ASSESSMENT OF GROUNDWATER POTENTIALS IN KAURA AND ITS ENVIRONS PARTS OF SHEETS 167 SE AND 168 SW KADUNA STATE, NIGERIA.

BY

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DEPARTMENT OF GEOLOGY AHMADU BELLO UNIVERSITY, ZARIA, NIGERIA.**

MARCH, 2012.

DECLARATION

I hereby declare that the research work presented in this thesis for the award of Master of Science in Geology (Hydrogeology) has been written and compiled by me, **Mr. YANET LA'AKIH JOEL** in the Department of Geology, Ahmadu Bello University, under the supervision of Dr. Emmanuel Abdullahi Bala and Dr. Solomon Ayo Alagbe.

The research is exclusively the report of investigation conducted by me. I also declare that this thesis has not been written or submitted in any form whether partly or wholly for any other degree in any other university or higher institution. All sources of publications and other related reports cited in this research have duly been identified in the reference section.

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YANET, LA'AKIH JOEL DATE

CERTIFICATION

This Thesis titled Assessment of Groundwater Potentials in Kaura and its Environs parts of Sheets 167 SE and 168 SW Kaduna State, Nigeria meets the regulations governing the award of the degree of Master of Science (Geology) in Ahmadu Bello University, Zaria, Nigeria.

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DEDICATION

This work is dedicated to my late parents Mr.& Mrs Yanet Aboi who could not live to reap the fruits of their own labour but had to hearken to nature's call.

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Finally my appreciation goes to my bosom friends whose names too numerous to mention, for their prayers and beloved wife **Mrs Helen Joel** and my two sons, **Daniel** and **Mordecai** who stood by me at all times.

ABSTRACT

Kaura and its environsis located between latitudes 9^0 30′ N and 9^0 45′ N and longitudes $8^0$20′ E and $8^0$35′ E. The area has an approximately landmass of 770 Km^2 and lies within the crystalline hydrogeological province of northern Nigeria belonging to the Younger Granite and Basement Complex suites. These rocks lack primary porosity where groundwater could accumulate for exploitation. Groundwater abstraction in the study area is chaotic due to lack of detailed geological, hydrogeological and geophysical studies before embarking on the borehole drilling process. Measurements of static water levels in hand dug wells and construction of groundwater configuration and the direction of flow, boreholes data inventory and interpretation of Vertical Electrical Soundings results correlated with geologic sections in order to assess groundwater potentials in the area have been conducted. The Kagoro Hills is the major recharged area, it discharges water every parts the study area and all streams in the study area are effluent. Soft overburden and the fractured crystalline aquifer across the major rock units and alluvium along river bed, River Kaduna have been depicted from the Hydrogeeological cross section along line SSW and NNE. Interpretations of the sounding curves suggest that the subsurface layers are basically four. Aquifer parameters of the twenty (20) boreholes had average yield of 0.64 l/s, average Static water level of 6.12 m, average Draw down, 10.18 m, average Specific capacity is 0.082m^2/day and the average depth of 31 m.

Resistivity values as low as 25 ohm-m of the weathered layer with thickness as low as 6.6 m were observed in Fadan Daji, 30 ohm-m in Tacherak with thickness value of 5 m, 55 ohm-m in Jankasa I with thickness value of 5.3 m, 29 ohm-m in Randiyam with thickness value of 6.7 m. These areas have resistivity values corresponding to the weathered regolith zone called saprolite (Jones, 1985); the above locations lie within the newer basalts terrain. These low resistivity values have been used to determine areas of high potentials for groundwater occurrence.

The temperature of water samples was in the range of 25.2-25.8^{o} C with an average value of 25.6^{o} C. The electrical conductivity (EC) values range from 38.8 µs/cm in hand dug wells to 330 µs/cm in boreholes with an average value of 40.04. The p^{H} in the water analyzed range from 6.96 to 7.80, with an average value of 7.25 which is within the recommended level (WHO, 2004).

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Chapter 1

INTRODUCTION

1.1 Preamble

Kaura and its environs have suffered a serious set back over the years as far as groundwater exploration and exploitation is concerned. As surface water is exposed to several kinds of abuse, groundwater remains the only reliable source of water supply that could be developed in response to the established problems of; cholera, diarrhea, typhoid fever and long trek of distances by women and children in search for water in dry season. The study area lies within the crystalline hydrogeological province of northern Nigeria belonging to the Younger Granite and Basement Complex suites. These rocks lack primary porosity where groundwater could accumulate for exploitation. For these rocks to store water, therefore there must exist in them secondary porosity, which invariably results from weathering and fracturing. However, the spatial distribution and depth of this kind of porosity vary from one location to another. Therefore, the occurrence of groundwater in these rocks is sporadic and borehole siting for its abstraction in this geological terrain is often difficult. Consequently, a combination of geology/hydrogeological, geophysical studies in Kaura and its Environs have been carried out in the Assessment of groundwater potential areas in the study area for future groundwater supply projects.

1.2 Statement of the Problem

Groundwater abstraction in the study area is chaotic due to lack of detailed geological, hydrogeological and geophysical studies before embarking on the borehole drilling process. Traditional method of sinking hand dug wells is on the increase without achievable results.

These wells dry up at peak of dry season, resulting to incessant cases of water borne diseases; typhoid, diarrhea and cholera. Assessment of groundwater potentials is necessary to curtail this menace for future provision of sustainable water sources in the study area.

1.3 Justification of the Study

Drilling of unproductive boreholes over the years has been a matter of concern to the inhabitants. The need for the exploration and exploitation of the weathered and fractured aquifers in the study area is necessary and this could only be achieved by a combination of detailed geological, hydrogeological and geophysical studies of the study area.

1.4 Objective of the Research

The research was aimed at measuring static water levels in hand dug wells and construction of groundwater configuration and the direction of flow, boreholes data inventory and interpretation of Vertical Electrical Soundings results to be correlated with geologic sections with the aim of assessing the groundwater potentials in the study area.

1.5 Statement of Research Hypothesis

The research hypothesis, adopted in this present work, is that the Basement Complex is heterogeneous and the aquifers are localized, the need for identification and delineation of these aquifers in the study area is very important.

1.6 Location, Extent and Accessibility

The area under study is located in Kaduna State within the Basement Complex rocks of north-Central Nigeria. It lies between latitudes $9^0$30' N and $9^0$45'N and longitudes $8^0$20'E and $8^0$35'E. The area has an approximately landmass of 770 km^2 Fig. 1.

The area is traversed by good roads network which are the Jos –Kagoro Kaduna road that runs East-West. Others are the Kagoro-Kafanchan road, Kagoro –Manchok Jos road and Kagoro-Mabushi road Manchok-Jankasa Mabushi roads. In the central part of the study area, Rail line traverses from Kafanchan-Kagoro to Jos Terminus in Plateau State.

1.7 Relief and Drainage

The relief is undulating highlands to average height of about 1,800 m above sea level in the study area. There are two major rivers in the area, these are River Kaduna at the NE of study area and River Assob at the SE. Most of the streams are seasonal. The course of these rivers seems to suggest features of structural significance, aided by fractures normal to direction of regional strike and drains to River Kaduna with its tributary at the north-eastern part of the study area (Fig. 1).

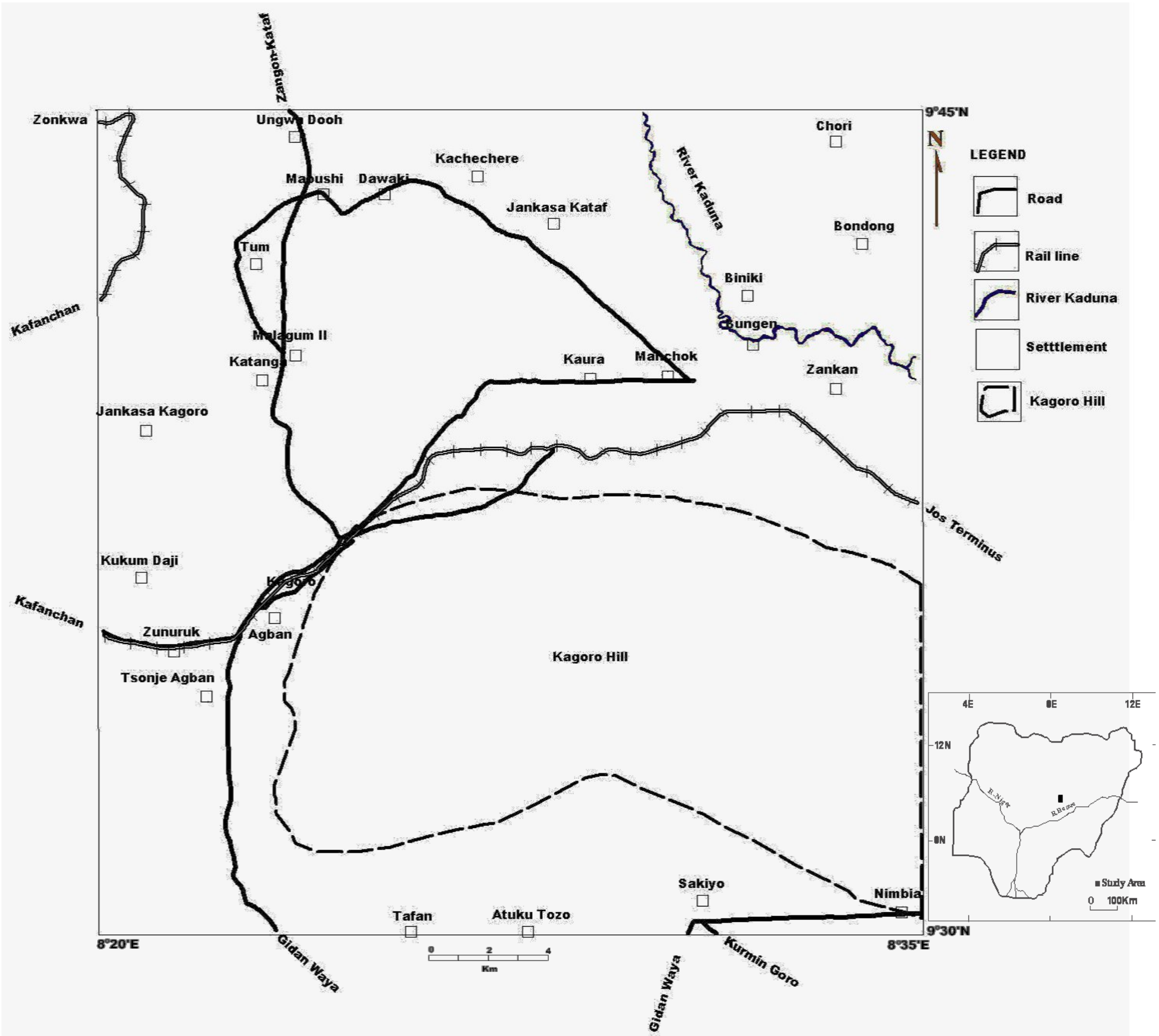

Fig.1.a. Location map of study area.

1.8 Climate, Vegetation and Land Use

The study area is situated in the tropics within the Guinea Savannah region. Rainfall is seasonal and moderate with a mean annual amount of 1524 mm. Rainfall usually commences in March and ends in October and for the rest of the year dry season prevails. Temperatures vary between less than 15^{o}C around December/ January and 32^{o}C in March and April with its annual mean between 24^{o}C and 28^{o}C. The relative humidity varies with the season with highest values in the rainy season and lowest values during the harmattan.The mean annual relative humidity is 57%.

The vegetation consists of broad-leaved savannah woodland and when properly developed, the trees may attain heights of 10-15 m. Relatively denser gallery forest occurs along some streams. The dominant trees within are <u>Isoberlina doka</u> while <u>Khaya senegalensis, Danielia oliveri, Perkia</u> and <u>Ficus sycomotus</u> are common. There are abundant grasses with annual types dominating the uplands while the perennial type such as <u>Hyparrhenia spp</u> and <u>Andropogon spp</u> are also common.

Sugarcane and other garden crops, mostly vegetable, are cultivated along streams courses. The perennial streams in the area sustain such cultivation in the dry seasons via shadoof irrigation systems. Dominant food crops found in the area include root crops e.g. yams and cassava while stem tubers include potatoes. These are sometime intercropped with millet and maize.

1.9 Previous Work

Assessment of groundwater potentials has not been carried out in Kaura and its Environs, but a lot of unpublished studies have been written on the northern region of Nigeria Basement Complex or just Western half of 1:100,000 Sheet 188 (Jema'a).

The Basement Complex formation constitutes the oldest geological formation in Nigeria. Kaura Local Government Area and its environs in Kaduna State fall within the northern Nigeria Basement Complex. The oldest rocks of the area are the gneisses and Older Metasediments believed to be Birrimian in age (about 2500 M.y) according to McCurry (1976).

Through the process of metamorphism, migmatization and granitization that occurred within at least two tectono-metamorpic cycles, the rocks were largely transformed into migmatites and granite gneiss, with some relics of the original gneisses McCurry (1976). The Basement Complex was later intruded by series of intermediate and acid plutonic rocks during the Pan African Orogeny according to McCurry (1976). Oyawoye (1970), showed that there is structural similarity between the study area and the rest of West Africa. (MacLeod *et al* 1971), reported that newer basalts often overlie alluvial deposits. The Younger Granites are high level discordant intrusions in the Basement Complex and occupy approximately 8% of the total surface area of Nigeria according to Rahaman (1976). These suites comprise non foliated alkaline granites and granitoids with basic and volcanic rocks centered mostly in the Jos Plateau region. During the Jurassic period (190 to 205 M.y), a major tectonic event occurred and principally affected the Jos Plateau and its environs, leading to emplacement of these assemblages, as Grant (1969) informs. The Younger Granites are characterized by pin point topography and ring structures. These include rhyolite, riebeckite granite, fayalite quartz porphyry, pyroxene fayalite porphyry and granite porphyry.

Previous workers on the Basement Complex in general which include the study area includes Du preez (1965), who worked on the groundwater distribution in northern Nigeria. He reported that the groundwater could be extracted by open wells and boreholes are located in the fracture systems of the fresh and weathered portions of the Basement Complex.

Mbonu (1988) reported that the major source of groundwater in north-central Nigeria is from the weathered/fractured zones, and that 91% sampled water points both surface and groundwater sources have nitrates concentration less than 45 mg/l.

Eduvie (1991), reported that the weathered/fractured zone has a depth of 60-70 m. Hazell *et al* (1992) stated that the crystalline basement exposures of northern Nigeria have areas of deeply weathered regolith estimated at 10-30 m which constitute useful aquifers separated by larger areas of relative unproductive shallow aquifers.

Barber and Akono (1964), did some electrical soundings in parts of the area and identified fractures in the Basement Complex on the basis of which borehole locations were identified.

Dunama (2000), reported the water quality of the Kachia grazing reserve to be slightly alkaline soft water which could be used for drinking, livestock, irrigation and fish farming. Eduvie (2003), reported the water samples in the study area to be slightly alkaline with p^H range of 5.85 to 7.60. Jatau (2007), reported the temperature of groundwater in parts of Jema'a Local Government Area to range from 22^0 C. p^H of the water samples analyzed ranged from 5.87 to 7.60.

1.9.1 Present Work

The present work evaluated the groundwater potentials in the study area. In this work, Water table measurements beneath the surface were first carried out with respect to the underlying geology. This was complemented by Vertical Electrical Soundings for qualitative and quantitative interpretation with respect to prospects of locating water bearing zones (weathered/fractured layers). Desk study of topographical Sheet 167 1:100,000 and geological map of Kaduna State were appraised. Results of existing borehole data were also collected and collated. This was also complemented by supervision of geophysical survey and borehole drilling, well design and pumping test conducted under the Millennium Development Projects (MDGs), 2008 and 2009 and the Educational Sector Support Program in Nigeria (ESSPIN), 2010.

Map of Groundwater configuration and the direction of flow, Hydrogeological cross section were produced and the aquifer systems delineated. The water type was also characterized.

Chapter 2

GENERAL GEOLOGY

2.1 Overview of the Geology of the Basement Complex

The Regional distribution of rocks of the Nigerian Basement Complex is presented Fig. 2.a

The Nigerian Precambrian basement is part of an Upper Proterozoic to lower Phanerozoic mobile belt situated between the West African and Congo cratons.

Three lithological groups are usually distinguished: Polymetamorphic gneiss-migmatite complex, the Schist belt and Syntectonic to late Pan African granitoids.

The Polymetamorphic gneiss-migmatite complex with ages ranging from Liberian (2800 M.y) to Pan African (600 M.y). Metamorphism is generally in the amphibolite – facies grade. According to Rahaman (1988), the following three petrological units characterize the migmatite complex:

a. A grey foliated biotite acid or bioyite hornblende quartz feldspathic gneiss of tonalitic to granodioritic composition which is now known as grey gneiss or early gneiss.

b. Mafic to ultramafic components, which were present, often outcrop as discontinuous boudinaged lenses or concordant sheet of amphibolites with minor amount of biotite-rich ultramafite. Except where it constitutes the paleosome to migmatite, it is present in grossly subordinate amount in grey gneiss.

c. The felsic component which is of a varied group of rocks consisting of pegmatite, aplite, quartz-oligoclase veins, fine grained granite gneiss and porphyritic granite.

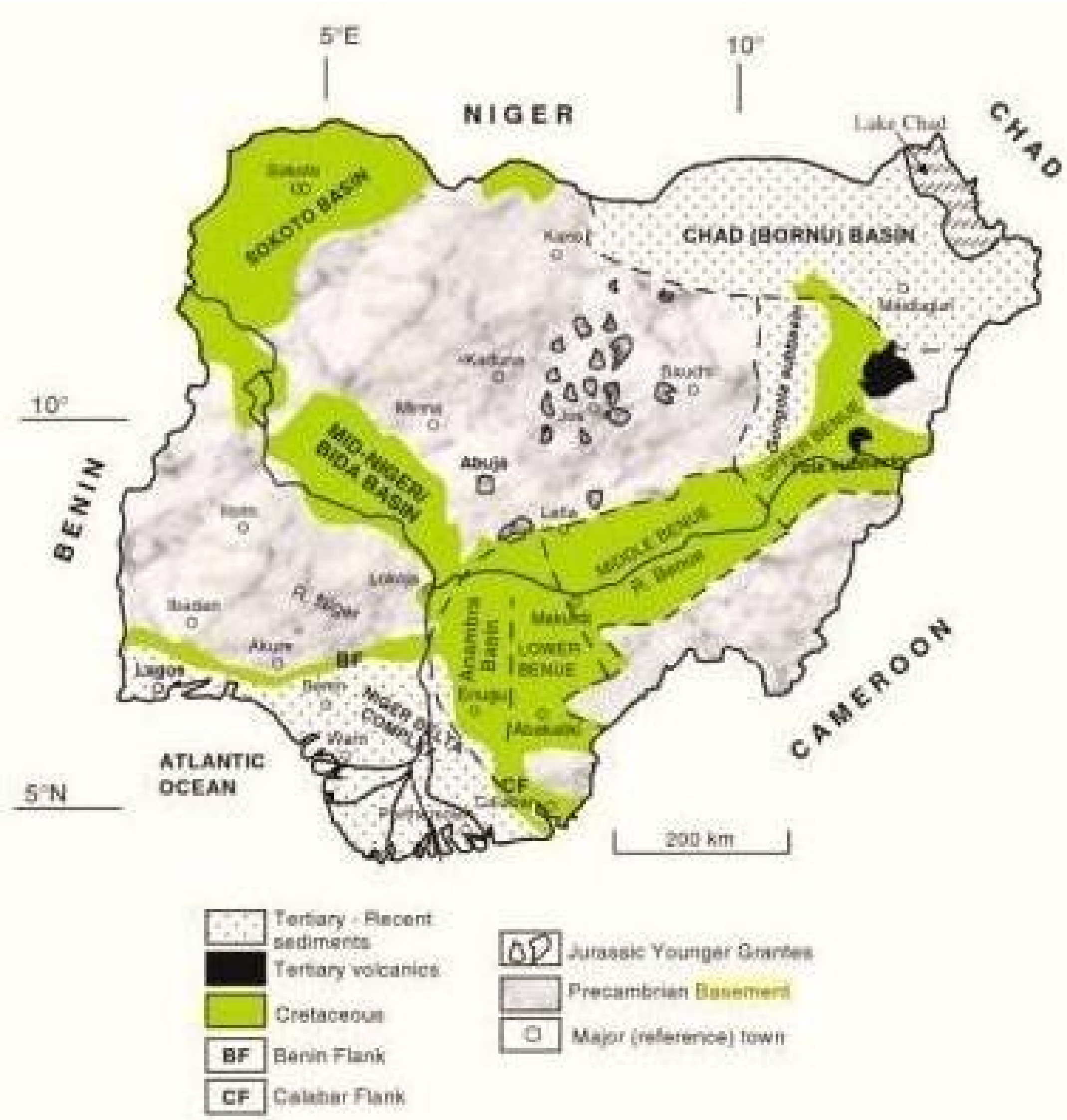

Fig. 2.a Geological Map of Nigeria (from: Geological Survey of Nigeria, 1974, modified).

The Schist Belts are of low- medium grade metamorphosed sedimentary and volcanic rocks(mainly green schist facies) supracrustal (and minor volcanic) assemblages, that occupy a prominent NNE - SSW trending synformal troughs infolded into the Migmatite-Gneiss Complex which are considered to be Late Proterozoic. Grant (1978) and Turner (1983) based on structural and lithological associations suggested that some of the schist belts are of Kibaran (110+200 Ma) and older age, whilst others are of Pan African age (600 Ma). But (Ajibade et al., 1979) disagrees with the structural evidence and proposed a Pan African age for all schist belts. Syntectonic to late tectonic Pan African granitoids that include both the Schist Belts and the Gneiss-Migmatite Complex. The Older Granites are the most obvious manifestation and they constitute 40-50% of the Basement Complex. They vary in composition from tonalite through granodiorites to granite and syenite. Texturally they vary from strongly foliated gneiss varieties to undeformed rocks.

The Pan African granitoids in Nigeria are referred to as the Older Granites to distinguish them from the anorogenic granite ring complexes (Younger Granites). The Younger Granites are high level discordant intrusions in the Basement Complex and occupy approximately 8% of the total surface area of Nigeria as Rahaman (1976) writes. These suites comprise non foliated alkaline granites and granitoids with basic and volcanic rocks centered mostly in the Jos Plateau region. During the Jurassic Period (190 to 205 M.y), a major tectonic event occurred and principally affected the Jos Plateau and its environs leading to emplacement of these assemblages, as Grant in 1969 informs. The Younger Granites are characterized by pin point topography and ring structures. These include rhyolite, riebeckite granite, fayalite quartz porphyry, pyroxene fayalite porphyry and granite porphyry.

2.2 Geology of the Study Area

The study area covering parts of Sheet 167 SE Kafanchan and 168 SW Naraguta Sheet , 1:50,000 is made up of the rocks of the Migmatite-Gneiss Complex, Gneiss, Younger Metasediments, Older Granites, Younger Granites and Newer Basalts. The distribution of the various rocktypes is as shown on the geological map of the area (Fig.2)

Basement rocks that occur in the study area could be classified into:

1. Migmatites-Gneiss Complex

2. Gneisses

3. Older Granites

4. Younger Granites

5. Newer Basalts.

6.Schists.

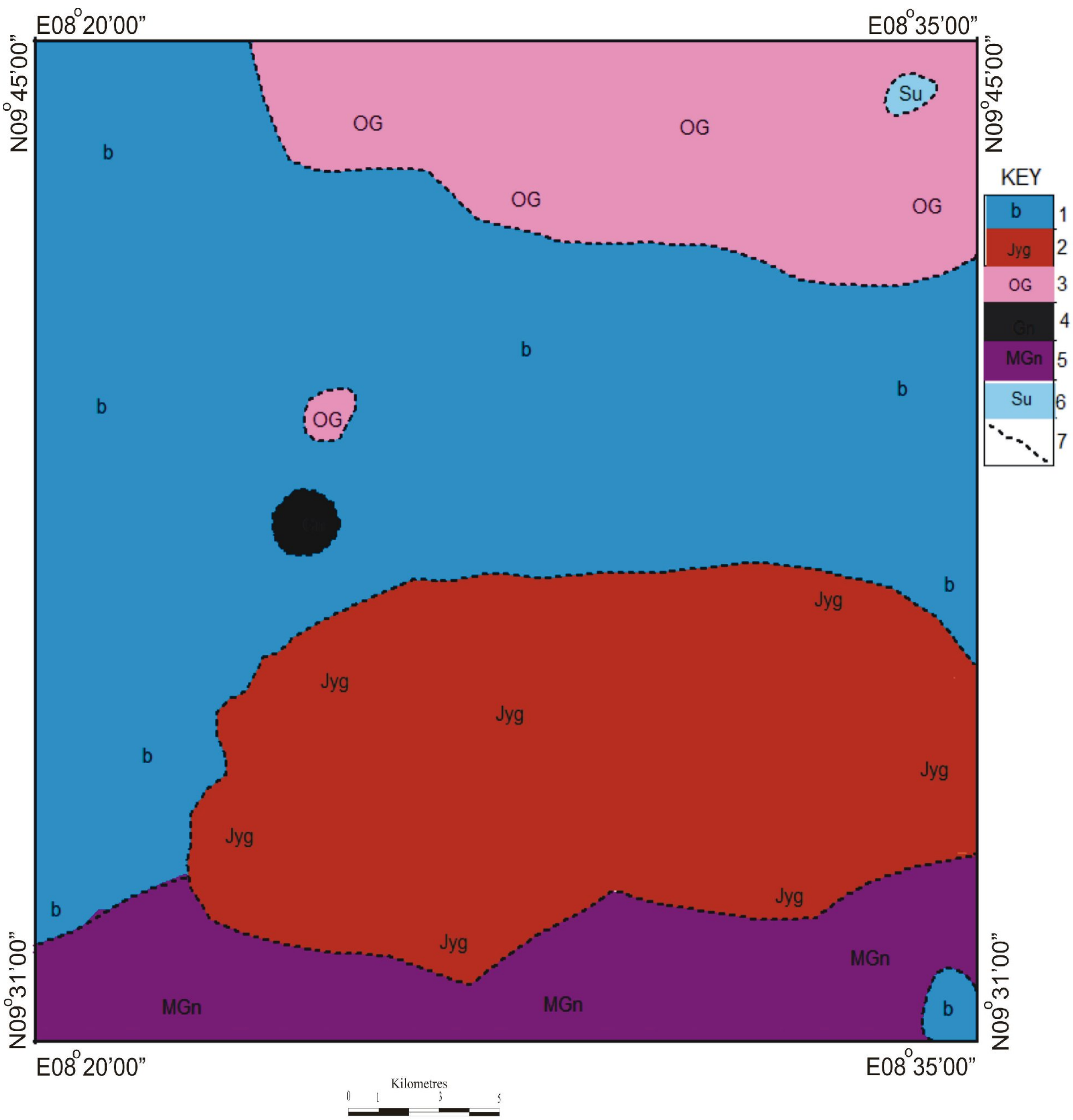

FIG 2: GEOLOGICAL MAP OF THE STUDY AREA

Explanation:
1. Newer Basalt
2. Younger Granite
3. Older Granite
4. Gneiss
5. Migmatitic Gneiss
6. Undifferentiated Schists
7. Geological Boundary

Fig.2.b Geological map of the study area.

2.2.1 Migmatite-Gneiss Complex

Texturally, migmatites commonly show granoblastic texture and foliation. Migmatites are characterized by light and dark bands with characteristic flow structures. Visible minerals include quartz, biotite and plagioclase. Gneisses vary in texture from being medium, even-grained to coarse porphyroblastic with alternate light and dark bands. Pegmatites and quartzofeldspathic **veins** also occur on migmatites. The rocks are pinkish to grey in colour and strongly foliated with veins containing quartz mineralization.

2.2.2 Gneisses

Gneisses vary in texture from medium to even-grained. The outcrops are grey in colour and strongly foliated with variable joint directions with quartz mineralization. They are composed essentially of feldspars, quartz and biotite minerals. Gneisses could be found at the mid-western part of the study area.

2.23 Older Granites

These rocks occur as hilly masses sometimes consisting huge blocks that have been derived from weathering. Mineralogically, they are composed of quartz, feldspars and biotite. When fresh, they are grayish blue in colour due to the prominence of biotite, and where weathered they exhibit brownish colour. Older Granites are very prominent in the northern part of the study area. In the field, the porphyritic granite which is characteristic of the study area consists of large, white and pink prismatic phenocrysts of microcline. The rock is pinkish grey in appearance. Outcrops are highly jointed and strike in N-S and sometimes in E-W directions.

2.24 Younger Granites

The Younger Granites are characterized by pin point topography and ring structures. The most striking petrographic feature of these rocks is the felsic nature; about 95 vol. % of the rocks is rhyolite, riebeckite granite, fayalite quartz porphyry, pyroxene fayalite porphyry and the remaining 5 vol. % is mafic rocks. The predominant rock type in the study area is the granite porphyry. The Younger Granites are centered mostly in the Jos Plateau region which forms part of Kagoro Hills generally known as the Ganuri- Kigom Ring Complex (Fig.2).

2.2.5 Newer Basalts

The Newer Basalts occur in the vicinity of Kafanchan and Kagoro along the western edge of the Jos Plateau. In the field Newer Basalts have vesicles with little occurrence of olivines. Outcrops occupy which comprise an the Ganawuri extension of basalts of Plateau State.

2.2.6 Schist

Undifferentiated schist, phyllites and quartzites occur around at the N-E part of the study area. Flaky minerals mostly muscovite and biotite could be observed along pegmatite and quartz veins in the field. The quartzites mostly occur as ridges trending NE-SW.

CHAPTER 3

MATERIALS AND METHOD

3.1 The study Design

The assessment of groundwater potentials was carried out in five stages; (a) desk study of physical and geological maps of the study area; (b) static water level measurements from hand dug wells; (c) Vertical Electrical Soundings; (d) comparison of data from existing and new boreholes.

3.2 Field Work

Identification of the various rock units to produce an outline geological map of the study area. Measurements of static water level and depth of about fifty-nine (59) selected hand-dug wells was done between March to April 2009 and August to September 2009 (at peak of dry season and peak of rainy season). Graduated tape, e-Trex Venture Garmin 12 XL Global Positioning System (GPS) for location marking and position heightening of hand dug wells, from which the configuration map of groundwater flow direction at peak of dry season was produced.

A total of thirty-nine (39) VES soundings were carried out using OMEGA Resistivity Meter by the application of Schlumberger configuration with a maximum half current cable spread (AB/2) of 1 to 100 m and MN/2 from 0.3 to 5 m with a view to determining the subsurface layering, overburden thickness, thickness of the aquiferous layer and the degree of fracturing of the bedrock. The observed field data were converted to apparent resistivity values by multiplying with the Schlumberger geometric factor. The sounding curve for each point was obtained by plotting the apparent resistivity on the ordinate against half current-electrode spacing on a bilogarithmic transparent paper. Parameters such as apparent resistivity and thickness obtained from partial curve matching were used as input data for computer iterative modeling using the computer aided IXid and IP12 WIN Software from WATSAN Project, Kaduna. The VES curves were qualitatively and quantitatively interpreted. The qualitative interpretation involved visual inspection of profiles and maps for signatures that are diagnostic of the target (groundwater).

Borehole drilling was also supervised to ensure proper well drilling, development and design for productive boreholes. Existing borehole data were collected and collated and compared to new boreholes data. Borehole profiles were compared to Vertical Electrical Soundings to ascertain the level of correlation between the two. Pumping test operations were conducted for twenty (20) boreholes to ascertain the drawdown, yield, specific capacity hydraulic conductivity and transmissivity using the Jacob's method. Drawdown curves and recovery phase diagrams were also established.

Chapter 4

RESULTS AND DISCUSSIONS

The results of the study are presented as groundwater configuration map, hydrogeological cross section, correlation of VES interpretation results with geologic sections and assessment of groundwater potentials based on the petrology of the rocks.

4.1 Measurements of depth to water table results

Water table measurements carried out in the study area during the peak of dry season are contained in a range between 7.31 m to 14.00 m bgl (wells number 1 and 59). The deepest value of 14.00 m bgl in well number 59 is as a result thick overburden that enhances the sustainability of the hand dug well.

Wells that dry up completely at peak of dry season are generally as a result of shallow depth to basement as observed in wells number, 5, 12, 13, 17, 20, 21, 36 and 54 (Fig.3.1). Wells that overflow at peak of rainy season are sunk in shallow overburden over the fresh basement. They include the following; wells number 14, 25, 29 and 32. Elevations of the water table above sea level in the study area ranges between 457 m to 1219 m asl..

Configuration map of groundwater table and directions of the groundwater flow shows that the Kagoro Hills is the major recharge area. It discharges water to all parts of the study area. All streams in the study area are effluent. The hydrogeeological cross section (Fig.3.2) along line

SSW - NNE depicts the surface of erosion, overburden and the fractured crystalline aquifer across the major rock units and alluvium along river Kaduna bed.

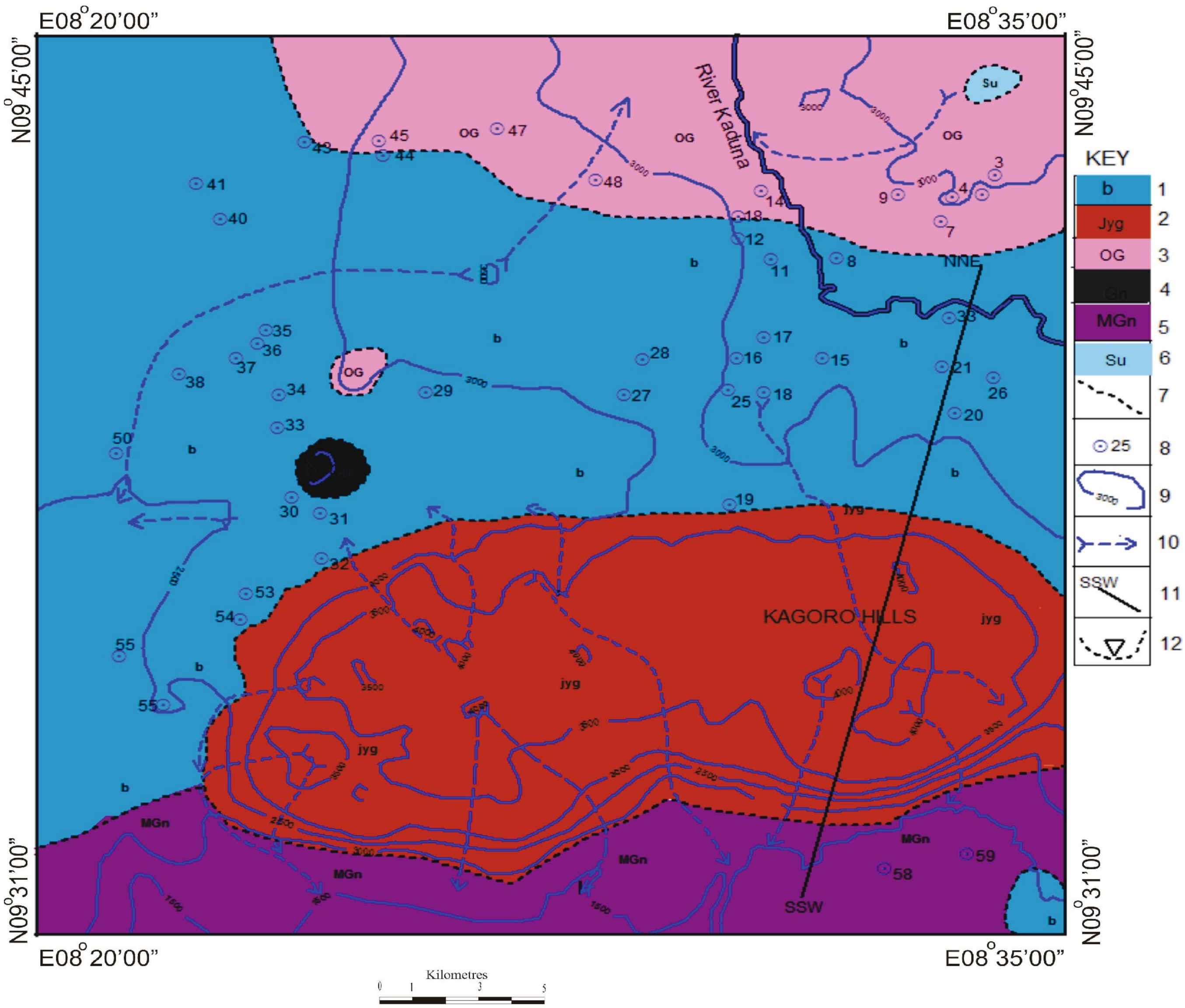

FIG 3.1: GROUNDWATER CONFIGURATION MAP SHOWING THE DIRECTION OF GROUNDWATER FLOW

FIG.3.1 GROUNDWATER CONFIGURATION MAP AND DIRECTIONS OF THE GROUNDWATER FLOW. Explanations (For the map above and cross section in Fig. 3.1):
1-Sandy alluvial aquifer up to 10 m thick; 2-Newr Basalt, forming fractured basaltic aquifer up to 40 m thick;
3-Younger Granite its uppermost fractured portion, up to 30 m thick, forming fractured granitic aquifer;
4-Older Granite its uppermost fractured portion up to 30 m thick, forming fractured granitic aquifer;
5-Gneiss, its fractured uppermost portion up to 10 m thick, forming fractured crystalline aquifer;
6-Migmatite- Gneiss, its fractured uppermost portion, up to 10 m forming fractured crystalline aquifer;
7- Undifferentiated crystalline schists,its fractured uppermost portion, up to 10 m thick, forming fractured crystalline aquifer; 8-Geological boundary;
9- Measured hand dug well and its identification number as in Appendix 1,
10-Groundwater table contour at the peak of dry season, in feet above sea level;
11-Directions of groundwater flow at the peak of dry season;
12- Line of hydrogeological cross section shown in Fig. 3.2. Base map; Federal Surveys Nigeria, 1:50,000 Serial Numbers, 167 SE Kafanchan Sheet and 168 SW Naraguta Sheet.

Fig.3.1 Configuration of the water table map showing direction of flow, for peak of dry season.

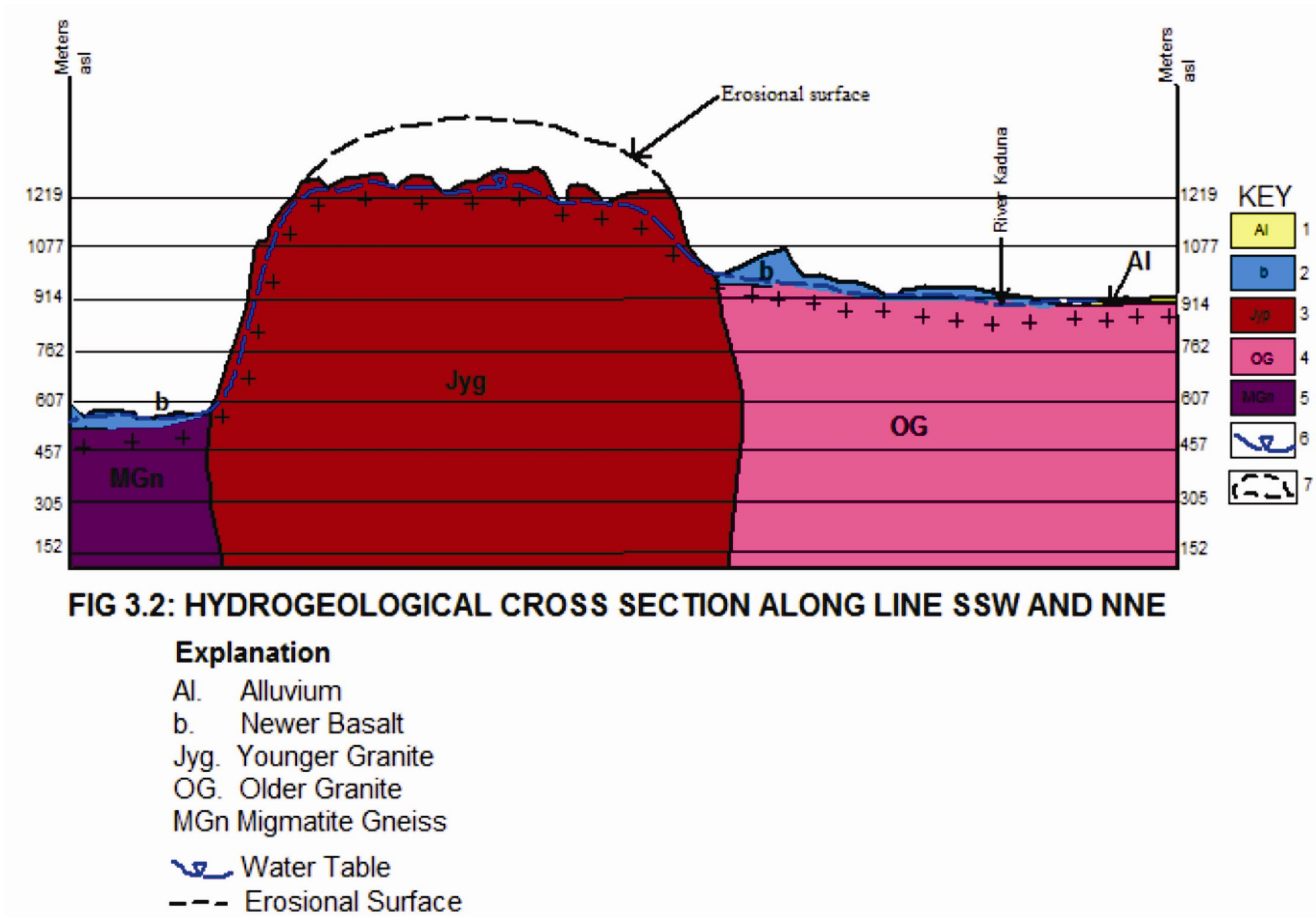

Fig. 3.2 Hydrogeological cross section along line SSW and NNE

4.2 Geophysical investigations results

Geophysical parameters are presented in Appendix 3 and typical curve types obtained in the study area are, H, KH and HK presented in Fig.4.1a-d. Interpretations Vertical Electrical Sounding curves obtained in the study area suggests that the subsurface layering ranges from 3-5 layers. The resistivity values of the first layer ranges from 135 to 7082 ohm-m with thickness ranging from 0.4-5.04 m, while the second layer ranges from 40 to 1880 ohm-m with thickness ranging from 0.9-14.00 m and that of the third layer ranges from 30 to 1397 ohm-m with thickness ranging from 4.00 to 39.60 m. In the fourth layer (regolith) resistivity values ranges between 23 and 593 ohm-m with thickness ranging from 4.00 to 40 m. This layer represents an important aquifer in the study area. The bedrock, which occurs as either the third , fourth or fifth layer in different parts of the study area has relatively high resistivity values ranging from 1000 ohm-m and above. The thickness of the fifth layer can not be measured because it is infinite. The estimated depth to basement is in the range of (5 m to 40 m) .The depths to bedrock obtained from the vertical electrical soundings are in agreement within 10% with that indicated by geologic sections in (Fig.4.2.a-b) . Emphasis was put on locating boreholes in areas of thick overburden. Results obtained from this research show that the fractured aquifers have 95% of productive wells. They are associated mainly with Newer Basalts although metamorphic terrains also yield moderate amount of water, because of the significant thickness of its soft overburden aquifer. The poorest is in terms of borehole yield are the Younger Granites terrains with their thin overburden aquifers of a maximum thickness of 10 m.

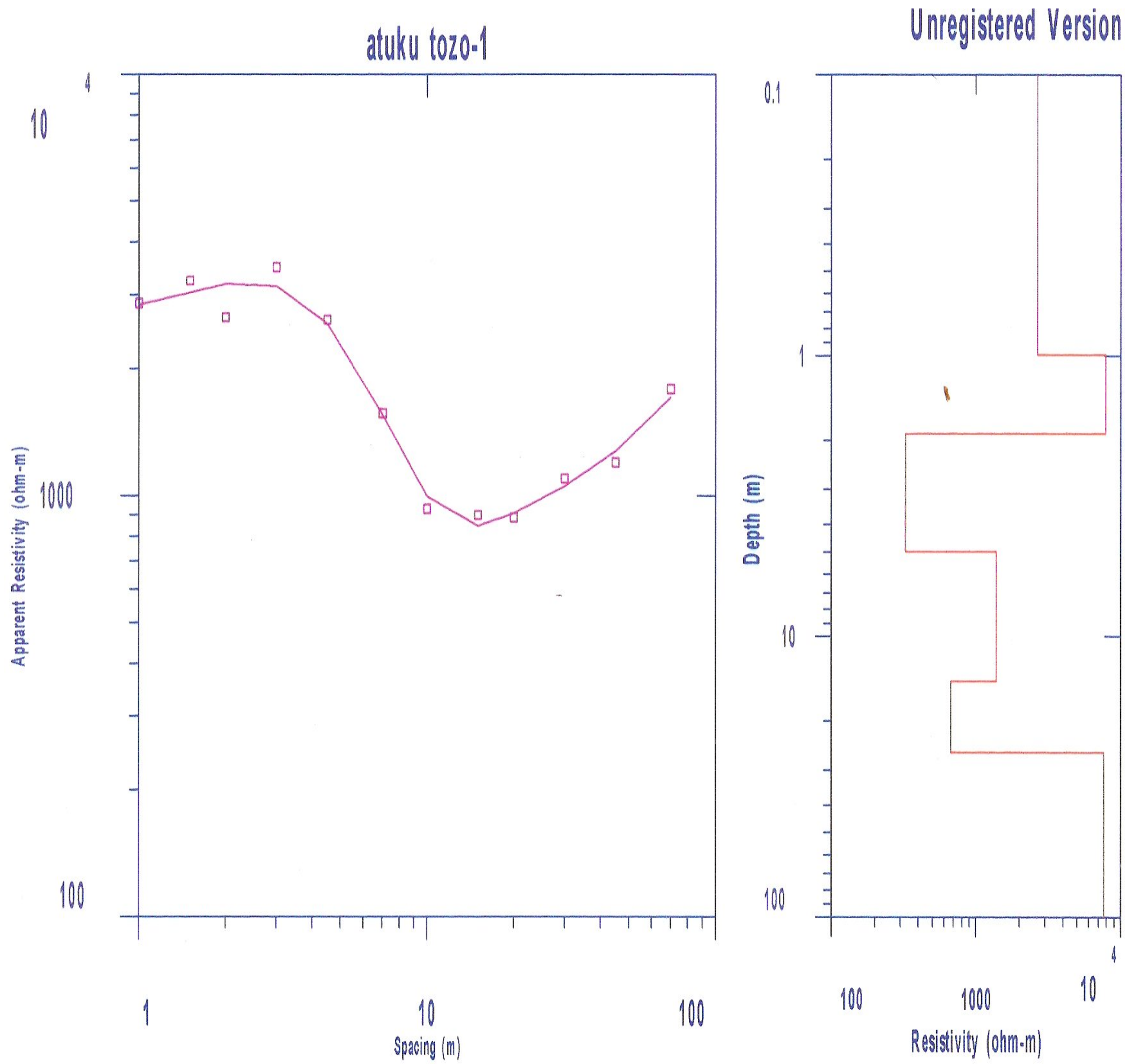

Fig. 4.1 a. LGEA Atuku Tozo. (HK – type curve)

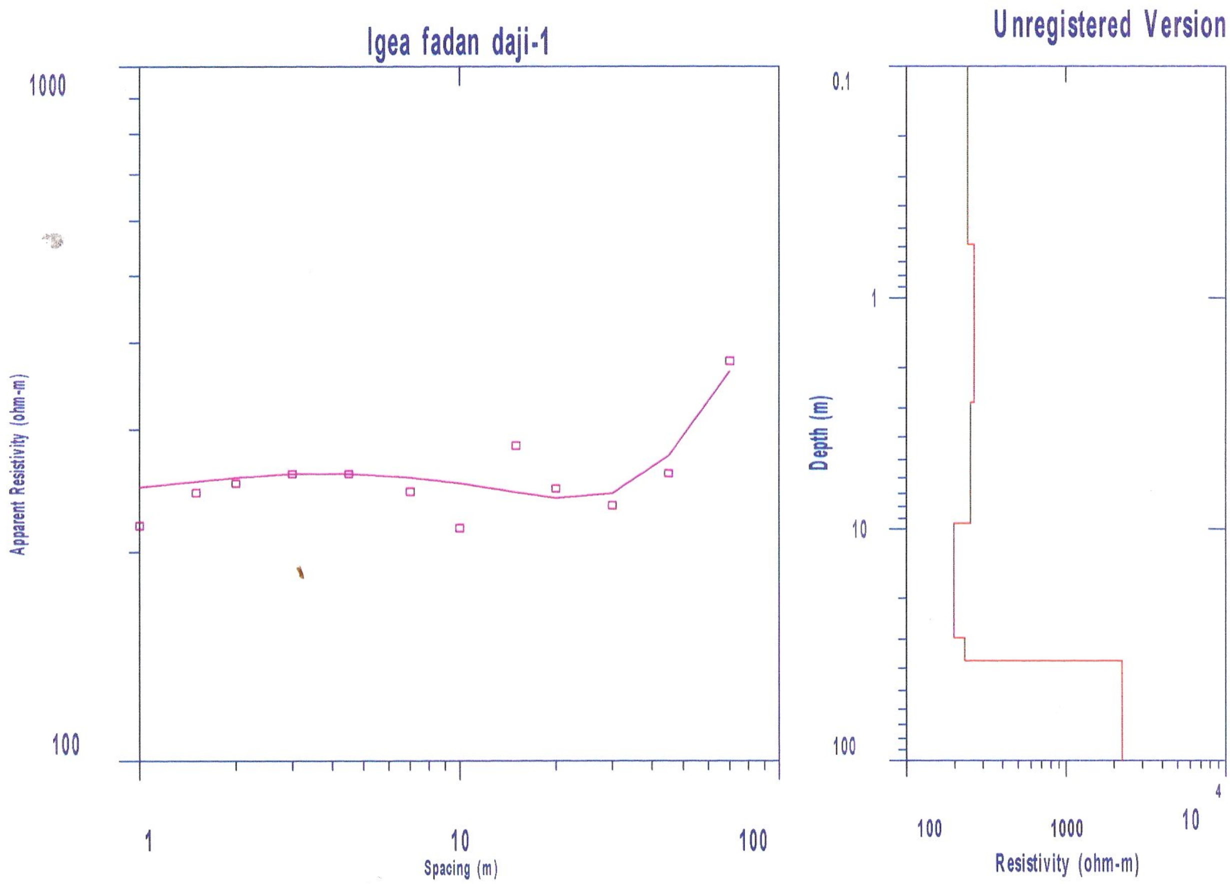

Fig. 4.1 b . LGEA Fadan Daji (KH – type curve)

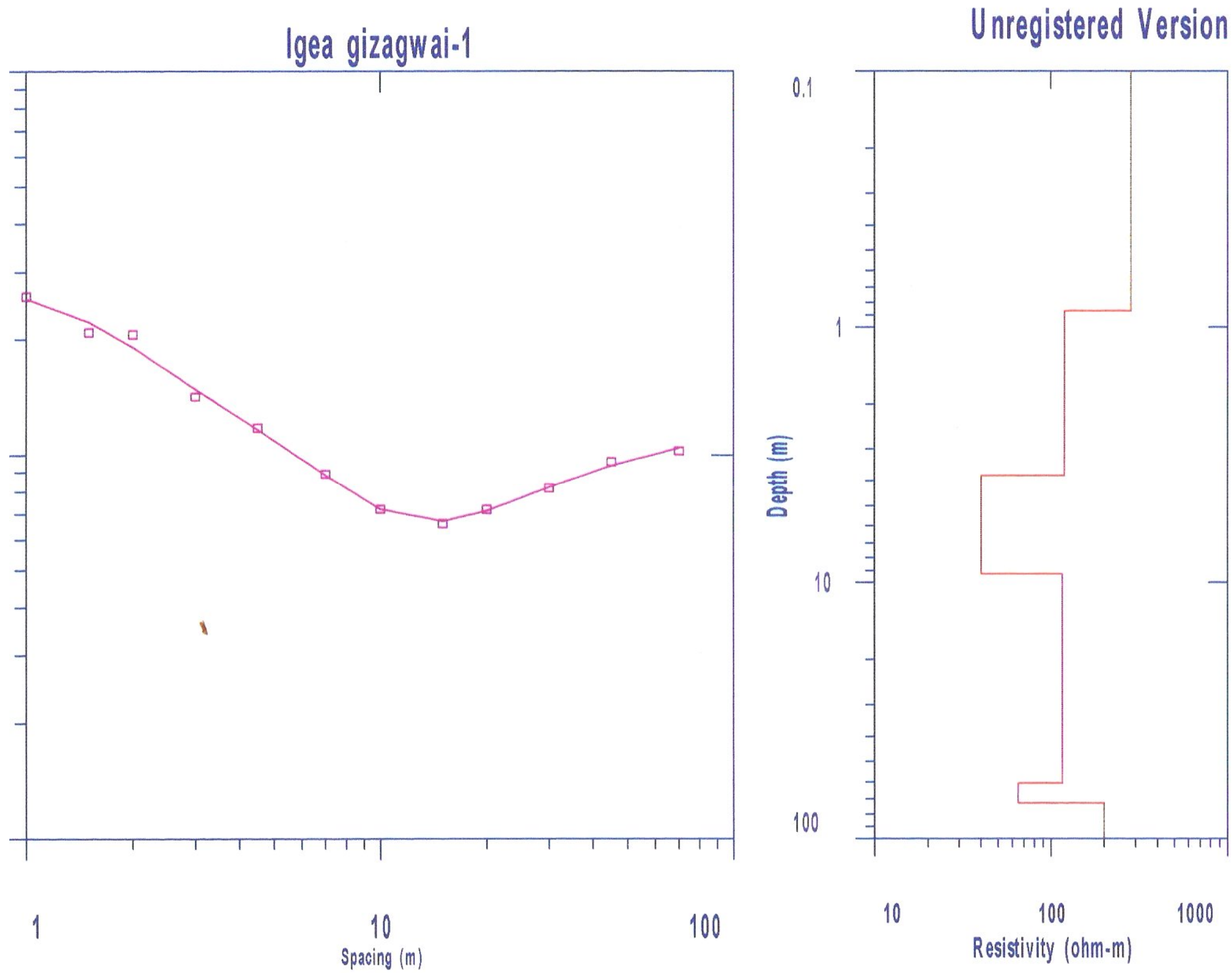

Fig. 4.1 c. LGEA Gizagwai (H- type curve)

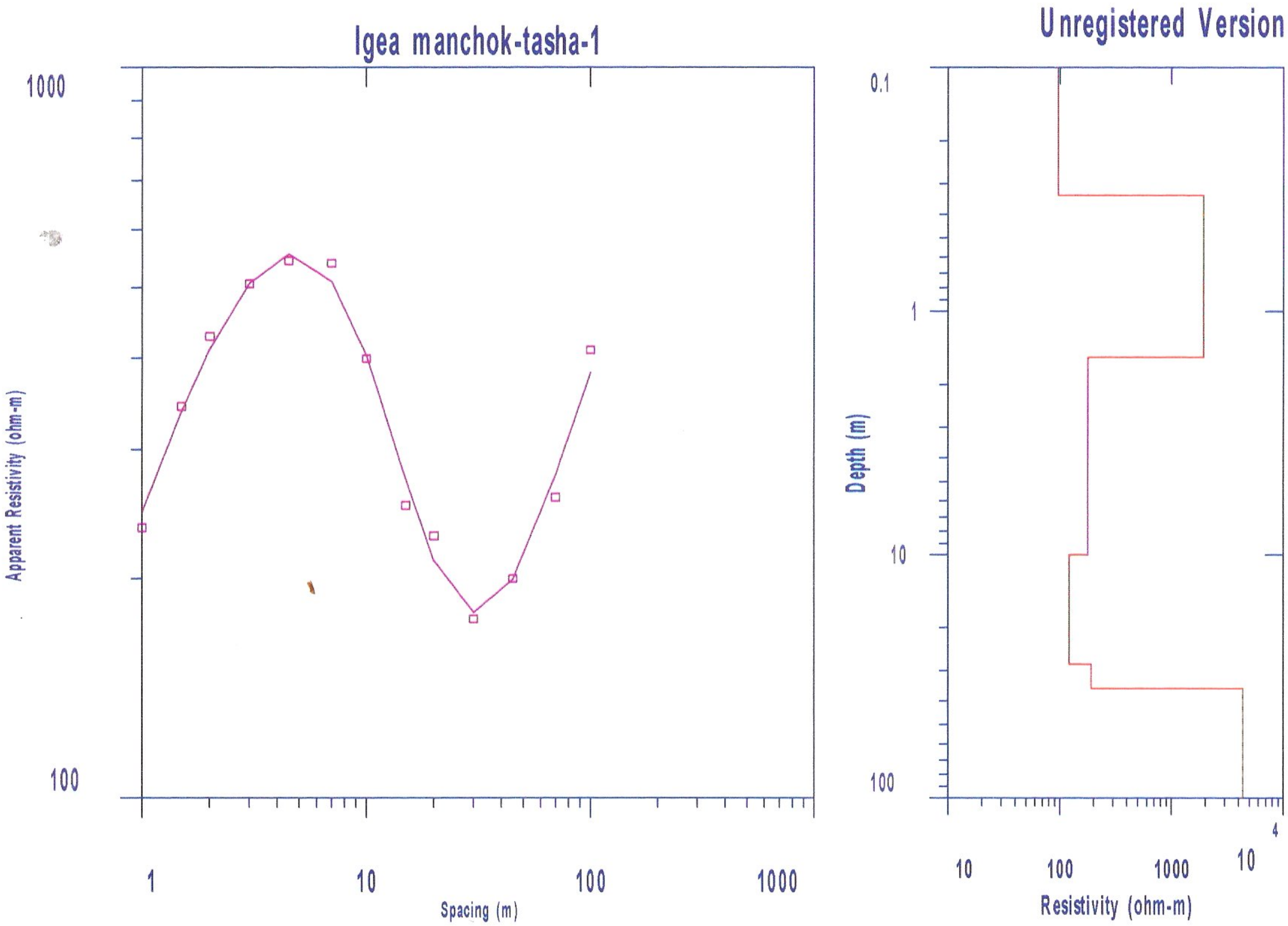

Fig. 4.1 d. LGEA Manchok Tasha (KH – type curve)

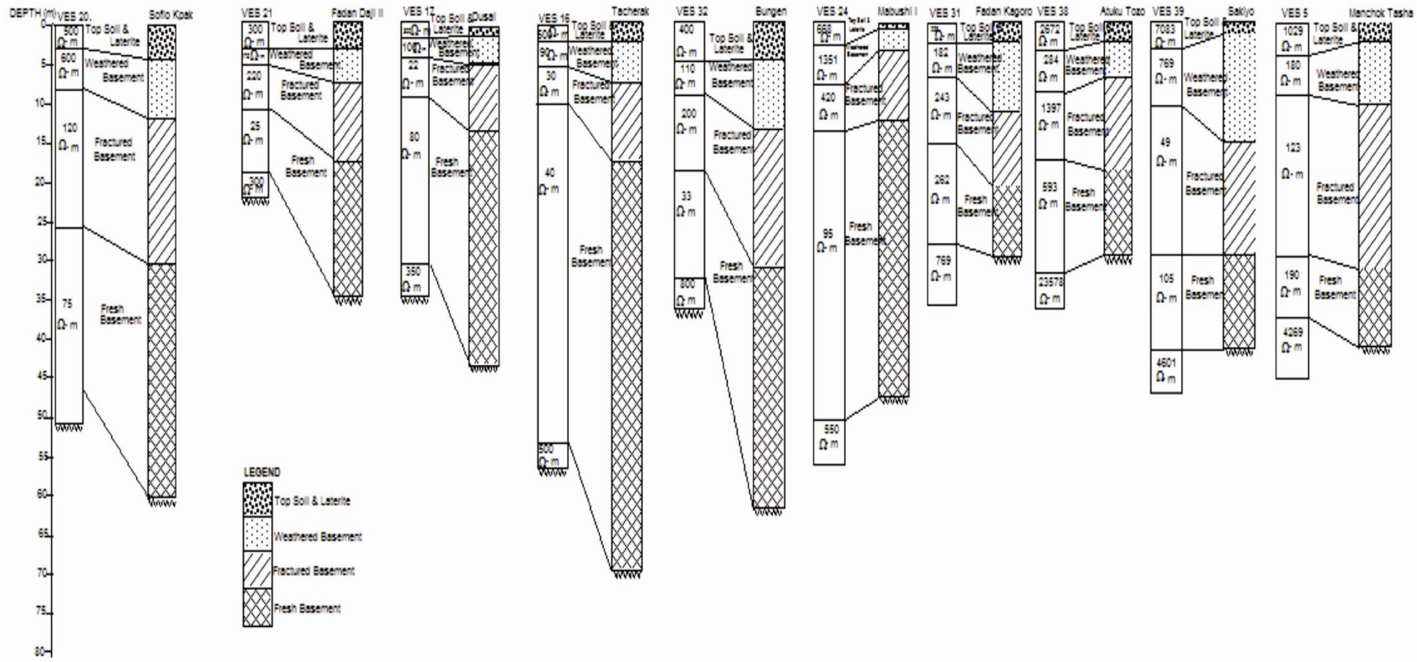

Fig. 4.2: Comparison of VES interpretation result with geologic section (VES Coordinate are presented in Appendix 3)

4.3 Groundwater Occurrence

Aquifers are geologic formations that are capable of yielding economic quantities of water to wells and boreholes. The characteristic aquifers identified in the basement complex are predominantly controlled by the nature of the rocks composing the area. The controlling factors are mostly the degree of weathering and density of fractures or joints in the rocks.

\ Groundwater occurrence in the study area is in conformity with the classification made earlier by (Eduvie, 2004).

The occurrence of groundwater in the study area is classified thus:

1. The overburden aquifer

2. The Newer Basalts aquifer

3. The weathered /fractured aquifer

4.3.1 Overburden aquifer

This type of aquifer is predominantly tapped or exploited through hand dug wells in areas where the overburden is sufficiently thick to contain water until the end of the dry season. Its thickness enhances the sustainability of hand dug wells. If thickness is low, then this type of aquifer in most instances dries up at the beginning or at peak of dry season. In areas of thin overburden aquifer very few of these wells survive up to the beginning of the rainy season. This aquifer is also interconnected with the weathered/ fractured aquifer in boreholes. Deep hand dug wells in the study area, indicating thick overburden aquifer, were observed in the south-eastern part of the study area; these provide water at all seasons. Very thick overburden in the study area is normally associated with the metamorphic rocks, while thin overburden characterized by poor groundwater conditions was observed on Younger Granites terrains.

4.3.2 Newer Basalts aquifer

The Newer Basalts contain vesicles and fractures that allow for percolation of water. Basalts often overlie alluvial deposits. Zones of weathering and beds of alluvium also occur between individual basalt flows. Basalts in their boulders form makes borehole drilling extremely difficult but in their loose form they are highly prolific aquifers. A borehole GWR/21/1 drilled in Tum, within the Newer Basalts aquifer yielded 12.6 m^3/h indicating that Newer Basalt can be a highly prolific aquifer. The present research conducted by writer of these words also shows that a borehole drilled at Sofio Kpak (see Table 1) on the Newer Basalt terrain, yielded 198.70 m^3/hr, what is also relatively a good yield.

4.3.3 Weathered/ Fractured aquifer

The weathered/ fractured aquifer is structurally controlled and underlies the overburden aquifer. This aquifer is composed of fresh, brittle, medium to coarse grained crystalline rocks that have reacted to tectonic stresses to cause fracturing and jointing. There is interconnectivity between the overburden aquifer and the weathered/fractured aquifer, this contributes to the rate of recharge and yield of the weathered/fractured aquifer. The main source of groundwater from the comparison of VES interpretation results with geologic sections conducted in the study area is the weathered zone/ fractured aquifer.

4.5 Hydrogeological parameters results

Borehole data of old boreholes are presented in Table 1. It was observed that borehole yield is independent of depth, this shows that fractures tends to close up at depth. This is illustrated at borehole ZK 4 A at Jankasa I, with 100 m depth and yield of 24.192 m^3/hr compared to borehole KU 33 B at Sofio Kpak, 50 m depth and yield of 198.720 m^3/hr .The aquifer parameters of the new twenty (20) boreholes are presented in Table 2.The average yield is 55.728 m^3/hr, average static water level is 6.15 m, average draw down is 10.40 m, average Specific capacity is 7.139 m^3hr/m and the average depth of 31 m. In Table 2 it could also be observed that yield of 103.680 m^3/hr at 31 m was obtained while a borehole drilled at 37 m had yield of 60.480 m^3/hr with variations in depth and yield. Data in Table 1 and 2 were obtained from computations from Table 3 a-b

TABLE 1. OLD BOREHOLE DATA IN THE STUDY AREA

S/NO	BOREHOLE NO.	LOCATION	COORDINATES	YIELD (m^3/hr)	SWL (m)	DRAW DOWN (m)	SPECIFIC CAPACITY (m^3/hr/m)	SCREEN SETTING (m)	BOREHOLE DEPTH (m)
1	ZK 14 B	Mabushi I	09^o 43.71' N, 008^o34.03' E	63.072	7.9	8.0	7.884	22.0-32.0	56.0
2	ZK 46 B	Mabushi II	09^o 44.33' N 008^O24.04' E	6.912	44	-.	-	-	56.0
3	ZK 46 B	Jankasa I	09^O 42.83' N 008^O 27.92' E	22.464	9.9	21.0	1.069	30.0-54.0	54.0
4	ZK 4 A	Jankasa I	09^O 42.89' N 008^O 28.10' E	24.192	12.0	25.7	0.941	69.3-75.3	100.0
5	KU 14 A	Randiyam	09^O 43.04' N 008^O 30.33' E	24.192	15.0	13.2	1.833	24.0-39.0	41.0
6	KU 3 D	Mahuta	09^O 42.11' N 008^O 30.70' E	69.120	3.6	10.8	6.400	23.5-41.5	42.0
7	KU 63 A	Ung. Shebayan Gizagwai	09^O 39.57' N 008^O 30.36' E	31.104	7.6	13.8	2.254	22.5-28.5	30.0
8	KU 59 B	Ung.Nka Gizagwai	09^O 39.55' N 008^O 30.21' E	43.200	8.6	13.4	3.224	21.0-33.0	33.0
9	KU 27 B	Dusai	09^O 37.76' N 008^O 24.04' E	22.464	7.2	19.1	1.176	36.0-54.0	54.0
10	KU 27 C	Dusai	09^O 37.95' N 008^O 25.22' E	60.480	5.2	14.4	4.200	17.5-41.5	42.0
11	KU 33 A	Sofio Kpak	09^O 37.33' N 008^O 24.50' E	181.440	0.5	6.4	28.350	43.5-49.5	54.0
12	KU 33 B	Sofio Kpak	09^O 37.44' N 008^O 24.70' E	198.720	1.5	2.1	94.629	43.5-49.5	50.0
13	KU 22 C	Malagum II	09^O 40.36' N 008^O 23.30' E	25.920	14.1	15.7	1.651	72.2-75.2	78.0
14	KU 35 B	Fadan Daji	09^O 40.36' N 008^O 23.30' E	95.040	5.8	9.4	10.111	30.0-42.0	44.0
15	KU 29 B	Tacharak	09^O 40.36' N 008^O 23.30' E	38.880	8.0	16.0	2.430	30.0-42.0	44.0
16	KU 32 A	Zakwa	09^O 36.98' N 008^O 19.30' E	25.920	9.8	22.1	1.173	36.5-54.5	50.0
17	KU 60 B	Tsokwai	09^O 35.71' N 008^O 21.59' E	30.240	8.1	22.2	1.362	37.0-55.0	50.0
18	KU 59 C	Ung. Nka Gizagwai	09^O 39.58' N 008^O 30.20' E	26.784	8.5	19.4	1.381	26.0-44.0	44.0
19	KU 64 A	Bungen Ung. Afong	09^O 40.75' N 008^O 32.71' E	41.472	7.9	11.9	3.485	25.5-43.5	44.0

TABLE 2. NEW BOREHOLES DATA IN THE STUDY AREA

S/NO	LOCATION	COORDINATES	YIELD (m^3/hr)	SWL (m)	DRAW DOWN (m)	SPECIFIC CAPACITY (m^3?hr?m)	SREEN SETTING (m)	BORE HOLE DEPTH (m)
1	Agban	09^o 35'19.98" N 008°22'25.38" E	43.200	7.13	13.33	3.241	22.0-18.0	30 m
2	Mutuak	09^o 42'5.4" N 008^O 32'39.48" E	60.480	5.36	6.00	10.080	27.0-35.0	37 m
3	Ungwa Goni	09^O 7.98" N 008^O 33'15.96" E	25.920	4.34	14.70	1.763	19.0-25.0	27m
4	LGEA Ashim	09'37'46.2" N 008°30'46.2" E	60.480	8.83	11.00	5.500	26.0-32.0	35 m
5	Zangang	09^O 37'1.8" N 008^O 33' 59.46" E	51.840	9.76	12.64	4.101	21.0-27.0	30 m
6	PHC Tsonje	09°33'44.64" N 008°22'1.38" E	69.120	7.10	10.90	6.341	26.0-32.0	35 m
7	PHC Mifi	09°37'2.34" N 008°30'11.28"E	77.760	6.70	11.87	6.551	22.0-28.0	30 m
8	Bondong	09^O 42'26.82" N 008^O 33'26.4" E	103.680	2.68	3.19	32.502	22.0-28.0	31 m
9	LGEA Zankam	09°37'38.22" N 008°22'30.3" E	51.840	9.20	15.78	3.285	22.0-28.0	30 m
10	LGEA Kukum Gida	09°35'56.88" N 008°22'31.92" E	60.480	4.50	12.54	4.823	19.0-25.0	27 m
11	LGEA Dusai Manyi	09°37'8.5" E 008°25'9.9" E	69.120	9.60	10.05	6.878	26.0-32.0	35 m
12	LGEA Kpak	09°37'58.4" N 008°23'43.32" E	43.200	4.80	11.04	3.913	19.0-25.0	27 m
13	LGEA Zakwa	09°36'35.04" N 008°19'31.62" E	34.560	6.20	9.89	3.494	18.0-24.0	25 m
14	LGEA Ungwa Shemang	09°44'5.22" N 008°31'16.08" E	25.920	5.58	14.64	1.771	25.0-31.0	35 m
15	UBE Mafok Gida	09°39'1.2" N 008°26'36.42" E	25.920	6.80	12.56	2.064	18.0-24.0	25 m
16	LGEA Madamai	09°40'23.58" N 008°24'11.8" E	43.200	4.60	9.76	4.426	19.0-25.0	27 m
17	Govt. College Kagoro	09°35'35.1" N 008°22'0.36" E	103.680	3.63	5.25	19.749	22.0-29.0	30 m
18	Ungwa Kukhat	09^o 39'37.5" N 008^{O}30'42.9" E	86.400	4.00	7.26	11.901	24.0-30.0	33 m
19	LGEA Atuku Tozo	09^{O}27'36" N 008^{O}29'24.42" E	51.840	8.08	11.15	4.649	27.0-33.0	35 m
20	LGEA Tacherak	09^O'38'28.92"N 008^{O}26'24.42" E	25.920	4.05	4.51	5.747	23.0-29.0	30 m

Table 3.a Pumping Test Results at Bondong

PUMPING TEST DATA SHEET Date: 20/5/2010								
Site Name: LGEA Primary School Bondong, Kaura LGA BH 4 Depth .31 m pump setting: 27 m .SWL: 2.68m								
Pumping Phase				Recovery Phase				
Clock Time	Time since pumping Started (m)	Pumping Water level (m)	Draw Down (m)	Pumping Rate (l/s)	Clock Time	Time since pumping stopped (min)	Recovery Water Level (m)	Residual Draw Down (m)
0 hr	0	2.68	0.00		0 hr	0	5.87	3.19
	1	3.54	0.86	1.20		1	5.43	2.75
	2	3.96	1.28			2	5.18	2.50
	3	4.24	1.56			3	4.68	2.00
	4	4.42	1.74			4	4.30	1.62
	5	4.54	1.86	1.20		5	4.08	1.40
	6	4.63	1.95			6	3.88	1.20
	7	4.88	2.20			7	3.63	0.95
	8	4.91	2.23			8	3.48	0.80
	9	4.94	2.26			9	3.28	0.60
	10	4.97	2.29	1.20		10	3.23	0.55
	12	5.06	2.38			12	3.16	0.48
	14	5.15	2.47			14	3.08	0.40
	16	5.18	2.50			16	2.88	0.20
	18	5.24	2.56			18	2.82	0.14
	20	5.30	2.62			20	2.78	0.10
	25	5.36	2.68			25	2.73	0.05
	30	5.43	2.75	1.20		30	2.69	0.01
	40	5.52	2.84					
	50	5.58	2.90					
	60	5.61	2.93					
	90	5.70	3.02	1.20				
	120	5.79	3.11					
	150	5.82	3.14					
	180	5.85	3.17					
	210	5.87	3.19					
	240	5.87	3.19					
	270	5.87	3.19					
	300	5.87	3.19					
	330	5.87	3.19					
	360	5.87	3.19	1.20				

Table 3.b Pumping Test Results at Tsonje

PUMPING TEST DATA SHEET					Date: 3/6/2010			
Site Name: Primary Health Clinic Tsonje Kaura LGA BH18 Depth .35 m pump setting: 27 m .SWL: 7.1 m								
Pumping Phase					Recovery Phase			
Clock Time	Time since pumping Started (m)	Pumping Water level (m)	Draw Down (m)	Pumping Rate (l/s)	Clock Time	Time since pumping stopped (min)	Recovery Water Level (m)	Residual Draw Down (m)
0 hr	0	7.10	0.00		0 hr	0	18.00	10.90
	1	9.20	2.10	0.90		1	16.10	9.00
	2	10.60	3.50			2	15.05	7.95
	3	11.30	4.20			3	13.90	6.80
	4	11.70	4.60			4	12.95	5.85
	5	12.10	5.00	0.83		5	12.10	5.00
	6	12.40	5.30			6	11.60	4.50
	7	12.65	5.55			7	10.90	3.80
	8	12.90	5.80			8	10.30	3.20
	9	13.25	6.15			9	9.90	2.80
	10	13.35	6.25	0.80		10	9.40	2.30
	12	13.60	6.50			12	9.00	1.90
	14	14.00	6.90			14	8.50	1.40
	16	14.30	7.20			16	8.20	1.10
	18	14.85	7.75			18	7.90	0.80
	20	14.94	7.84			20	7.60	0.50
	25	15.20	8.10			25	7.35	0.25
	30	15.85	8.75	0.80		30	7.25	0.15
	40	16.30	9.20			40	7.18	0.08
	50	16.87	9.77			50	7.14	0.04
	60	17.06	9.96			60	7.11	0.01
	90	17.50	10.40	0.80				
	120	17.90	10.80					
	150	17.95	10.85					
	180	17.98	10.88	0.80				
	210	17.99	10.89					
	240	18.00	10.90					
	270	18.00	10.90					
	300	18.00	10.90					
	330	18.00	10.90					
	360	18.00	10.90					

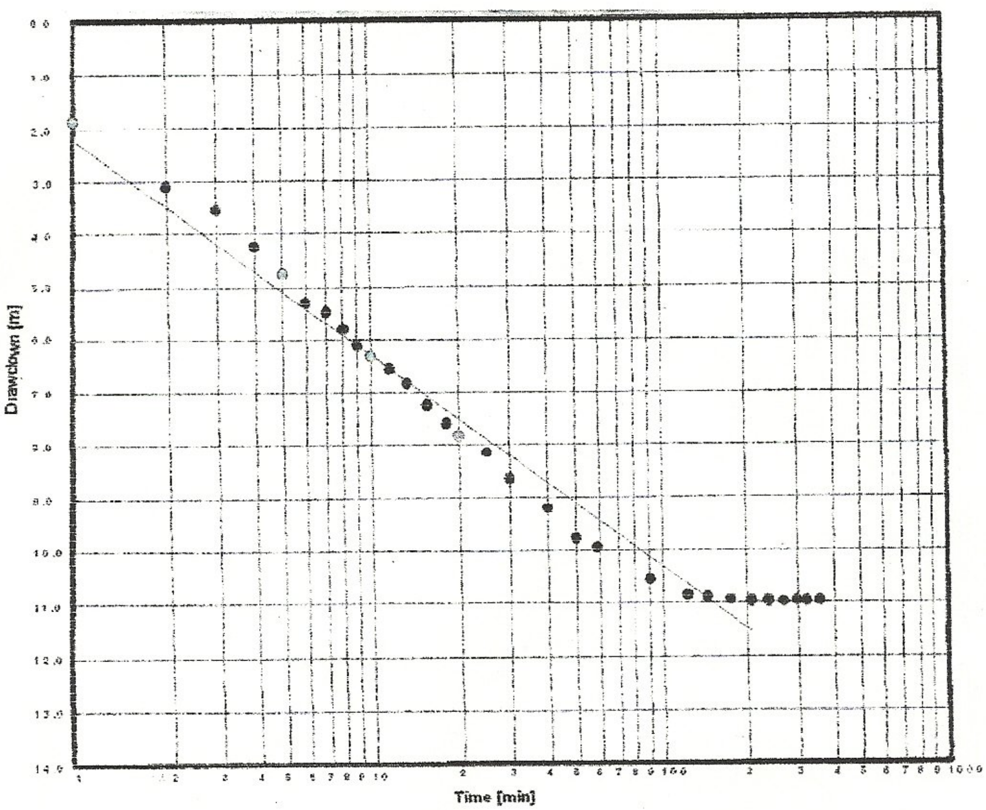

Fig. 4.4 a Drawdown –Time curve for Bondong.

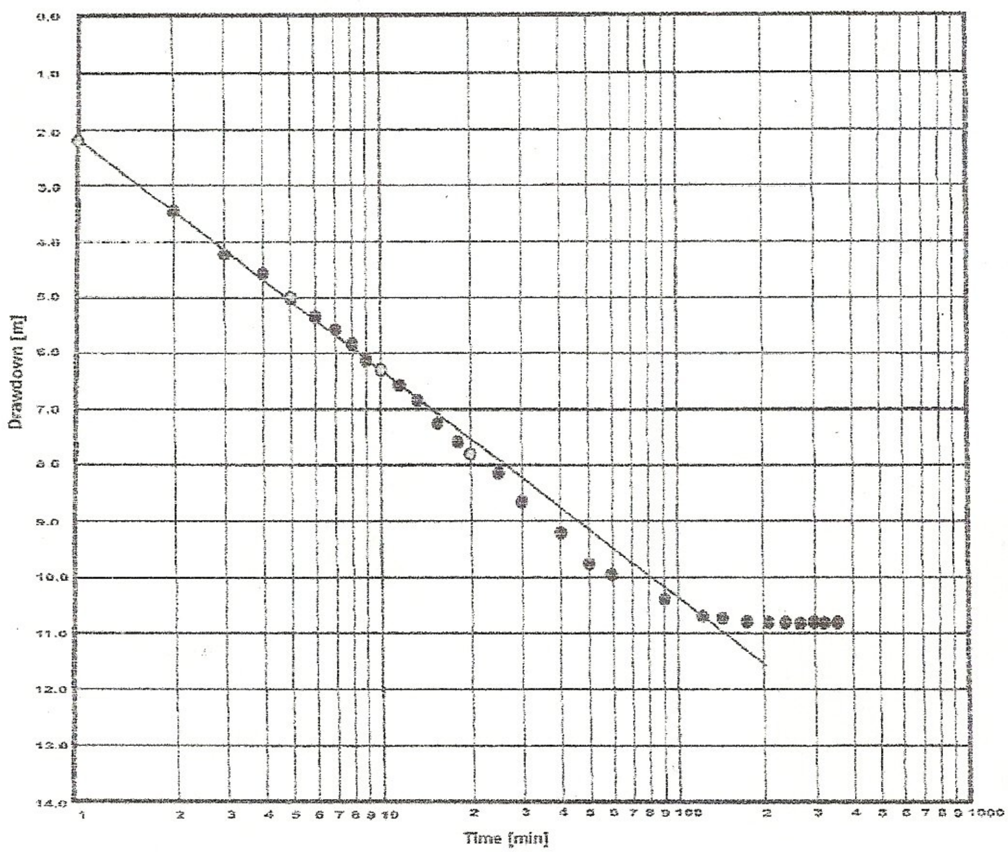

Fig.4.4 b Draw down –Time curve for PHC Tsonje.

Chapter 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The general geology comprises Younger Granites, Migmatite-Gneiss, gneisses, Older Granites and schist which is undifferentiated with phyllies. Newer Basalts and the Younger Granites occupy greater parts of the study area, while the least portion is occupied by schists.

Configuration map of groundwater table and directions of the groundwater flow shows that the Kagoro Hills is the major recharge area. It discharges water to all parts of the study area. Interpretations of Vertical Electrical Sounding curves obtained in the study area suggests that the subsurface layering ranges from 3-5 layers. It was observed that borehole yield is independent of depth, this shows that fractures tends to close up at depth. The aquifer parameters obtained from the study area are:

An average yield of 55.728 m^3/hr, average static water level is 6.15 m, average draw down is 10.40 m, average Specific capacity is 7.139 m^3hr/m with an average depth of 31 m. High yields/groundwater potentials were observed to be predominant in Newer Basalt terrains. Three aquifer types based on the petrology were identified namely; overburden aquifer, Newer Basalt aquifer and the weathered/fractured aquifer, but hydrogeologically two major aquifer types were encountered. These are the soft overburden aquifer and the weathered/fractured aquifer which are also interconnected.

5.2 Recommendations

It is possible to evaluate the groundwater potentials and show the results as figures but it will need much more time, effort and resources to go into exploitation.

The research work noted that there is need for extensive and intensive for both local and regional appraisal and therefore recommend that detailed geological studies be carried out through geological field works and photogeological study to determine the intensity of geophysical investigation. It is suggested that a more systematic scientific approach be applied for a better assessment of groundwater potentials in the study area. Investigations with Landsat imageries for groundwater investigation will also assist to assess the potentials of the soft overburden aqufer and water bearing alluvium within the area and the conduct of structural analysis for identifying fractures.

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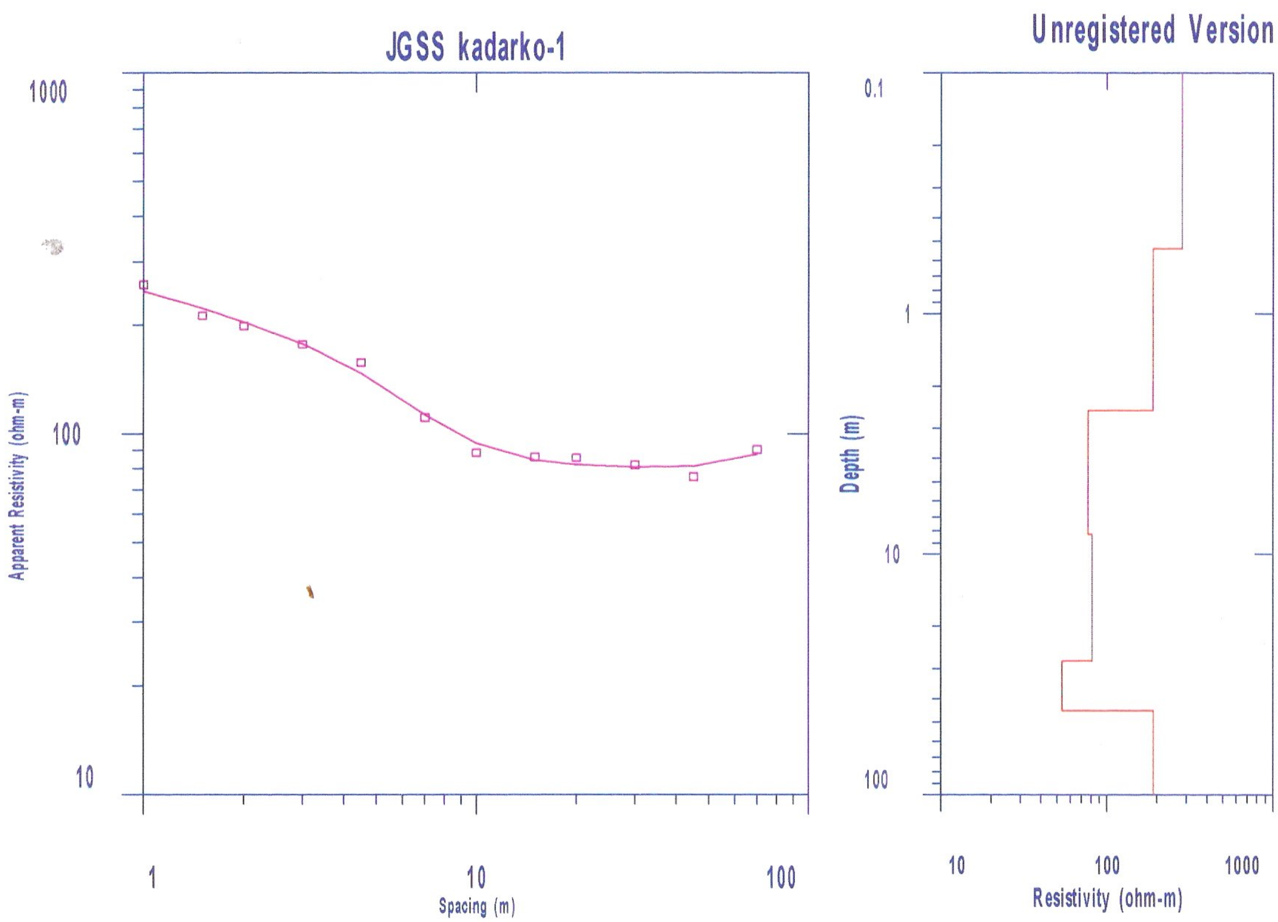
APPENDIX 2



JGSS kadarko-1
Unregistered Version
1000
100
10
Apparent Resistivity (ohm-m)
1
10
100
Spacing (m)
0.1
1
10
100
Depth (m)
10
100
1000
Resistivity (ohm-m)

GJSS Kadarko-1

Schlumberger Array

Northing: 9.4 Easting: 8.3 Elevation: 855.0

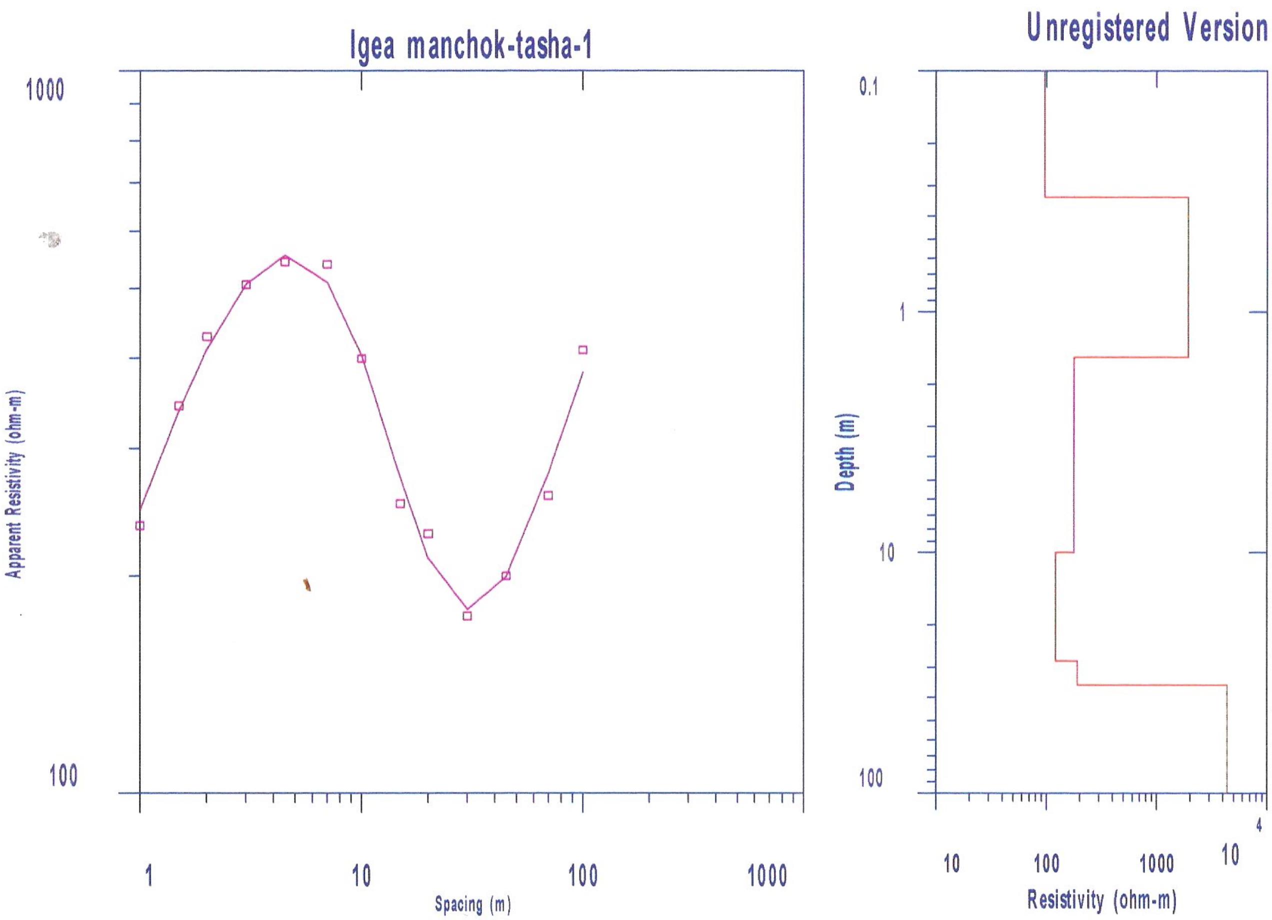
No.	Spacing (meters) AB/2	MN	Data Resistivity	Layered Model: Synthetic Resistivity	DIFFERENCE	Smooth Model: Synthetic Resistivity	DIFFERENCE
1	1.00	0.300	258.8	248.7	3.89		
2	1.50	0.300	212.5	222.3	-4.60		
3	2.00	0.300	198.9	203.9	-2.51		
4	3.00	0.300	177.1	177.9	-0.433		
5	4.50	1.00	157.6	147.0	6.70		
6	7.00	1.00	110.9	112.6	-1.54		
7	10.00	1.00	88.64	93.93	-5.97		
8	15.00	1.00	86.33	84.40	2.23		
9	20.00	1.00	85.85	81.94	4.55		
10	30.00	5.00	81.96	80.63	1.61		
11	45.00	5.00	76.03	81.17	-6.76		
12	70.00	5.00	90.36	87.96	2.65		

NO DATA ARE MASKED

Layered Model

L #	RESISTIVITY (ohm-m)	THICKNESS (meters)	ELEVATION (meters)	LONG. COND. (Siemens)	TRANS. RES. (Ohm-m^2)
1	290.2	0.498	854.5	0.00172	144.5
2	191.6	2.00	852.4	0.0104	384.4
3	76.95	5.98	846.5	0.0777	460.4
4	81.36	20.31	826.2	0.249	1652.5
5	50.64	18.15	808.0	0.358	919.3
6	237.0		808.0		

ALL PARAMETERS ARE FREE



Igea manchok-tasha-1
Unregistered Version
1000
100
Apparent Resistivity (ohm-m)
1
10
100
1000
Spacing (m)
0.1
1
10
100
Depth (m)
10
100
1000
10
4
Resistivity (ohm-m)

LG.P.S. MANCHOK T.-1

Schlumberger Array

Northing: 9.4 Easting: 8.3 Elevation: 903.0

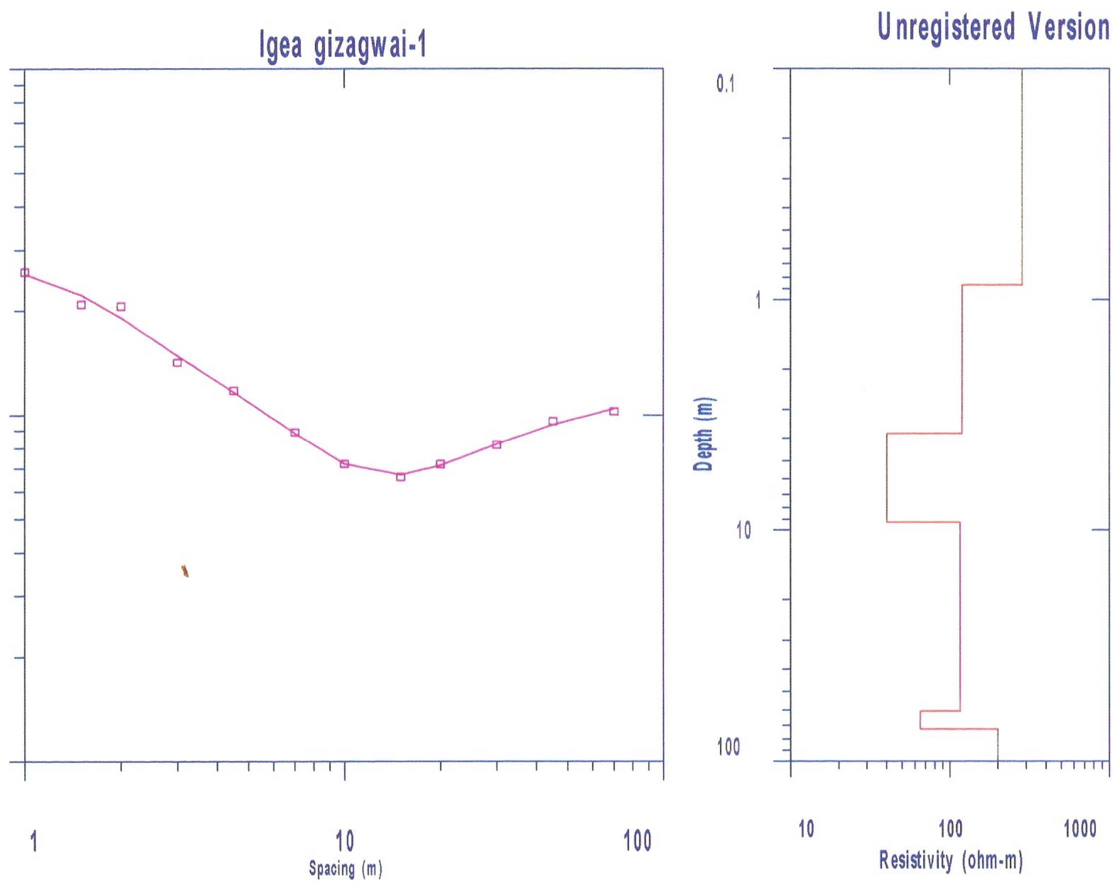
No.	Spacing (meters) AB/2	MN	Data Resistivity	Layered Model: Synthetic Resistivity	DIFFERENCE	Smooth Model: Synthetic Resistivity	DIFFERENCE
1	1.00	0.300	234.5	246.4	-5.05		
2	1.50	0.300	343.0	338.5	1.31		
3	2.00	0.300	428.5	411.5	3.96		
4	3.00	0.300	505.6	506.6	-0.204		
5	4.50	1.00	543.5	555.2	-2.15		
6	7.00	1.00	539.8	509.6	5.59		
7	10.00	1.00	399.5	403.5	-1.01		
8	15.00	1.00	251.6	272.9	-8.46		
9	20.00	1.00	228.7	211.3	7.61		
10	30.00	5.00	175.8	179.2	-1.92		
11	45.00	5.00	199.0	199.4	-0.194		
12	70.00	5.00	258.2	277.0	-7.26		
13	100.0	5.00	410.4	381.7	6.98		

NO DATA ARE MASKED

Layered Model

L #	RESISTIVITY (ohm-m)	THICKNESS (meters)	ELEVATION (meters)	LONG. COND. (Siemens)	TRANS. RES. (Ohm-m^2)
1	96.11	0.337	902.6	0.00351	32.43
2	1929.8	1.20	901.4	6.263E-04	2332.6
3	179.9	7.91	893.5	0.0439	1424.0
4	122.8	18.98	874.5	0.154	2333.1
5	190.4	7.29	867.2	0.0383	1389.9
6	4269.2		867.2		

ALL PARAMETERS ARE FREE



Igea gizagwai-1
Unregistered Version
1
10
100
Spacing (m)
0.1
1
10
100
Depth (m)
10
100
1000
Resistivity (ohm-m)

LG.P.S. MANCHOK T.-1

Schlumberger Array

Northing: 9.4 Easting: 8.3 Elevation: 903.0

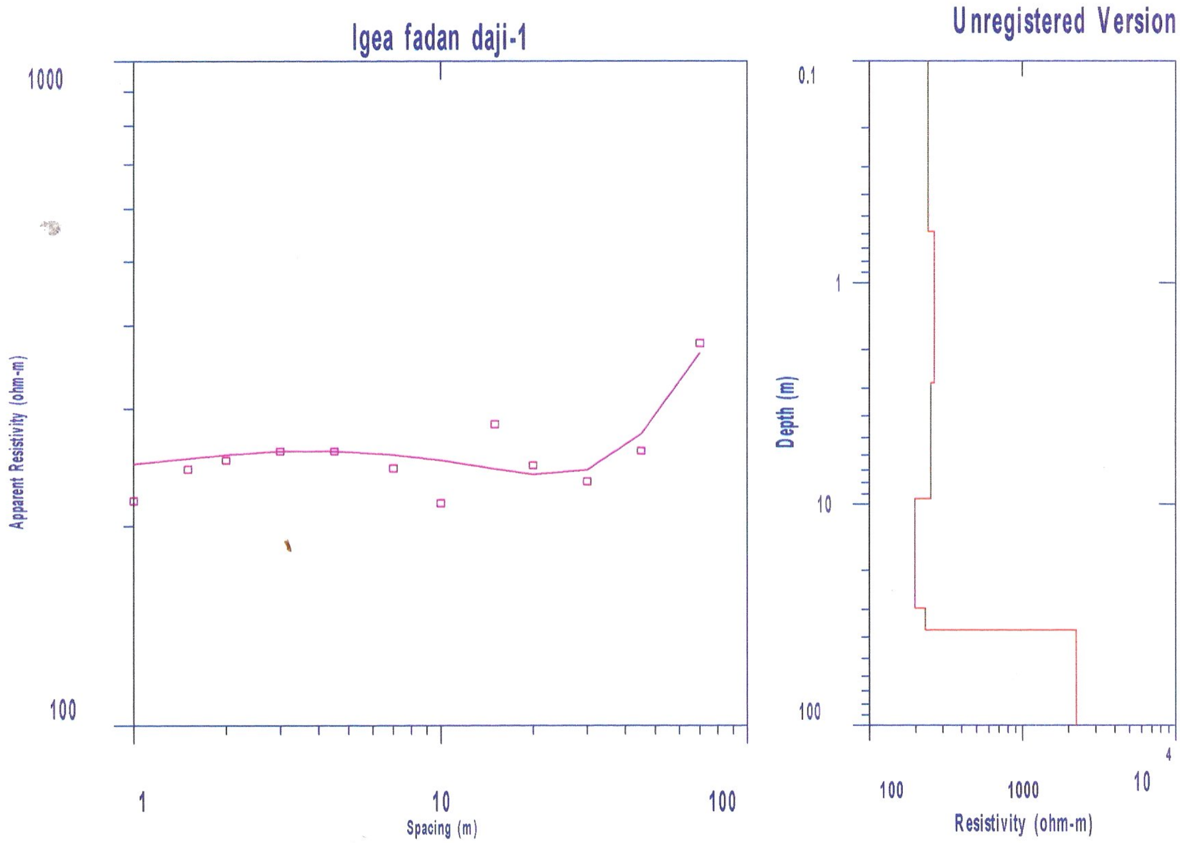
No.	Spacing (meters) AB/2	MN	Data Resistivity	Layered Model: Synthetic Resistivity	Layered Model: DIFFERENCE	Smooth Model: Synthetic Resistivity	Smooth Model: DIFFERENCE
1	1.00	0.300	234.5	246.4	-5.05		
2	1.50	0.300	343.0	338.5	1.31		
3	2.00	0.300	428.5	411.5	3.96		
4	3.00	0.300	505.6	506.6	-0.204		
5	4.50	1.00	543.5	555.2	-2.15		
6	7.00	1.00	539.8	509.6	5.59		
7	10.00	1.00	399.5	403.5	-1.01		
8	15.00	1.00	251.6	272.9	-8.46		
9	20.00	1.00	228.7	211.3	7.61		
10	30.00	5.00	175.8	179.2	-1.92		
11	45.00	5.00	199.0	199.4	-0.194		
12	70.00	5.00	258.2	277.0	-7.26		
13	100.0	5.00	410.4	381.7	6.98		

NO DATA ARE MASKED

Layered Model

L #	RESISTIVITY (ohm-m)	THICKNESS (meters)	ELEVATION (meters)	LONG. COND. (Siemens)	TRANS. RES. (Ohm-m^2)
1	96.11	0.337	902.6	0.00351	32.43
2	1929.8	1.20	901.4	6.263E-04	2332.6
3	179.9	7.91	893.5	0.0439	1424.0
4	122.8	18.98	874.5	0.154	2333.1
5	190.4	7.29	867.2	0.0383	1389.9
6	4269.2		867.2		

ALL PARAMETERS ARE FREE


Igea fadan daji-1
Unregistered Version
1000
100
Apparent Resistivity (ohm-m)
1
10
100
Spacing (m)
0.1
1
10
100
Depth (m)
100
1000
10
4
Resistivity (ohm-m)

P. D. Kagoro-1

Schlumberger Array

Northing: 9.4 Easting: 8.2 Elevation: 773.0

No.	Spacing (meters) AB/2	MN	Data Resistivity	Layered Model: Synthetic Resistivity	DIFFERENCE	Smooth Model: Synthetic Resistivity	DIFFERENCE
1	1.00	0.300	218.2	231.6	-6.15		
2	1.50	0.300	243.6	237.4	2.56		
3	2.00	0.300	251.1	243.3	3.13		
4	3.00	0.300	259.1	251.2	3.03		
5	4.50	1.00	259.1	252.6	2.47		
6	7.00	1.00	244.3	241.6	1.07		
7	10.00	1.00	216.3	226.6	-4.78		
8	15.00	1.00	204.6	214.6	-4.88		
9	20.00	1.00	246.8	215.7	12.62		
10	30.00	5.00	233.4	235.4	-0.862		
11	45.00	5.00	259.5	278.9	-7.49		
12	70.00	5.00	376.6	353.0	6.25		

NO DATA ARE MASKED

Layered Model

L #	RESISTIVITY (ohm-m)	THICKNESS (meters)	ELEVATION (meters)	LONG. COND. (Siemens)	TRANS. RES. (Ohm-m^2)
1	227.5	1.00	771.9	0.00441	228.3
2	282.2	2.72	769.2	0.00965	768.9
3	182.3	10.03	759.2	0.0550	1829.7
4	243.9	7.68	751.5	0.0315	1876.0
5	261.6	8.71	742.8	0.0333	2281.0
6	769.2		742.8		

ALL PARAMETERS ARE FREE

L.P.S.K.Gizanwai-1

Schlumberger Array

Northing: 9.4 Easting: 8.3 Elevation: 903.0

No.	Spacing (meters) AB/2	MN	Data Resistivity	Layered Model: Synthetic Resistivity	DIFFERENCE	Smooth Model: Synthetic Resistivity	DIFFERENCE
1	1.00	0.300	259.1	255.2	1.48		
2	1.50	0.300	209.0	222.3	-6.36		
3	2.00	0.300	206.3	191.1	7.33		
4	3.00	0.300	142.1	148.6	-4.58		
5	4.50	1.00	117.9	116.4	1.26		
6	7.00	1.00	89.13	88.77	0.393		
7	10.00	1.00	72.21	72.33	-0.177		
8	15.00	1.00	66.23	66.90	-1.02		
9	20.00	1.00	72.00	71.33	0.918		
10	30.00	5.00	82.00	82.63	-0.770		
11	45.00	5.00	96.00	94.04	2.03		
12	70.00	5.00	102.4	103.8	-1.38		

NO DATA ARE MASKED

Layered Model

L #	RESISTIVITY (ohm-m)	THICKNESS (meters)	ELEVATION (meters)	LONG. COND. (Siemens)	TRANS. RES. (Ohm-m^2)
1	282.4	0.870	902.1	0.00308	245.8
2	118.0	2.98	899.1	0.0252	352.3
3	40.32	5.61	893.5	0.139	226.3
4	119.4	39.62	853.9	0.331	4731.8
5	86.64	9.92	843.9	0.114	860.3
6	128.3		843.9		

ALL PARAMETERS ARE FREE

Prepared for Unregistered Version

VES NO	LOCATION	LAT	LONG	1ST LAYER APP. RES (Ohm-m)	1ST LAYER THICKNESS (m)	2ND LAYER APP. RES (ohm-m)	2ND LAYER THICKNESS (m)	3RD LAYER APP. RES (ohm-m)	3RD LAYER THICKNESS (m)	4TH LAYER APP. RES (ohm-m)	4TH LAYER THICKNESS (m)	5TH LAYER APP.RES (Ohm-m)	5TH LAYER THICKNESS (m)	ESTIMATED DEPTH TO BASEMENT (m)
1	Kufum Daji	9.6	8.337	446	2.19	175	5.3	100	10.6	99.2	33	455	Infinity	25
2	Zankan	9.657	8.55	683	1	74	3.8	83	4	347	4	2749	Infinity	9
3	Tum	9.705	8.38	433	2.1	68	5	149	13.5	64	26	471	Infinity	21
4	Kadarko	9.641	8.427	290	2	77	6	81	20	59	18	237	Infinity	28
5	Manchok Tasha	9.652	8.528	1929	1.2	180	7.9	122	16.9	190	7	4269	Infinity	28
6	Madamai	9.677	8.412	370	3	357	4.9	35.9	9.2	164	5.7	2338	Infinity	40
7	Kaura Model	9.663	8.467	257	4.2	618	4	63.8	8.5	302	5.5	7180	Infinity	17
8	Fadan Daji	9.629	8.373	282	3.7	182	10	244	7.7	262	8.7	769	Infinity	21
9	Ungwa Abagai Kaura	9.502	8.487	458	3.2	247	4	150	8.6	167	38.7	837	Infinity	16
10	Garaje	9.598	8.323	135	1.9	46	5.3	74	7.2	195	13.5	777	Infinity	14
11	Korga Zankan	9.358	8.335	1168	1.23	156	6.3	649	9	705	6.5	720	Infinity	12
12	Gizagwai	9.665	8.524	282	2.9	40	5.6	119	39.6	86.4	10	128	Infinity	40
13	Bondong	9.697	8.557	855	1.7	75	2.2	189	18.9	89.3	10	627	Infinity	23
14	Binki	9.701	8.528	472	3.2	156	5.7	145	17.7	174	7.6	824	Infinity	27
15	Tacherak	9.633	8.447	288	4.6	93	8.8	75	30	101	9	413	Infinity	40
16	Tacherak	9.63	8.446	500	2	90	5	30	10	40	52	5000	Infinity	13
17	Dusai	9.629	8.401	103	0.9	73	12.5	324	31	44	52	5000	Infinity	5
18	Malagum II	9.673	8.388	150	6	75	12	120	25	70	80	9999	Infinity	9
19	Anturung	9.649	8.484	550	0.5	1200	1.5	454	23	104	18	569	Infinity	10
20	Sofio Kpak	9.624	8.412	500	3	600	6	120	28	75	40	750	Infinity	6
21	Fadan Daji	9.64	8.356	300	2.4	25	4.5	220	10	25	18	3000	Infinity	6
22	Tsokwai	9.595	8.36	400	0.4	700	2	200	6	100	45	2000	Infinity	10
23	Jankasa I	9.714	8.463	180	0.4	280	1.7	160	7	55	40	3000	Infinity	8
24	Mabushi I	9.7	8.509	668	0.6	1351	3.5	420	10	95	38	550	Infinity	24
25	Randiyam	9.717	8.506	280	1.6	77	9.3	736	16	29	30	5000	Infinity	9
26	Sabon Gari Zankan	9.653	8.526	2400	1	1000	3.5	150	10	65	20	9999	Infinity	10
27	Ungwa Nka Gizagwai	9.639	8.304	150	2.5	70	4.5	250	10	50	25	800	Infinity	6
28	Gizagwai Ung. Sheba	9.66	8.506	550	4	150	8.5	430	15	50	30	9999	Infinity	33
29	Zakwa	9.61	8.325	556	1.5	76.6	6	398	19.7	71	8	658	Infinity	12
30	Malagum II	9.678	8.388	689	2.2	1368	3.3	89	14.52	78	39	677	Infinity	10
31	Fadan Kagoro	9.609	8.387	251	3.4	118	12	47	14	123	9	3302	Infinity	12
32	Bungen Ung. Afong	9.684	8.558	400	4.5	110	9	200	18	33	30	800	Infinity	32
33	Ungwa Kajit	9.778	8.467	270	0.3	1880	0.9	197	8	1611	33	829	Infinity	10
34	Fadan Daji II	9.663	8.535	300	2.4	25	4.5	220	10	25	18	3000	Infinity	6
35	Zakwa	9.626	8.355	900	0.4	2000	2	250	6.5	23	24	220	Infinity	36
36	Jankasa I	9.716	8.468	180	0.4	280	1.7	160	7	55	40	300	Infinity	8
37	Mabushi II	9.735	8.406	333	5.2	95	7.6	609	15.9	103	33.5	3481	Infinity	18
38	Atuku Tozo	9.557	8.469	2672	1.02	284	3	1397	11.21	593	12.26	23578	Infinity	13
39	Sakiyo	9.593	8.478	7082	0.9	769	14	49	14	105	9.23	4601	Infinity	12