator of heaven and earth, the one who has always made it possible for me to go this far.

Also to my wonderful and incomparable mother for her prayer and support over me and also my guardian who played a very important role in my education up till this moment.

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I appreciate the Almighty God for the grace he gave to me to complete the research work and also crown it with success.

I also want to acknowledge my mother and my guardian for their prayer and support over me throughout my degreeprogramme. I say a big thank you and I pray that you will reap the fruit of your labour.

To my uncles and aunt Mr&MrsTaiwoAbiodun, Mr&MrsPhilip Lawal,Mr&MrsSeunKuforiji, my brother from another mother MrAkintaroIfeoluwa, my friends AkinboboseOludeji, AkanbiOluwabusayomi, Oloja Olusegun,OdeleyeOpeoluwa and BodundeOlajumoke Grace I say thank you and may God love you as you do towards me.

To my boss like a father, DrFatoba J.O. my boss like an uncle, Dr. Eluwole A.B, and my boss like a brother, Mr. Sanuade, thanks for your concern, advice and effort towards my success.

I cannot but remember all members of staff of the Department of Geophysics, Federal University OyeEkiti, especially all my lecturers; Prof. Isaac Osazuwa, Prof. M.O Olorunfemi, Dr. Bayewu O.O, Mr. Fajana, Mr. Olabode, Mr. Bamidele, Mrs.Olaseeni, I say a big thanks to you all.

I will not but also acknowledge the effort of my class members for their support and believe in me as their leader and a good friend. I say thank you and God bless you all.

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ABSTRACT

A geophysical investigation involving the electrical resistivity method was carried out at IkoleEkiti of South Western, Nigeria with the main aim of investigating the area for groundwater potential of the regolith aquifer.

The objectives are to identify geological structures and aquifers favorable to groundwater accumulation andalso input geoelectric layers parameters into a software to produce maps of the subsurface in order todetermine the groundwater potential of the regolith aquifer.

Thirty (30) Vertical Electrical Soundings (VES) using the Schlumberger array with maximum electrode separation AB/2 of 100m was carried out with ABEM SAS-300 Resistivity Meter. The VES data were presented as sounding curves and interpreted quantitatively through the method of partial curve matching and 1-D computer assisted forward modelling. The sounding curves show three layers tofour layers earth models. The three layer curve are characterized by H and A type which represents altogether about 54% of the curve types in the study while the four layer models are characterized by KH, KQ, QH and AH which altogether covers about 46% of the curve type in the study area. The overburden was assumed to include the topsoil, upper and lower saprolite, saprock, and weathered basement.

The weathered basement is the aquifer type delineated for the area. Groundwater potential was evaluated from the maps (i.e. overburden thickness, weathered layer thickness, weathered layer resistivity,and bedrock relief maps) revealing that the Northeastern, Eastern and Southeastern parts of the study area are the mostpromising region for borehole development. However, the western region of the study area can also be considered as fair forborehole development.

CHAPTER 1

INTRODUCTION

1.1 General Statement

The science of geophysics applies the principles ofphysics to the study of the Earthapplicable in the delineation or mapping of subsurface features arising from local variation in the measured physical properties of specific target relative of its host. Thus, the measurements taken during geophysical investigation are influenced by the internal distribution of physical properties of underlying rocks(Keary*et al.*,2002).

Geophysical investigation is the process of selecting an area of geologic interest and delineate the physical parameter of the object involved. The acquisition of data is fundamental to geophysical investigations and 'real' data is only acquired in the field. Without real data no true practical conclusions can be made about a targeted causative.

Geophysical investigation is found relevant in groundwater exploration, mining, engineering site investigation and environmental impact assessment.

Water,remains one of the vital elements in life and it is very much important to human existence. It is one natural resource that is not only essential for the survival of mankind but also for the survival of the natural environment. The availability of water has played a key role in the development of all civilizations. Indeed, especially in the ancient times, water scarcity prevented the development of settlements. Social welfare and economic development may also be hampered in theabsence of reliable water supplies.The rapid increase in population of the study area owing tourbanization has led to an increased pressure on underground water which is the major water resource in the area (Alabi*et al.*, 2016).

The geoelectrical resistivity method has been successfully employed in the delineation of subsurface geological sequence, geological structures/features of interest, aquifer units, types and depth extent in almost all geological terrains (Oladapo*et al.*, 2004; Ako*et al.*, 2005). This is because of the significant resistivity contrasts that exist between different earth materials (Olorunfemi*et al.*, 1993).

The Vertical Electrical Soundings (VES) has proved very popular with groundwater studies due to simplicity of the technique. Using this method, depth and thickness of various subsurface layers and their water yielding capabilities can be inferred. Therefore, evaluation of groundwater potential was done in order to know the groundwater yielding capabilities or groundwater conditions of the study area. In basement complex, unweathered basement rocks contain negligible groundwater. Significant aquifers however, develop within the weathered overburden and fractured bedrock. This research is particular to know feasibility of potable water (i.e. to know the promising areas for groundwater prospects) within the study area.

However, the groundwater conditions of an area is properly understood, it could be used as an effective tool in the planning of reliable water borehole in such area (Sunmonu*et al.*, 2012).

1.2 Description of the Study Area

1.2.1 Location and Accessibility of the Study Area

The study area is located in IkoleEkiti of EkitiState, South western, Nigeria. The study area lies within 7^{o}45'52.1"N – 7^{o}48'54.5" N and 5^{o}28'05.3"E– 5^{o}33'08.5"E(Fig 1.1). The area is accessible through various footpaths or pathways.

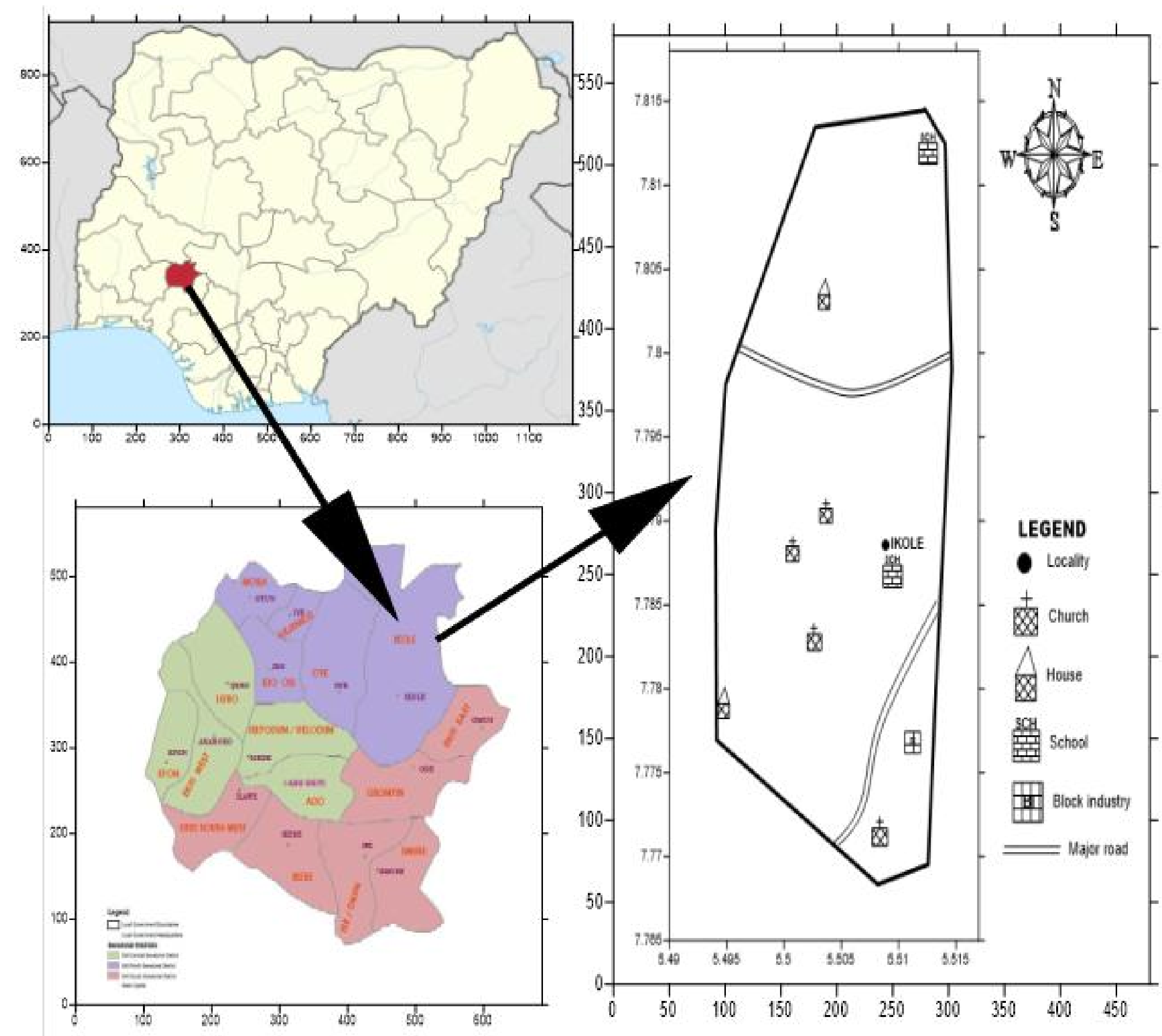


Figure 1.1: LocationMap of the study area

1.2.2 Relief, Climate and Vegetation

The relief are of very rough hills to isolated hills and low lands. The study area falls within the tropical rain forest of southwestern Nigeriawith two distinct seasons which are the rainy season (April–October) and the dry season (November–March). Temperature ranges between 21°C and 28°C while the mean humidity is over 70%. The south westerly wind and the northeast trade winds blow in the rainy and dry (Harmattan) seasons respectively. Tropical forest exists in the south, while savannah occupies the northern peripheries. The mean annual rainfall is about 1800 mm. (http://ekitistate.gov.ng/about-ekiti/overview/).

The vegetation of the study area is greatly influenced by climate and relief of the area. It is the evergreen forest type which comprises of palm trees, timbers and grass. Human activities such as farming and hunting are prevalent in the study area. Industries thriving in the study area are Agriculture and Lumbering which include Timber/Saw mills.

1.2.3 Drainage Pattern of the Study Area

The most common type of drainage pattern in this area is dendritic type with undulating topography, where the small tributaries is joining to the main river. The study area is one of the most fertile, and with high degree of accessibility to itapaji dam with enormous mini-hydroelectric power potential, as well as water supply opportunities for irrigation and townships. Even Oye river nearby flows into River Ele and provides substantial alluvial deposits in the study area plains for year round agriculture. Ero dam in Moba is also nearby.

1.3 Aim and Objectives

The aim of the study was to determine the groundwater potential of the regolith aquifer in the study area. The objectives of the study include:

i. Carry out reconnaissance survey of the study area and also acquire geographical coordinates of the study area in order to generate the base map.
ii. Acquisition and interpretation of the Vertical Electrical Sounding data for structure and subsurface geologic sequence delineation respectively.
iii. From(ii), identify geological structures and aquifers favorable to groundwater accumulation and
iv. From (iii), geoelectric layers parameters was inputinto a software to produce maps of the subsurface in order todetermine the groundwater potential of the regolith aquifer.

1.4 Scope of the Project Work

The scope of this study involve consultation of previous works of different geoscientists on related topics in scientific and geological journals, texts and goggling online researches on Precambrian Basement Complex, aquifer units and groundwater exploration.

Preliminary study of the area for reconnaissance survey geological and geophysical mapping of the study was carried out. Electrical resistivity data were acquired using the ABEM SAS-300 Resistivity Meter.

The processing and interpretation of the data were done. The VES data were interpreted using partial curve matching technique in terms of layer parameters underneath the sounding positions and the interpretation results are used to generate maps.

1.5 Previous Work

Various works, projects and researches had been carried out to delineate regolith aquifer groundwater potential, particularly in respect to their hydrogeological characteristics using various geophysical methods.

Akana*et al.*, (2016) carried out an investigation on the assessment of aquifer groundwater potential and its protective capacity in some towns of Yenagoa using the electrical resistivity method. They concluded that the Dar-zarrouk parameter (i.e. longitudinal conductance LC) indicate that the Southern Yenagoa had good to moderate aquifer protective capacity rating, while the Northern area had poor to weak aquifer protective capacity.

Alabi*et al.*, (2016) carried out a geophysical investigation around the University Health Sciences of the Osun State University, Osogbo using the Schlumberger technique of the electrical resistivity method with the aim of evaluating the groundwater potential and access how protected the aquifer in the area could be to surfacepollutants. They concluded from their results that the study area might show good potential for groundwater but the groundwater is not safe.For groundwater development, adequate measure should be made to establish water treatment facility.

Eke *et al.*, (2015) carried out a detailed hydro geophysical study of the aquifers of the Upper Imo River Basin, Southeastern Nigeria which they delineated the aquifers, evaluate their geometric characteristics and to assess their vulnerability of pollution from surface contaminants. Layer parameters interpreted from the VES data together with the available well datawere used to assess the vulnerability of the shallow aquifers using the DRASTIC model. The aquifer vulnerability index assessment revealed that about 55% of the study area falls within the moderate vulnerability zones with DRASTIC index values ranging from 102 to 140. About 30% of the study area have high vulnerability index while the remaining 15% of the study area have low vulnerability index with DRASTIC index values of between 85 and 99.

Farid*et al.*, (2017) carried out a research about site-specific aquifer characteristics, subsurface lithology, and groundwater potentialby conducting 80 vertical electrical sounding surveys (VESs) in Rahim Yar Khan District (RYK), Punjab, Pakistan to distinguish the fresh groundwater aquifer from saline groundwater and to evaluate the aquifer protective capacity (APC) of overburden.

Oloruntola*et al.*, (2017) conducted a combination of vertical electrical soundings (VES), 2D electrical resistivity imaging (ERI) surveys and borehole logs at Magodo, Government Reserve Area (GRA) Phase 1, Isheri, Southwestern Nigeria, with the aim of delineating the different aquifers present and assessing the groundwater safety in the area. Their result shows that the underlying confined aquifer is well protected from contamination and can be utilized as a source of potable groundwater in the study area. This study therefore enabled the delineation of shallow aquifers, the variation of their thicknesses and presented a basis for safety assessment of groundwater potential zones in the study area.

Oni *et al.*, (2017) carried out groundwater vulnerability assessmentat IgbaraOke Southwestern Nigeria, with a view to classifying the area into vulnerability zones, by applying the electrical resistivity method, using Schlumberger electrode arrays. Geoelectric parameters (layer resistivity and thickness) were determined from the interpreted data. The geoelectric parameters of the overlying layers across the area were used to assess the vulnerability of the underlying aquifers to near-surface contaminants with the aid of vulnerability maps generated. The total longitudinal conductance map shows the north central part of the study area as a weakly protected (0.1–0.19) area, while the northern and southern parts have poor protective capacity (<0.1); this is in agreement with the GOD method which shows the northern part of the study area as less vulnerable (0–0.1) while the southern part has low/moderate (0.1–0.3) vulnerability to contamination. The longitudinal conductance exaggerates the degree of susceptibility to contamination than the GOD and GLSI models. From the models, vulnerability to contamination can be considered higher at the southern part than the northern part and therefore, sources of contamination like septic tank, refuse dump should be cited far from groundwater development area.

Sunmonu*et al.*, (2012) conducted a vertical electrical sounding method at Oyo State industrial estate Ogbomoso with a view to determining thegroundwater potential of the study area. The geoelectric sections obtained from the sounding curves revealed 3-layer and 4-layer earth models respectively. The models showed the subsurface layers categorized into the topsoil, weathered/clay, fractured layers and the fresh bedrock. The weathered basement and fractured basement are the aquifer types delineated for the area. Groundwater potential evaluated from the maps (i.e. overburden thickness, anisotropic coefficient, weathered layer isothickness, weathered layer isoresistivity, transverse resistance and bedrock relief maps) revealed that the Southern and Eastern parts of the study area are the most promising region for borehole development. However, Northeastern region of the study area can also be considered as fair for borehole development.

The various investigation and studies carried out by the different authors above, provided basic background information on the hydrogeological framework, changes in lithology, electrical properties and nature of the rocks in typical basement environment.

1.6 Expected Contribution to Knowledge

This study will provide adequate information about the groundwater potential of regolith aquifer and lithological sequences of the study area.

CHAPTER 2

LITERATURE REVIEW

2.1 Regional Geology of the Study Area

Nigeria is located on the western part of the Africa continent. It falls at the Northern end of the Eastern branch of the East Africa Rift System. The total surface area of Nigeria is 93,768 km^2 which is covered by crystalline and sedimentary rocks nearly in equal proportion. Previous works by Oyawoye (1964), Odeyemi (1977), Grant (1978), Rahaman (1988) among others have given account of the geology of Nigeria.

Generally, the geology of Nigeria is classified mainly into the crystalline basement and sedimentary rocks. The basement complex is one of the three major litho-petrological components that make up the geology of Nigeria (Fig.2.1). It forms part of the pan-African mobile belt and lies between the West African and Congo craton and the south of the Tuareg shield (Black, 1970). It is intruded by the Mesozoic calc-alkaline ring complex also known as the younger granite of the Jos Plateau and overlain unconformably by Cretaceous and younger sediments.

The crystalline basement rocks of Nigeria are classified into various lithological groups by Elueze (1982) and Rahman (1988). These groups are the

1. Migmatite-Gneiss-Quartzite complex
2. Charnokitic, Gabbroic and Dioritic rocks
3. Unmetamorphosed Dolerite, Basic Dykes and Syenite Dykes

4. Older Granite suite (Pan African Granitoids)
5. Slightly Migmatized to Non-Migmatized Meta-Sedimentary and Metaigneous rocks
6. Metamorphosed calc-alkaline volcanic and Hyperbysal rocks

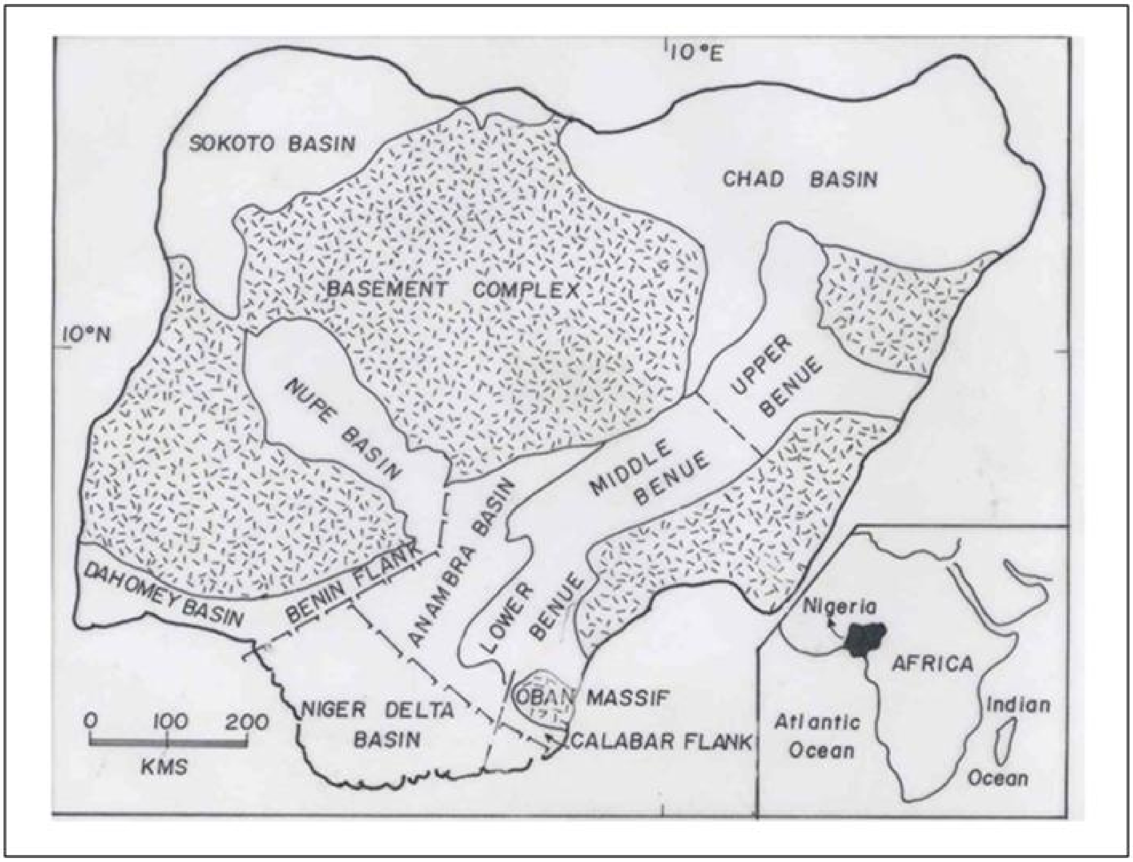


Figure 2.1 Geological sketch map of Nigeria showing the major geological components; The Basement Complex, and Sedimentary Basins(Adapted from research gate).

2.1.1Migmatite-Gneiss-Quartzite Complex

This group of rock type is widely spread, constituting about 60% of the basement complex rocks of Nigeria. It has a heterogenous assemblage comprising migmatites, paragneisses, orthogneises, and series of basic and ultrabasic metamorphosed rocks. Petrographic evidence indicates that the Pan-African reworking led to recrystallization of many of its constituent minerals by partial melting with majority of the rock types displaying medium to upper amphibolitesfacies metamorphism. The Migmatite-Gneiss Complex age ranges from Pan-African to Eburnean.

2.1.2Slightly Migmatized to Non-Migmatized Meta-Sedimentary and Metaigneous rocks

This group has been called different names ranging from the 'New sediment to Schist Belt by different authors. The Schist Belt is a N-S trending synformal trough that folded into the magmatic-gneiss complex. It is best developed in the western part of the country (Grant, 1978). Based on structural and lithological association, it is suggested by some authors that, Schist Belts are of Kibaran age (1100-1200 Ma). However, Ajibade*et al.*, (1979) disagreed with this structural evidence and proposed a Pan African age for the Schist Belt. Rahaman (1976) argued that based on the available geochronological data, the Schist Belt preclude an Archean to late Proteozoic. They are largely dominated by sediment that differentiates it from other Schist Belts such as in Australia and South Africa. Prominent belts among the Schist Belt that have been mapped and studied include the MaruAnka, Zuru, Zungeru, Isheyin and the Ilesha Schist Belt known to be associated with gold mineralization.

2.1.3Older Granites (Pan African Granitoids)

The term “Older Granite” is introduced to distinguish the deep-seated, often concordant or semi-concordant granites of the Basement Complex from the high-level, highly discordant tin-bearing granites of Northern Nigeria. It is believed to be pre-, syn- and post-tectonic rocks which cut both the migmatite-gneiss-quartzite complex and the Schist Belts. This comprises rocks of varying compositions ranging from granodiorite to true granites and potassicsyenite. They are generally intrusions notable for their general lack of associated mineralization and the most obvious manifestation of the Pan-African Orogeny [Pan African, 750 – 450 Ma].

2.1.4Younger Granites

The most extensive outcrop of Tertiary-Recent activities is found on the Jos Plateau and other part of North-Central Nigeria. Disseminated occurrences also exist within the Benue Trough. They are structurally and petrologically distinct from the older granite. The dominant rock types are granites and rhyolites. Rahaman (1988) put the age very systematically from Carboniferious, 313Ma in the north to about 141Ma in the south.

2.2 Geology of the Study Area

The study area lies in the Basement Complex of Nigeria (Fig. 2.2). The terrain is composed basically of magmatic gneiss. Geologically, the region forms part of the Basement Complex of the southern part of Nigeria. Major rock types around the area are chanockite, migmatite gneiss, Quartzite, and Biotite gneiss. These Precambrian rocks have however, been subjected to tectonic activities and distributed in various ways resulting in fracturing, jointing, cracking among others.

The migmatite gneiss which is a mixture of metamorphic rock and igneous rock is created when a metamorphic rock such as gneiss partially melts, and recrystallizes into an igneous rock creating a mixture of the unmelted metamorphic part with the recrystallized igneous part.

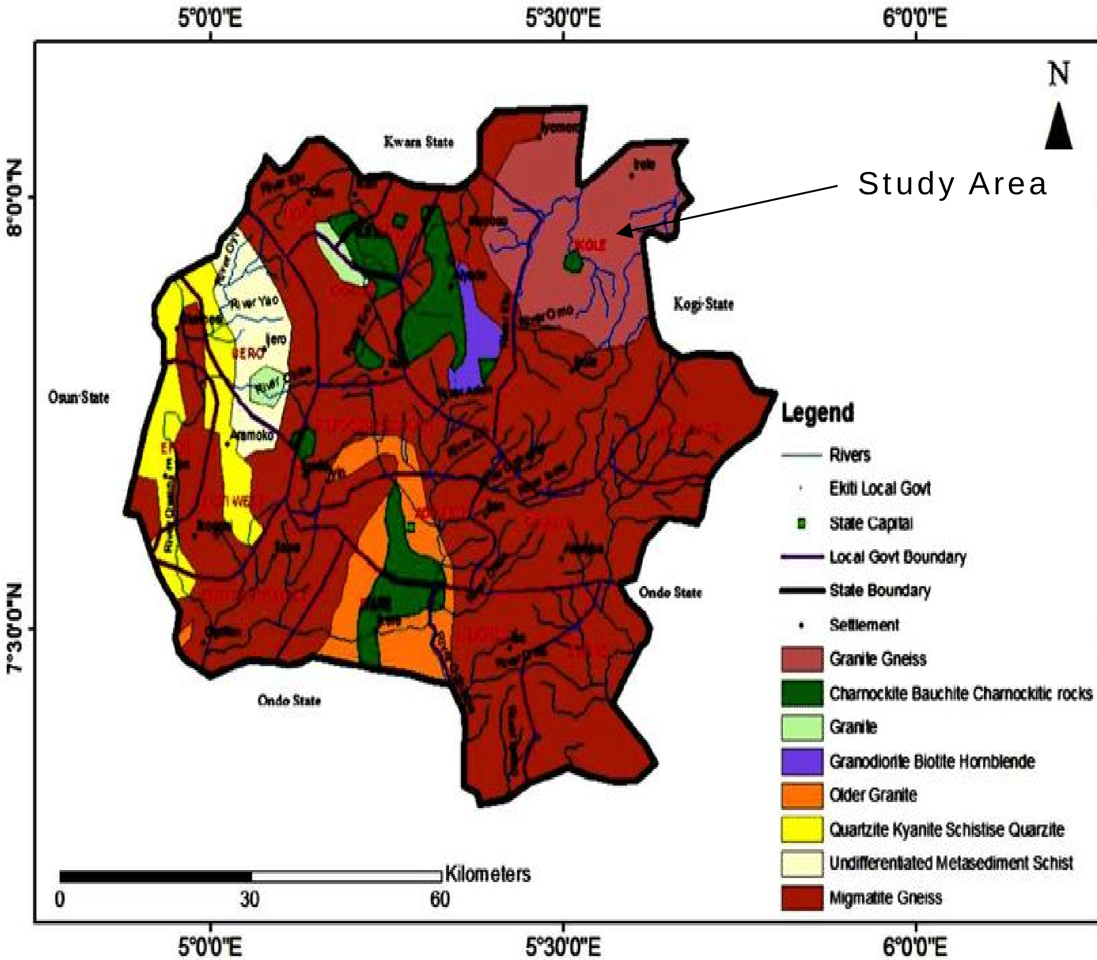


Figure 2.2: Geological map of Ekiti State showing the study area (Adapted from research gate)

2.3 Hydrogeology of the Study Area

The rocks of the basement complex terrain are relatively impermeable and lack primary porosity i.e. interconnected pore spaces which are formed during rock formation. The presence of fractures (secondary porosity) and the nature and thickness of the material overlying the basement rocks are factors that control groundwater storativity and potential. Fractures in rock are mainly caused by tectonic activities within the crustal rocks. These are important in basement rocks as its increases weathering activities. The mineralogy of a rock type also determines the degree of weathering. Recoverable groundwater in the basement complex often occur in the weathered layer and fractured basement. The detection/or delineation of hydrogeological structure usually facilitate the location of groundwater prospective zones in a typical complex settings (Omosuyi*et al.,* 2007).

2.3.1 Groundwater

Groundwater begins with precipitation that seeps into the ground. The amount of water that seeps into the ground will vary widely from place to place depending on the slope of the ground surface, amount and intensity of rainfall and nature of the regolith (weathered layer). Some soil can allow as much as fifty (50) percent of precipitation to percolate into the ground as groundwater while a less permeable soil may allow as little as five (5) percent to infiltrate. The rest becomes runoff or evaporates. Over half of the fresh water on earth is stored as groundwater. As water percolates through permeable ground, it continues until it reaches a depth where water has filled all the porous spaces in the soil or rock. This is known as the saturated zone. The top of the saturated zone is called the water table. The water table can rise or fall according to the season of the year and the amount of precipitation that occurs.

2.4 Principle of Electrical Resistivity Method

The electrical resistivity method measures both lateral and vertical variations in ground resistivity values on the earth surface. The method involves the passage of electric current (usually direct current or low frequency alternating current) into the subsurface through two electrodes (the current electrodes). The potential difference is measured between another pair of electrodes, which may or may not be located within the current electrodes depending on the electrode array used. The apparent resistivity value is determined by multiplying the resistance resulting from the potential measurement with an appropriate geometrical factor. (Telford *et al.*, 1990). The true resistivity of subsurface layer is determined from this apparent resistivity values.

2.4.1 Factors Affecting Resistivity of Earth Materials

There are several factors that influence the electrical resistivity of the earth materials. These include:

i. Chemistry or salinity of the saturating fluid: Earth resistivity decreases with increase in the concentration or salinity of the saturating fluid.
ii. Porosity: Generally, resistivity of earth materials deceases with increase in porosity.
iii. Temperature: This influences viscosity, the higher the temperature of a material the lower its viscosity and the higher is the ion mobility. This will lead to higher conductivity and hence lower resistivity.
iv. Rock Texture: Well sorted sandstone with large void will exhibit high resistivity. Poorly sorted sandstone with small void will display low resistivity.

v. Rock Types: The resistivity of rocks varies with rock types e.g. the resistivity of granite will be higher than that of clay.

vi. Geological Processes: The resistivity of rocks is influenced by geological processes such as Fracturing which increases porosity and decreases resistivity.

vii. Water Saturation: The resistivity of earth materials increases with decrease in the degree of fluid saturation.

viii. Permeability: Ideally, when permeability increases resistivity decreases but the reverses is the case in clay materials low permeability and low resistivity.

2.4.2 Basic Theory of Electrical Resistivity Method

The foundation of electrical resistivity theory is the Ohm's law (Grant and West, 1965) which states that the ratio of potential difference (V) between two ends of a conductor in an electrical circuit to the current (I) flowing through it is a constant.

$V = IR$

Where R is a constant known as resistance measured in ohms (Ω).

The law governs the development of basic equations of electrical resistivity method.

Consider a current (I) flowing in a cylindrical conductor of length L, cross-sectional area A, (Fig. 2.3).

The resistance, R, of the conductor to current flow is expressed as:

$$R \propto \frac{L}{A} \qquad 2.1$$

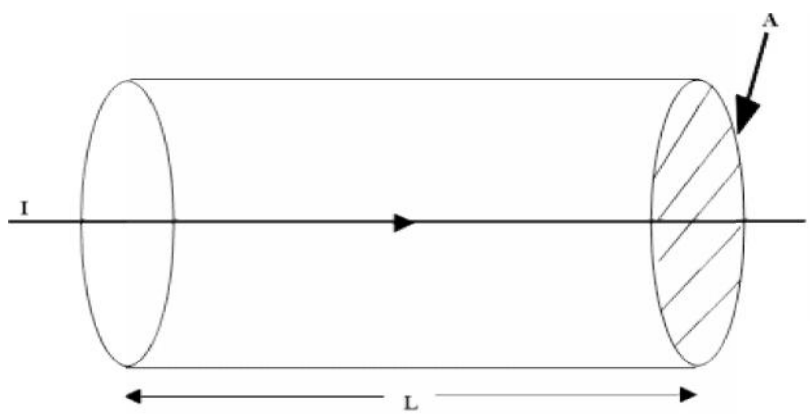


Figure 2.3: Schematic Diagram of the Flow of Current through a Cylindrical Model.

$$R = \rho \frac{L}{A} \qquad 2.2$$

Where ρ is the constant of proportionality called resistivity.

But from ohms law:

$$R = \frac{\Delta V}{I} \qquad 2.3$$

By substituting for 'R' in equation 2.2

$$\frac{\nabla V}{I} = \rho \frac{L}{A} \qquad 2.4$$

$$\frac{\nabla V}{I} = \rho \qquad 2.5$$

$$\rho = \frac{\Delta V}{I_l} \qquad 2.6$$

Where:

ΔV = Potential difference between any two points, measured in volts.

I = Current flowing in the conducting medium between points, measured in amperes

R = Resistance between two points in the medium, measured in ohms.

ρ = Resistivity, measured in (Ωm)

Equation 2.6 can be used to determine the resistivity of any homogenous medium provided the

geometry is simple. But when the medium is semi-infinite, equation 2.6 needs to be modified before it can be applicable.

If we allow parameters A and L to shrink to infinitesimal size.

Then:

$$\rho = \frac{\lim_{L \to 0} \frac{\Delta V}{L}}{\lim_{A \to 0} \frac{I}{A}} \quad = \frac{E}{J} \qquad 2.7$$

$$\rho = \frac{E}{J} \qquad 2.8$$

Where E is the electric field and J is the current density.

From Equation 2.8

$$J = \frac{E}{\rho} \qquad 2.9$$

$$\therefore E = J\rho \qquad 2.10$$

Imagine that the current source is located at the center of a spherical body of radius ‘r’ Fig. 2.4

The current density at the spherical surface is:

$$J = \frac{I}{A} \qquad 2.11$$

Where A = area of the spherical surface given as

$A = 4\pi r^2$

$$\therefore J = \frac{I}{A} = \frac{I}{4\pi r^2} \qquad 2.12$$

Substitute equation (2.12) into (2.10)

$$E = \frac{I\rho}{4\pi r^2} \qquad 2.13$$

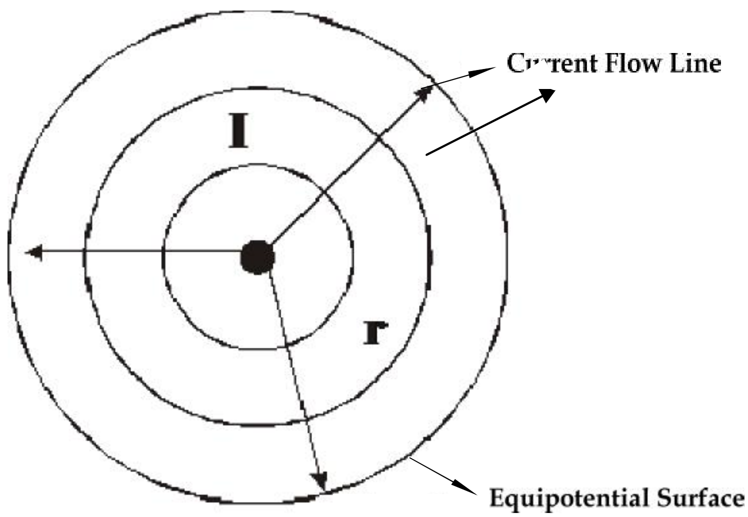


Figure 2.4: Spherical Body of Radius ‘r’

But E is the gradient of scalar potential i.e.

$$E = -\nabla V = \frac{-¢V}{¢r} \quad 2.14$$

Equating equations (2.13) and (2.14)

$$\frac{I_\iota}{4\pi r^2} = \frac{-\delta}{\delta}$$

$$\frac{\delta}{\delta} = \frac{-I_\iota}{4\pi\ \ ^2}$$

$$\therefore \partial \ = \frac{-I_\iota}{4\pi r^2} \quad 2.15$$

Taking the integral of both sides:

$$\int \delta \ = \int \frac{-I_\iota}{4\pi\ \ ^2}$$

$$\therefore V = \frac{I_\iota}{4\pi} \quad 2.16$$

In practice, the earth surface is taken as a hemisphere (Fig. 2.5) with the current source (C) located at the surface.

The current density (J) is defined as:

$$J = \frac{l}{A} \quad 2.17$$

The area of a hemisphere is $2\pi r^2$

y Equation (2.17) becomes

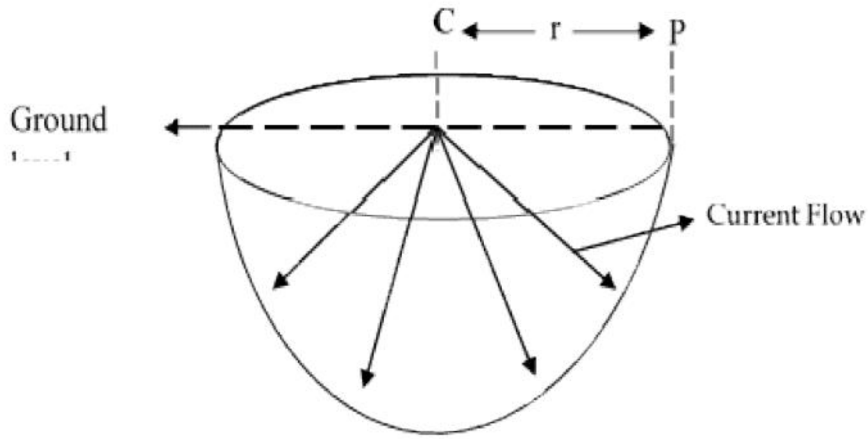


Figure 2.5: Current Source on aHemispherical Surface

$$J = \frac{1}{2\pi r^2} \qquad 2.18$$

$$\therefore E = \frac{I\iota}{2\pi r^2} \qquad 2.19$$

But $E = -\nabla V = -\frac{\partial}{\partial}$

$$\therefore \frac{\partial}{\partial} = \frac{-I\iota}{2\pi r^2}$$

$$\partial \quad = \frac{-I\iota}{2\pi r^2} \qquad 2.20$$

Taking the integral of both sides:

Equation 2.20 becomes

$$\int \partial \quad = \frac{-I\iota}{2\pi} \int \frac{1}{r^2} \, \partial$$

$$V = \frac{-I\iota}{2\pi} \left(\frac{-1}{r} \right)$$

$$V = \frac{I\iota}{2\pi} \qquad 2.21$$

This is the potential at point P due to current at point C on the surface of the earth.

2.4.3 Generalized Apparent Resistivity Equation

Consider the diagram in Figure. 2.6. The diagram illustrates a simple 2-electrode system array at the surface of the earth. The potential ‘P_1’ at a distance ‘r’ from the current source ‘C_1’ as given as:

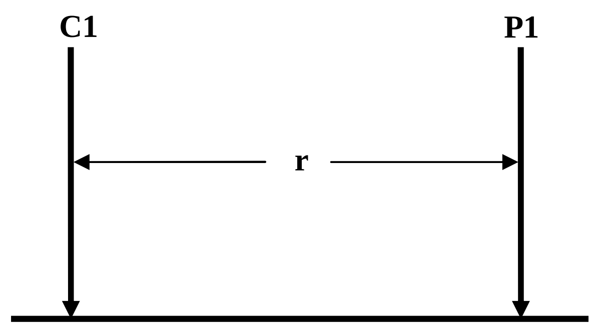


Figure 2.6: A Simple 2-Electrodes Array System

$$V = \frac{I\rho}{2\pi r}$$

In practice, four electrodes are used in resistivity survey as shown in Figure 2.7

Where;

r_1 is the Distance between P_1 and C_1

r_2 is the Distance between P_1 and C_2

r_3 is the Distance between P_2 and C_1

r_4 is the Distance between P_2 and C_2

C_1 and C_2 are Current Electrodes

P_1 and P_2 are Potential Electrodes

AB = Current Electrode Distance

MN = Potential Electrode Distance

The potential at P_1 due to current at C_1 is;

$$V_{11} = \frac{I\rho}{2\pi r_1}$$

The potential at P_1 due to current at C_2 is;

$$V_1 = \frac{-I\rho}{2\pi r_2}$$

The sum total of potential at P_1 due to current at C_1 and C_2 is;

$$V_{11,12} = \frac{I\rho}{2\pi r_1} + \frac{(-I\rho)}{2\pi r_2}$$

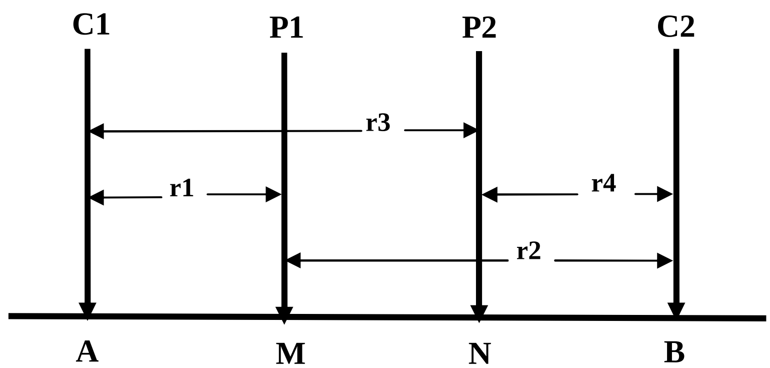


Figure 2.7: Typical Electrical Resistivity Array

$$V_{11,12} = \frac{I^{\circ}}{2^{\circledR}r_1} - \frac{I^{\circ}}{2^{\circledR}r_2}$$

$$V_{11,12} = \frac{I^{\circ}}{2^{\circledR}}\left[\frac{1}{r_1} - \frac{1}{r_2}\right] \qquad 2.22$$

Similarly,

Potential at P_2 due to current at C_1 is given as

$$V_{21} = \frac{\rho I}{2\pi r_3}$$

The potential at P_2 due to current at C_2 is;

$$V_{22} = \frac{-\rho I}{2\pi r_4}$$

The sum total Potential of P_2 due to current at C_1 and C_2 is;

$$V_{21,22} = \frac{I^{\circ}}{2^{\circledR}r_3} - \frac{I^{\circ}}{2^{\circledR}r_4}$$

$$V_{21,22} = \frac{I^{\circ}}{2^{\circledR}}\left[\frac{1}{r_3} - \frac{1}{r_4}\right] \qquad 2.23$$

The potential difference ΔV between P_1 and P_2 can be obtained by subtracting equation (2.23) from (2.22)

$$\Delta V = V_{11,12} - V_{21,22}$$

$$\Delta V = \frac{I\iota}{2\pi}\left[\frac{1}{r_1} - \frac{1}{r_2}\right] - \frac{I\iota}{2\pi}\left[\frac{1}{r_3} - \frac{1}{r_4}\right]$$

$$\Delta V = \frac{I\iota}{2\pi}\left[\frac{1}{r_1} - \frac{1}{r_2} - \frac{1}{r_3} + \frac{1}{r_4}\right]$$

$$\rho = \frac{2\pi\Delta V}{I}\left[\frac{1}{r_1} - \frac{1}{r_2} - \frac{1}{r_3} + \frac{1}{r_4}\right]^{-1}$$

Recall that $R = \frac{\Delta V}{I}$ (ohm's law)

$$\therefore \rho_a = 2\pi \quad \left[\frac{1}{r_1} - \frac{1}{r_2} - \frac{1}{r_3} + \frac{1}{r_4}\right]^{-1} \qquad 2.24$$

Therefore, ρ = KR

Where;

K is the Geometric Factor

2.4.4 Electrode Array or Configuration

The type of electrode configuration or array is defined by the mode of arrangement of both the current and the potential electrodes. There are several types of electrode array used in electrical resistivity method which include Schlumberger, Dipole-dipole, Wenner, Pole-dipole, Pole-pole, Cross-squared to mention but few. However, the Schlumberger electrode array used for this study will be discuss in detail.

2.4.4.1 Schlumberger Electrode Array

The Schlumberger electrode array utilizes four electrodes system that are arranged co-linearly with different inter-electrode spacing as shown in the Figure 2.8. The electrodes are arranged such that the distance AB between the current electrodes is greater or equal to five times the distance MN, between the potential electrodes. The potential electrodes are occasionally moved as the current electrodes are expanded until the required maximum separation is attained.

Where:

AB	=	Current Electrode Distance (2L)
MN	=	Potential Electrode Distance (2 l)
AB	≥	5MN

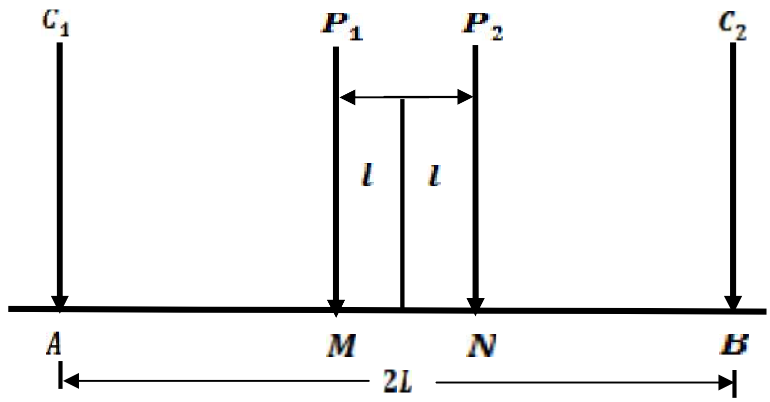


Figure 2.8: Typical Schlumberger Electrode Configuration

The apparent resistivity equation for schlumberger array is derived as:

Recall the generalized apparent resistivity equation.

$$\rho_a = 2\pi \left(\frac{1}{r_1} - \frac{1}{r_2} - \frac{1}{r_3} + \frac{1}{r_4}\right)^{-1} \qquad 2.24$$

Considering the array in Figure 2.8

If	AM	=	L – l
	MB	=	L + l
	AN	=	L + l
	NB	=	L – l

Substituting these into equation (2.24)

$$\rho_a = 2\pi \left(\frac{1}{L-l} - \frac{1}{L+l} - \frac{1}{L+l} + \frac{1}{L-l}\right)^{-1}$$

$$\rho_a = 2\pi \left(\frac{L-l - L+l - L+l + L-l}{L^2 - l^2}\right)^{-1}$$

$$\rho_a = 2\pi \left(\frac{4l}{L^2 - l^2}\right)^{-1}$$

$$\rho_a = 2\pi \left(\frac{L^2 - l^2}{4l}\right) \qquad 2.25$$

But, $l^2$is small when compared with L^2 therefore, equation 2.18 becomes;

$$\rho_a \approx \frac{\pi \;\; L^2}{2l} \qquad 2.26$$

Equation (2.26) is the apparent resistivity equation for the Schlumberger electrode array.

2.5 Field Techniques

Geophysical traverses are usually established along directions normal or perpendicular to the general strike of the geology or a target.

Three survey techniques are commonly used in resistivity method, these are:

i. Horizontal Profiling (HP)
ii. Vertical Electrical Sounding (VES)
iii. Combined Horizontal Profiling and Vertical Electrical Sounding. (VES) or 2D Imaging

Horizontal Profiling (HP)

This technique measure lateral variation in ground resistivity value with respect to a specific depth extent or datum that is determined by the electrode spacing. The electrode array is kept constant, while the entire electrode array is moved after each measurement. The common electrode arrays used in HP technique include; Wenner, Pole-pole, Pole Dipole and Gradient array. Horizontal profiling technique can be adopted in mineral exploration, geological mapping, groundwater, environmental and engineering geophysics.

Vertical Electrical Sounding (VES)

The Vertical Electrical Sounding (VES) technique measures vertical variations in ground resistivity with respect to a fixed center of the electrode array. The survey is carried out by gradually expanding the current electrodes spacing with respect to the fixed center. The common electrode arrays used for VES technique are the Wenner and Schlumberger array. Vertical Electrical Sounding technique is applied in groundwater exploration, environmental and engineering geophysics and to some extent in mineral exploration.

Combined Horizontal Profiling (HP) and Vertical Electrical Sounding (VES) or 2D Imaging

This technique measures variations in ground resistivity value along horizontal and vertical directions. The measuring station is defined as the point of intersection of two 45^o inclined lines from the midpoints of the current and the potential dipoles. The data are presented as a psuedosection or false vertical section that requires inversion to reposition the image in their correct positions

2.6 Data Presentation

Electrical resistivity data can be presented as profiles, stacked profiles, VES curves, pseudosection and maps. The HP data can be presented as profiles and maps when it involves more than three traverse lines. Profiles are generated by plotting resistivity values against station positions along a particular traverse line. The station position is determined by the electrode configuration used.

Maps are generated by posting the apparent resistivity values on their relative measuring positions and the values contoured. Maps give location of the target, geometry, width extent and strike length.

VES data are presented as a sounding curve - plot of apparent resistivity against spacing on log-log (bi-log) graph paper.

The combine HP and VES or 2D imaging data are presented as 2-D pseudosection. Such section gives the location of the target, lateral extent and orientation of the target.

2.7 Data Interpretation

The interpretation of resistivity data can be qualitative, semi-quantitative or quantitative depending on the field procedure.

The qualitative interpretation involves visual inspection of profiles, maps and pseudosections for signatures or pattern diagnostic of a particular target. For example;

i. Very low resistivity anomalies are typical of saline water intruded area or conductive mineralized zone, saline water based hydrocarbon impacted area or corrosive (aggressive) soil within a resistive environment.
ii. High resistivity anomalous zones are diagnostic of hydrocarbon or refined oil-impacted zone, areas polluted by organic compound, areas with shallow basement or sand\gravel deposit in a clay host rock.

Quantitative interpretation is applied to VES data. Quantitative interpretation of VES data can be:

i. Empirical semi-empirical technique which is used mostly for Wenner array.
ii. Analytical method which involves partial curve matching and computer assisted 1D forward modeling with WinResist computer software.

CHAPTER 3

MATERIALS AND METHODOLOGY

3.1 Materials

The materials used during the study include:

i. ABEM SAS-300 Resistivity Meter
ii. Hammers
iii. Electrodes
iv. Measuring tape
v. Cable reels
vi. Calculator
vii. Recording sheets
viii. Crocodile clips
ix. Connecting twines and cable
x. GPS
xi. Compass Clinometer

ABEM SAS 300 Resistivity Meter: This instrument was used to measure the earth subsurface resistivity. The resistivity meter send current into the ground with the aid of two current electrodes while measuring the potential through another part of potential electrodes. The meter is equipped with a microprocessor that computes the resistance by dividing the measured potential (voltage) by the input current. The resistance is then multiplied with appropriate geometry factor (K) to determine the apparent resistivity of the subsurface.

Hammers: This is a hand held tool consisting of a heavy metal head which is used in driving electrodes into the ground.

Electrodes: These are stainless steel rods of about 0.5 m long used in passing direct current into the ground. It is also used to measure the potential generated due to the injected current. It has a very sharp pointed end for easy penetration into the earth while the other end flat and blunt. Four (4) electrodes, two current and two potential electrodes were used during the study.

Measuring tape: This is used for measuring distance e.g. (inter-station and traverse spacing) during the course of the study.

Cable reels: These were used for connecting the electrodes to the resistivity meter. Usually four cables are used, two for current and the other two for potential. The cables were reeled around a wheel made of either steel or plastic.

Calculator: This was used to calculate and compute measurement on the field.

Recoding sheets: This is the sheet on which data taken on the field were recorded.

Crocodile clips: These are metallic instruments used in connecting the cables to the electrodes firmly.

Connecting twines and cable: Cables fitted with crocodile dips at both ends were used to connect the current source to the electrodes.

GPS unit: This is known as the Global Positioning System. It is used to acquire the geographical coordinates (latitudes and longitudes) of the study area.

Compass Clinometer: This helps to locate ourselves on maps and measured the strike and dip of major geological feature on the field. It also assisted during traverse cutting.

3.2 Methodology

Preliminary investigations involving literature review of previous work related to the project work and acquisition of the geographical coordinates used to generate the base map of the study area was carried out.Zones that favor the exploration for groundwater resource were the ones investigated in this work using the geoelectrical method.

The geophysical method adopted is the electrical resistivity method. Thirty (30) VES stations were evenly distributed within the study area Figure 3.1.Vertical Electrical Sounding (VES) using Schlumberger arraywith maximum current electrodes spread (AB) of 100m was used for the VES data acquisition with the aid of ABEM SAS-300 Resistivity Meter.The apparent resistivity values ($°_a$) at each station were plotted against half electrode spacing (AB/2) on a bi-logarithmic graph and partial curve matching was carried out for the quantitative interpretation of the curves.

The results of the curve matching (layer thickness and resistivity) wasfed into the computer as starting model parameters in an iterated forward model using *WinResist*software.

The VES curves generated gives the thickness and the resistivitiesof different layers. The depth sounding curves were then classified according to the resistivity contrasts between the layers as H, K, A, Q or multiples thereof, following the classification by Keller and Frischnecht (1970) and Patra and Nath (1999). The modeling produced series of curves as shown in figure 4.1. Twelve out of the thirty curves were A-type ($\rho_1<\rho_2<\rho_3$), four were H-type ($\rho_1 > \rho_2 < \rho_3$), nine were KH-type ($\rho_1 < \rho_2 > \rho_3 < \rho_4$), one is KQ-type ($\rho_1 < \rho_2 > \rho_3 > \rho_4$) and QH-type curves respectively, while the remaining three showed AH-type ($\rho_1 < \rho_2 > \rho_3 < \rho_4$). Surfer 10 software was further used on personal computer to produce an overburden isopach map, weathered layer isothickness map, weathered layer isoresistivity map, 3-dimensional bedrock relief map and groundwater potential map in order to evaluate the groundwater potential of the study area.

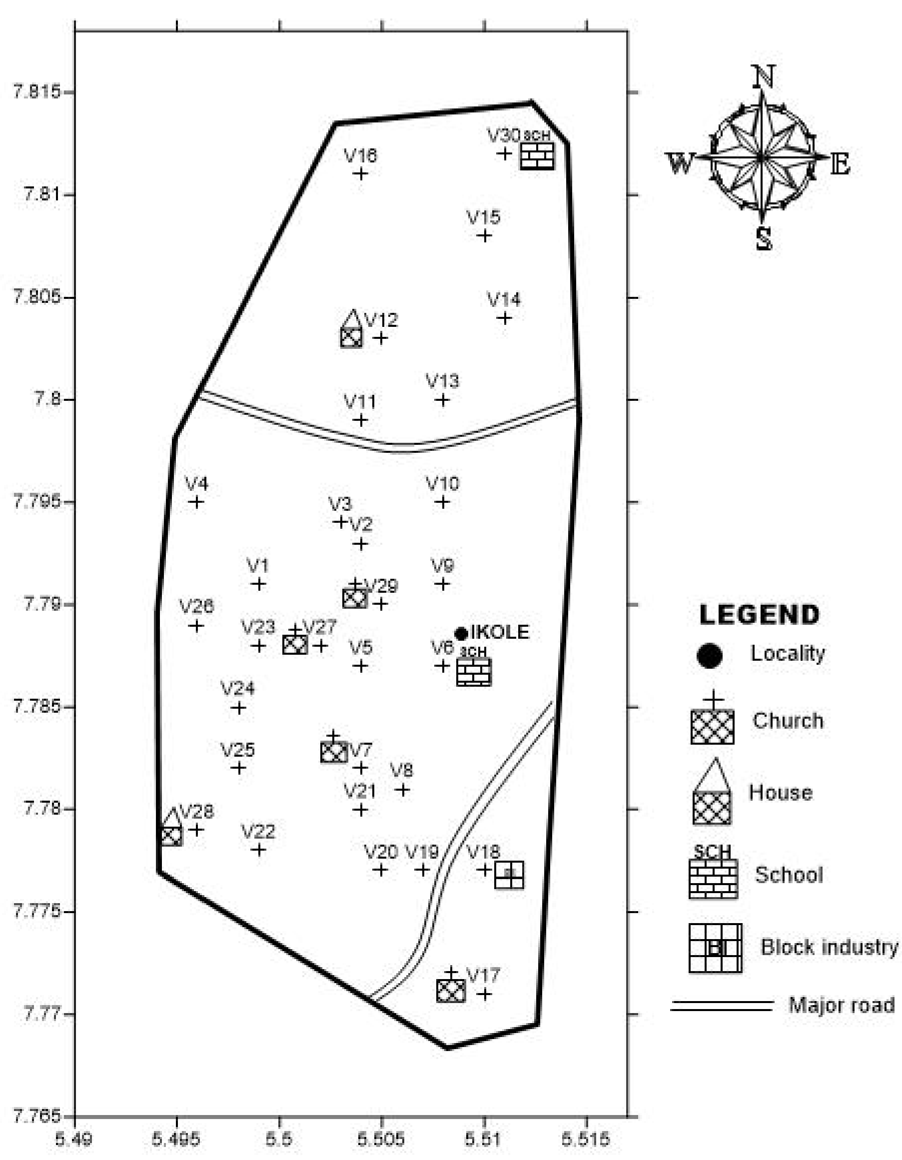


Figure 3.1: Map showing the distribution of VES points

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Preamble

From the interpretation of the VES data acquired, the resistivities associated with each layer were derived together with corresponding thicknesses and the lithologic interpretation as shown in Table 4.1. The typical representatives of the thirty (30) curves as obtained from the computer iteration processes are as shown in Figure 4.1.

The sounding curves show three layers tofour layers earth models. The three layer curve are characterized by H and A type which represents altogether about 54% of the curve types in the study while the four layer models are characterized by KH, KQ, QH and AH which altogether covers about 46% of the curve type in the study area as shown in Table 4.2, Figure 4.2.

Figure 4.3 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.

Table 4.1: Summary of the layer geoelectricparameters and lithologic interpretation

VES NO	RESISTIVITY(Ωm)	THICKNESS(m)	DEPTH(m)	CURVE TYPE	LITHOLOGY
1	37	0.8	0.8	A	Topsoil
	86	9.0	9.8		Upper Saprolite (Clayey sand)
	6267	------	------		Fresh basement
2	113	0.7	0.7	KQ	Topsoil
	197	2.2	2.9		Upper Saprolite (Clayey sand)
	47	27.9	30.8		Lower saprolite (Sandy clay)
	36	------	------		Weathered basement
3	113	1.0	1.0	A	Topsoil
	188	6.2	7.2		Upper Saprolite (Clayey sand)
	1518	------	------		Fresh basement
4	188	3.3	3.3	A	Topsoil
	783	1.8	5.1		Saprock
	1975	------	------		Fresh basement
5	231	1.1	1.1	KH	Topsoil
	3537	0.8	1.9		Upper Saprolite (Clayey sand)
	160	13.2	15.1		Lower saprolite (Sandy clay)
	593	------	------		Saprock
6	46	2.3	2.3	A	Topsoil
	109	9.8	12.1		Upper Saprolite (Clayey sand)
	269	------	------		Saprock
7	221	1.3	1.3	H	Topsoil
	134	7.8	9.1		Upper Saprolite (Clayey sand)
	527	------	------		Saprock
8	386	1.1	1.1	A	Topsoil
	689	31.4	32.5		Upper Saprolite (Clayey sand)
	6002	------	------		Fresh basement
9	22	0.3	0.3	H	Topsoil
	48	28.4	28.7		Lower saprolite (Sandy clay)
	1717	------	------		Fresh basement
10	230	1.0	1.0	A	Topsoil
	1668	10.3	11.3		Saprock
	2179	------	------		Fresh basement
11	208	0.8	0.8	KH	Topsoil
	311	4.9	5.7		Upper Saprolite (Clayey sand)
	117	15.0	20.7		Lower saprolite (Sandy clay)
	749	------	------		Saprock
12	321	0.8	0.8	KH	Topsoil
	393	2.0	2.8		Upper Saprolite (Clayey sand)
	107	6.3	9.1		Lower saprolite (Sandy clay)
	1532	------	------		Fresh basement

Table 4.1 Contd.: Summary of the layer geoelectricparameters and lithologicinterpretation

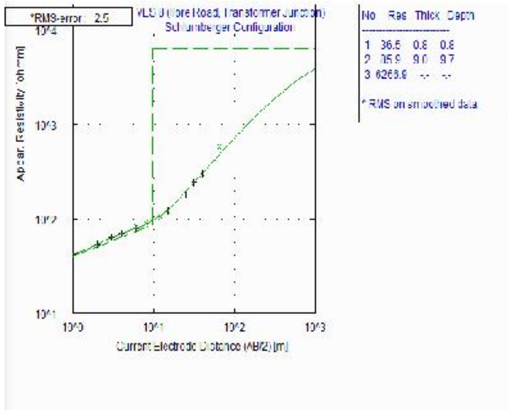
VES NO	RESISTIVITY(Ωm)	THICKNESS(m)	DEPTH(m)	CURVE TYPE	LITHOLOGY
13	107	1.0	1.0	KH	Topsoil
	282	7.1	8.1		Upper Saprolite (Clayey sand)
	67	16.1	24.2		Lower saprolite (Sandy clay)
	628	------	------		Saprock
14	176	1.5	1.5	H	Topsoil
	37	26.3	27.8		Upper Saprolite (Clayey sand)
	1844	------	------		Fresh basement
15	946	1.0	1.0	QH	Topsoil
	302	5.1	6.1		Upper Saprolite (Clayey sand)
	112	20.0	26.1		Lower saprolite (Sandy clay)
	605	------	------		Saprock
16	501	0.9	0.9	KH	Topsoil
	1160	3.2	4.1		Upper Saprolite (Clayey sand)
	497	16.1	20.2		Lower saprolite (Sandy clay)
	1589	------	------		Fresh basement
17	259	1.0	1.0	A	Topsoil
	529	16.5	17.5		Upper Saprolite (Clayey sand)
	953	------	------		Fresh basement
18	226	1.4	1.4	AH	Topsoil
	393	6.8	8.2		Upper Saprolite (Clayey sand)
	209	18.2	26.4		Lower saprolite (Sandy clay)
	1177	------	------		Fresh basement
19	146	1.5	1.5	AH	Topsoil
	215	4.3	5.8		Upper Saprolite (Clayey sand)
	27	9.8	15.6		Lower saprolite (Sandy clay)
	1436	------	------		Fresh basement
20	384	1.3	1.3	AH	Topsoil
	523	7.8	9.1		Upper Saprolite (Clayey sand)
	201	11.5	20.6		Lower saprolite (Sandy clay)
	5309	------	------		Fresh basement
21	261	0.8	0.8	KH	Topsoil
	1131	4.8	5.6		Upper Saprolite (Clayey sand)
	302	17.1	22.7		Lower saprolite (Sandy clay)
	1594	------	------		Fresh basement
22	292	0.6	0.6	KH	Topsoil
	843	10.7	11.3		Upper Saprolite (Clayey sand)
	202	19.3	30.6		Lower saprolite (Sandy clay)
	1284	------	------		Fresh basement

Table 4.1 Contd.: Summary of the layer geoelectricparameters and lithologic interpretation

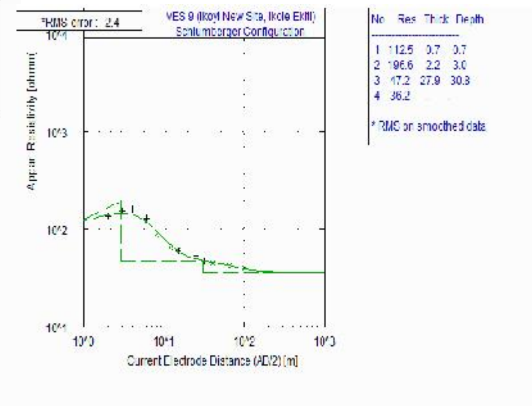
VES NO	RESISTIVITY(Ωm)	THICKNESS(m)	DEPTH(m)	CURVE TYPE	LITHOLOGY
23	29	0.9	0.9	A	Topsoil
	206	10.4	11.3		Upper Saprolite (Clayey sand)
	787	------	------		Saprock
24	93	1.1	1.1	A	Topsoil
	216	16.3	17.4		Upper Saprolite (Clayey sand)
	635	------	------		Saprock
25	65	1.2	1.2	A	Topsoil
	961	10.9	12.1		Upper Saprolite (Clayey sand)
	895	------	------		Saprock
26	28	0.5	0.5	KH	Topsoil
	66	5.1	5.6		Upper Saprolite (Clayey sand)
	54	4.1	9.7		Lower saprolite (Sandy clay)
	819	------	------		Fresh basement
27	235	0.9	0.9	H	Topsoil
	61	5.1	6.0		Upper Saprolite (Clayey sand)
	1129	------	------		Fresh basement
28	400	1.0	1.0	A	Topsoil
	518	13.7	14.7		Upper Saprolite (Clayey sand)
	1992	------	------		Fresh basement
29	52	0.9	0.9	KH	Topsoil
	222	5.6	6.5		Upper Saprolite (Clayey sand)
	114	13.4	19.9		Lower saprolite (Sandy clay)
	537	------	------		Saprock
30	220	0.9	0.9	A	Topsoil
	259	7.9	8.8		Upper Saprolite (Clayey sand)
	1168	------	------		Fresh basement

Table 4.2: Classification of the resistivity sounding curves

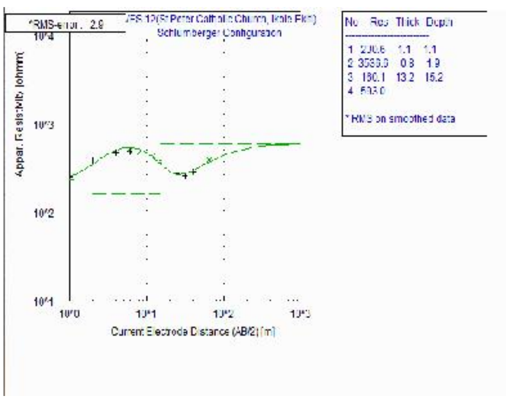
CURVE TYPES	RESISTIVITY MODEL	MODEL FREQUENCY	VES LOCATIONS
A	$\rho_1 < \rho_2 < \rho_3$	12	1,3,4,6,8,10,17,23,24,25,28,20
H	$\rho_1 > \rho_2 < \rho_3$	4	7,9,14,27
KH	$\rho_1 < \rho_2 > \rho_3 < \rho_4$	9	11,12,13,16,21,22,26,29
KQ	$\rho_1 < \rho_2 > \rho_3 > \rho_4$	1	2
QH	$\rho_1 > \rho_2 > \rho_3 < \rho_4$	1	15
AH	$\rho_1 < \rho_2 > \rho_3 < \rho_4$	3	18,19,20
TOTAL		30	



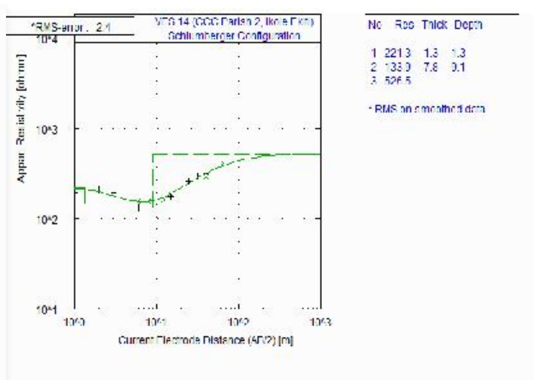
a. A-type



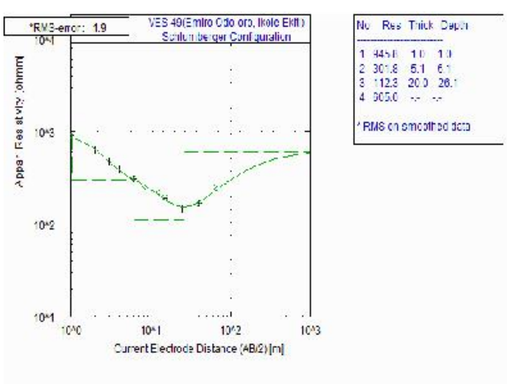
b. KQ



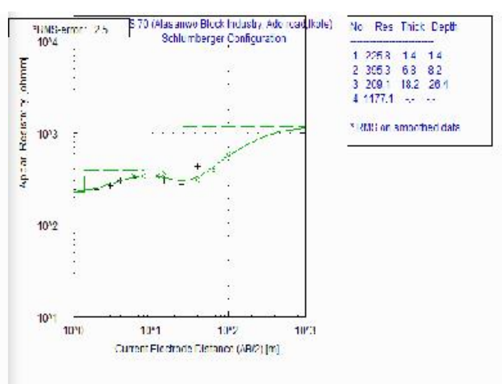
c. KH-type



d. H-type



e. QH-type



f. AH-type

Figure 4.1: Typical VES representative model curves

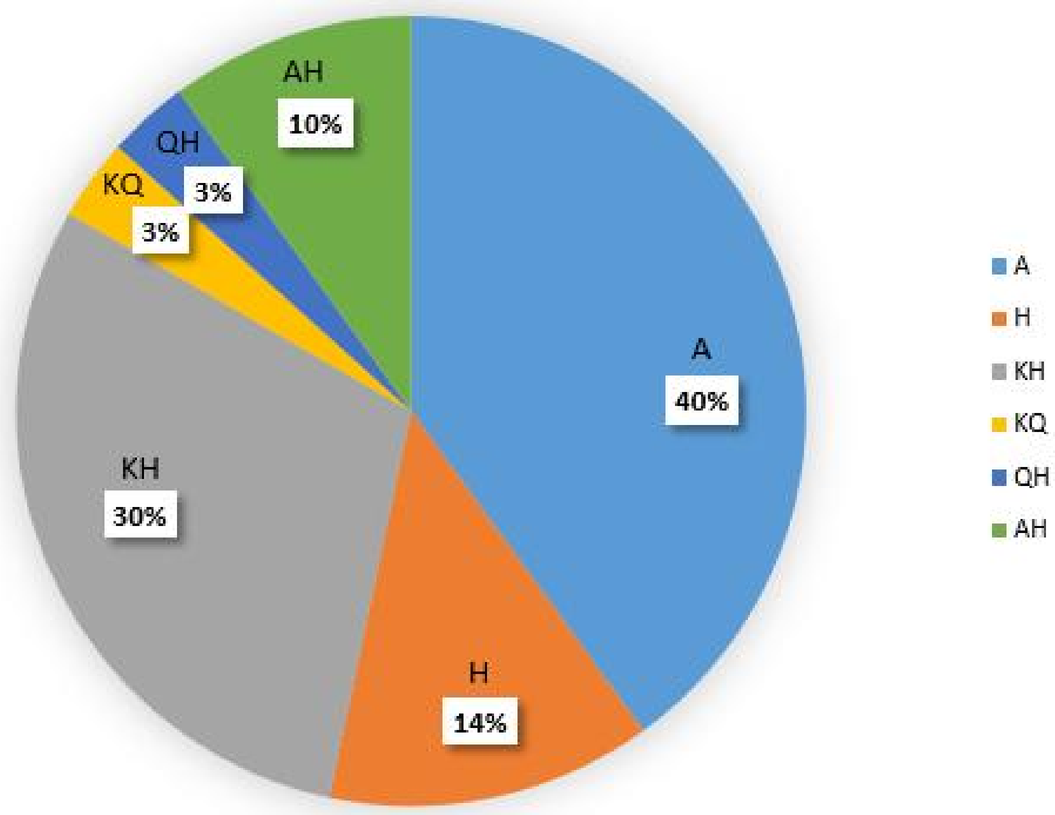


Figure 4.2: Pie chart showing the frequency of curve types obtained from the study area

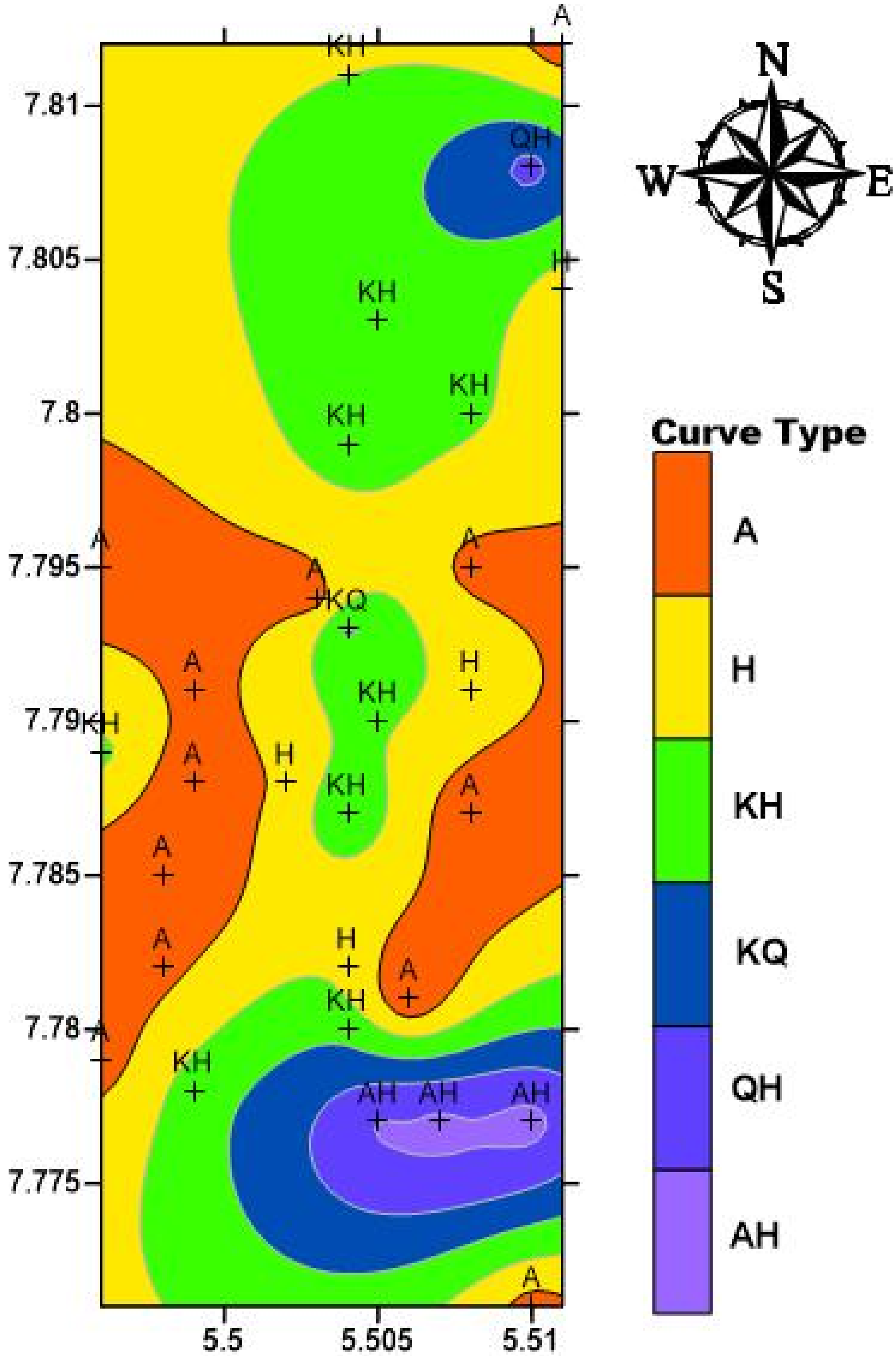


Figure 4.3: Map showing the distribution of the curve types

4.2 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 geoelectricparameters enabled the groundwater potential rating at each VES location.

These maps are as presented and discussed below:

4.2.1 Overburden Thickness Isopach Map

The depth to the basement (overburden thickness) beneath the sounding locationswere plotted and contoured at 1m interval as shown in Figure 4.4. 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, and weathered basement. The values range from 5.1 m and 32.5 m. Areas with thick overburden and not clayey in materials are corresponding to basement depression which are known to have high groundwater potential particularly in the basement complex area (Wright, 1990; Olorunfemi andOkhue, 1992; Meju*et al.*, 1999).

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 centraland southwestern part of the map while the western and northwestern flank of the study area showed thin overburden thickness as shown in Figure 4.4.

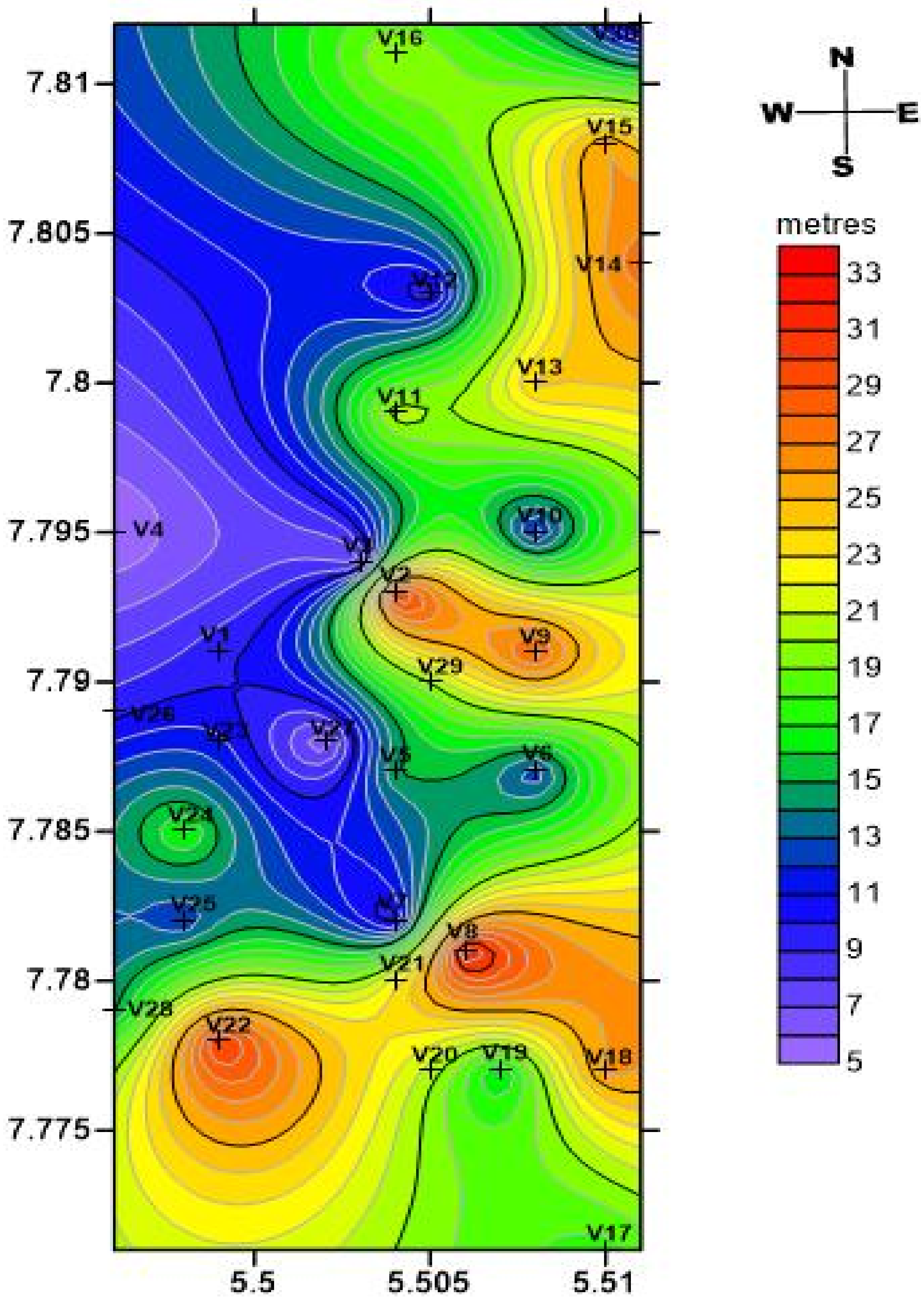


Figure 4.4: Overburden thickness isopach map

4.2.2 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 isopachmap was produced using a contour interval of 1 m (Fig. 4.5). The map was produced with a view to observing how the weathered basement layer considered to be 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 centraland 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.

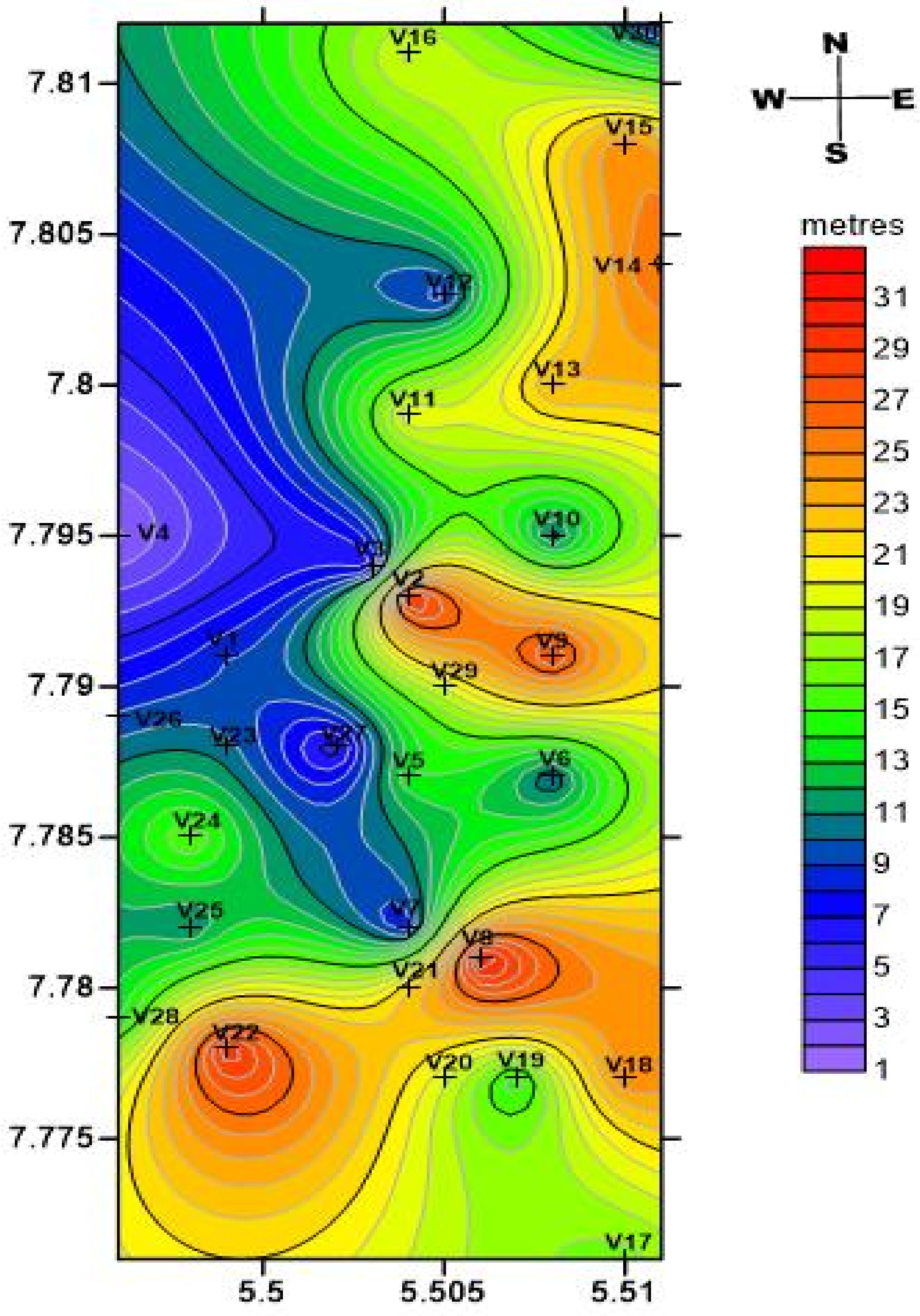


Fig. 4.5: Weathered layer thickness map

4.2.3 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 (Fig. 4.6) 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 interval of 100 Ω-m. 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 from point 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 the southwestern, 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 moderateresistivity 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(Wright, 1990; Meju*et al.*, 1999). Some portion of the western part could also be considered as another promising area for groundwaterprospect but due to its thinoverburden (Lenkey*et al.*, 2005), the water present in the aquifer might not be able to serve the industrial purposes in the time of prolonged dry season.

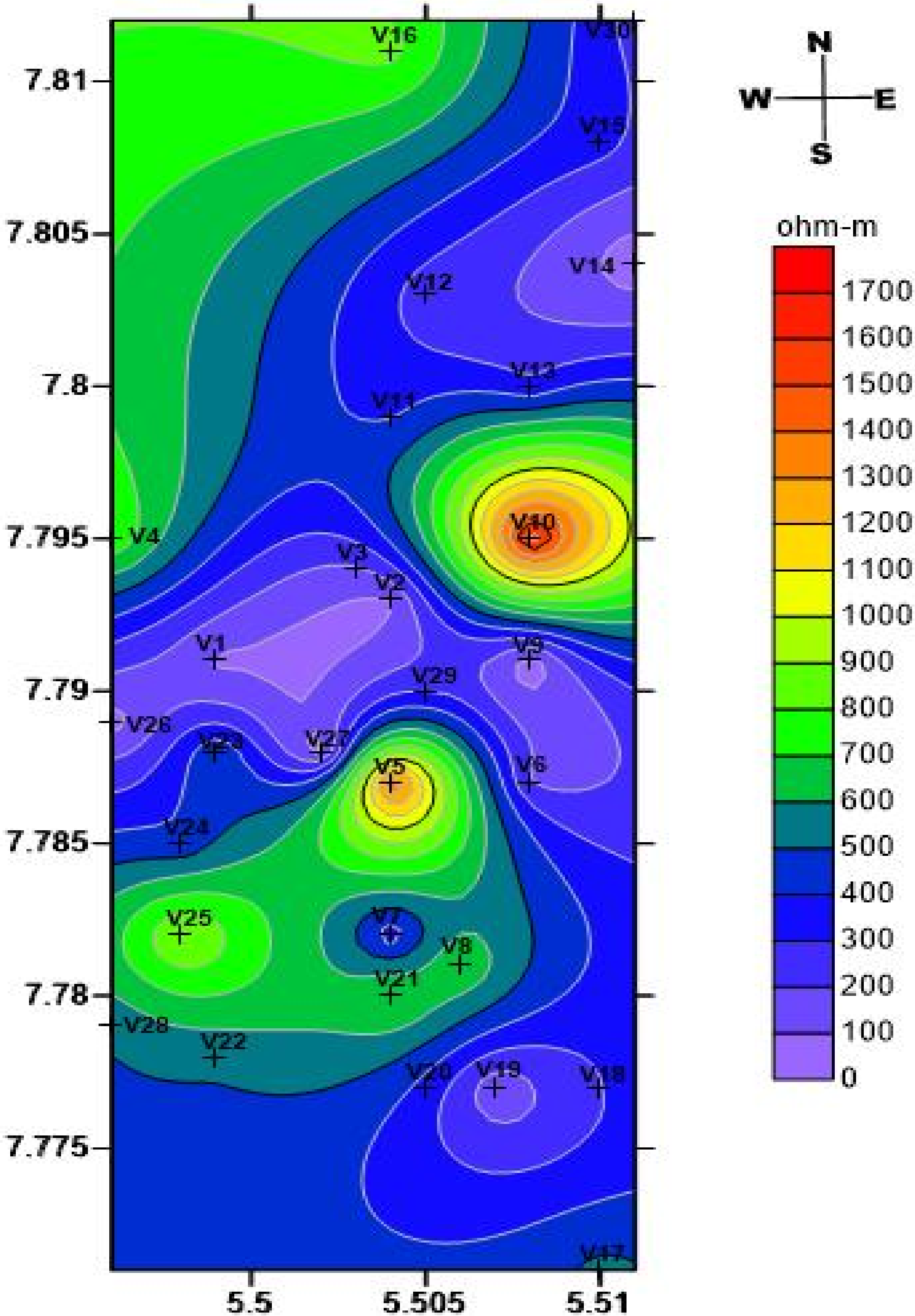


Figure 4.6: Weathered layer isoresistivity map

4.2.4 Bedrock Relief Map

The bedrock relief map (figure 4.7) 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 part 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. (Omosuyi*et al.*, 1999) findings revealed that depressions zone in the basement terrain serves 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.

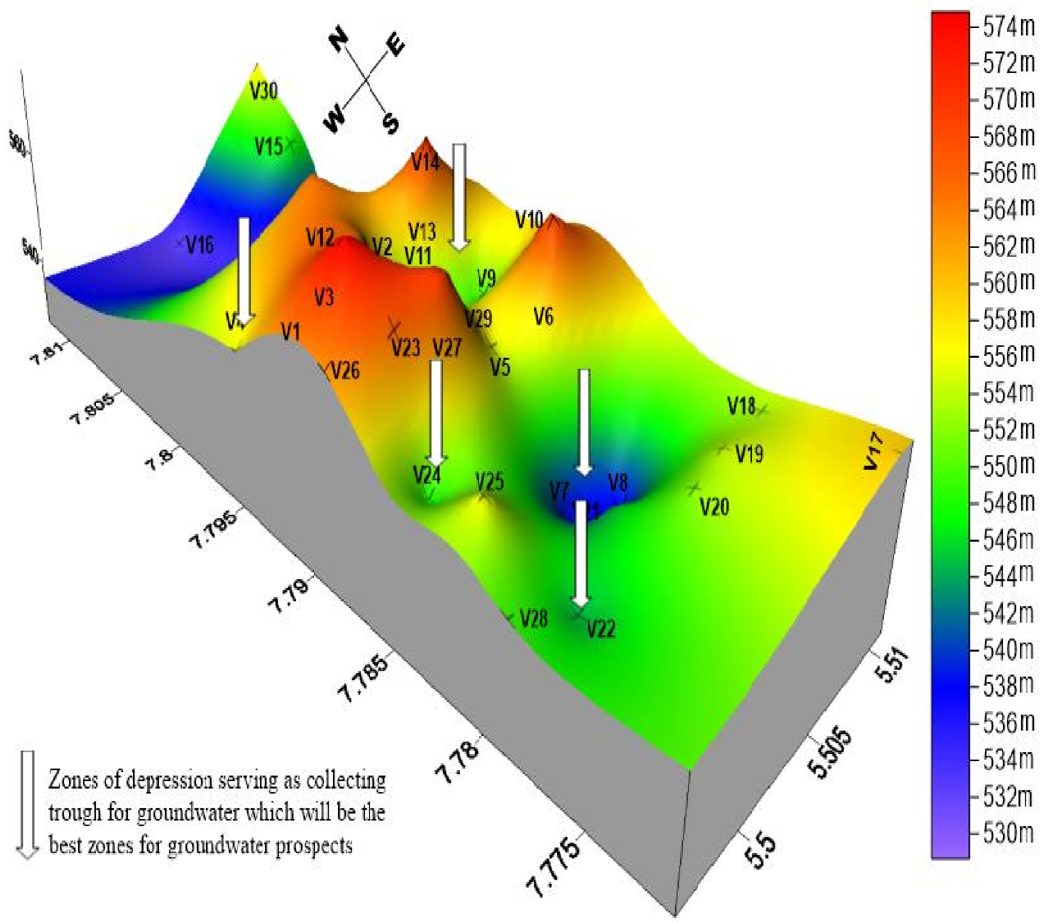


Figure 4.7: Bedrock relief map

4.2.5 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 todraw the final conclusion from the evaluated maps (Fig. 4.8). The map presents local groundwater prospects of the study area which is zoned into low, moderateand 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).

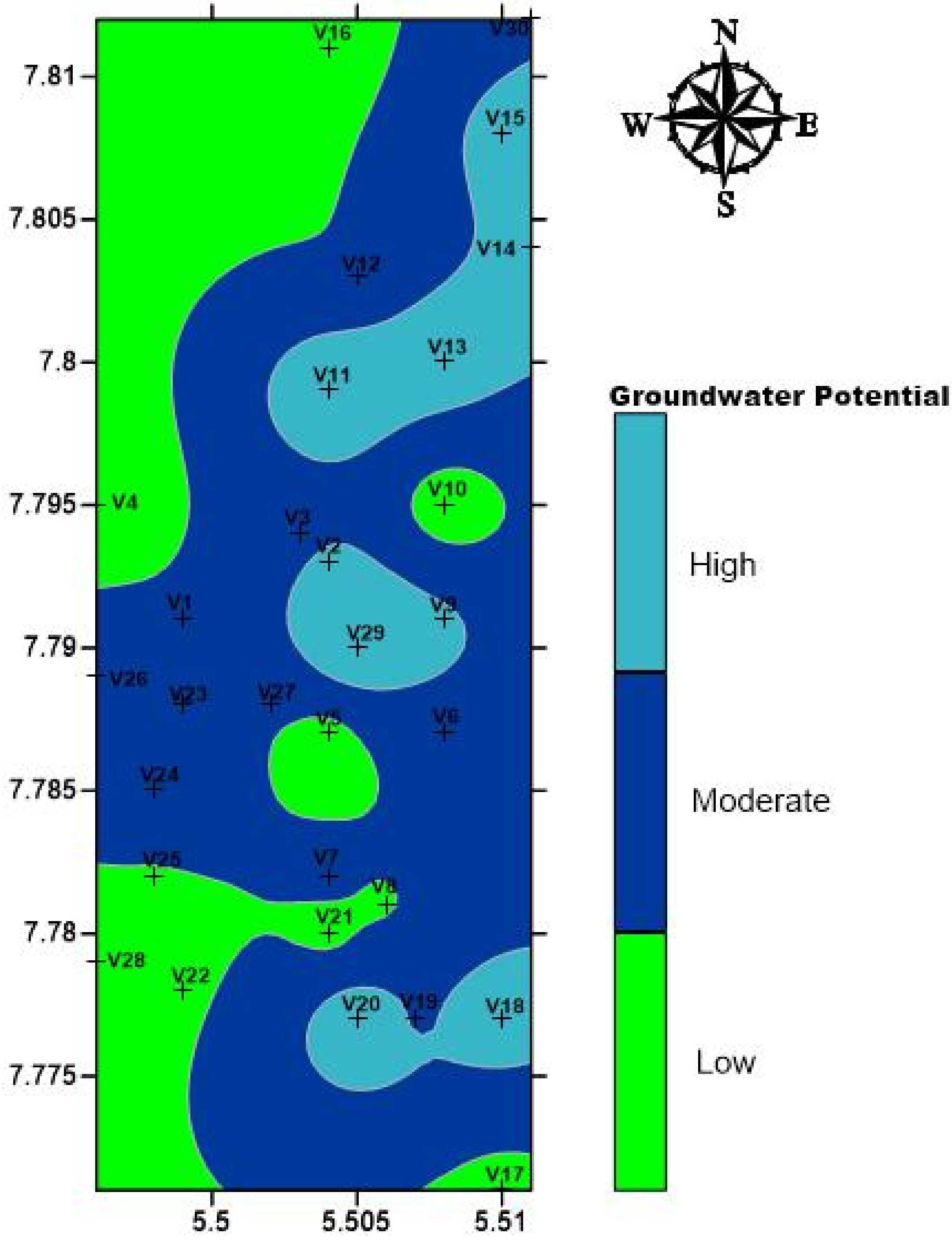


Figure 4.8: Groundwater potential map

CHAPTER 5

CONCLUSIONS AND RECOMMENDATION

5.1 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 foreffectivehydrogeologic characterization and town planning. The presence of weathered layer is a key components of aquifer system and zone of groundwater accumulation.

It can be concluded that the low resistivity and significantly thick weathered rock/clay constitute the aquifer in this area. 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 as shown in Figure 4.8.

5.2 Recommendation

It is recommended that further studies using integrated geophysical investigation for subsurface characterization which will aid community planning in terms of water works construction in areas of high groundwater potential should be done.

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