American Journal of Environmental Protection, 2015, Vol. 3, No. 3, 60-66
Available online at http://pubs.sciepub.com/env/3/3/1

DOI:10.12691/env-3-3-1

Aquifers Characterization in Agaie, North-Central Nigeria Using Electrical Resistivity Method and Borehole Lithologs

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Received December 17, 2014; Revised February 19, 2015; Accepted April 20, 2015

Abstract The aquifer systems in Agaie area, North-Central Nigeria have been characterized using electrical resistivity technique and borehole lithologs. Electrical resistivity techniques of geophysical survey were used for data generation through Schulumberger and Wenner configuration. The acquired data were subjected to manual and computer aided interpretation methods which enabled the delineation of the lithological sequence of the subsurface. A total of nineteen boreholes were drilled and systematically logged during the drilling process. The geoelectric sections were overlaid with lithological logs and the result used in the characterization of the aquifer in the area. Information obtained from 98 hand-dug wells inventory and 19 drilled boreholes were used to supplement the geophysical investigation. The study revealed area with shallow and deep wells in relation to the groundwater flow direction of NE and SW corresponding to high groundwater potential while the southern portion of Agaie has medium groundwater potential. The geoelectric section and lithologs obtained presents two aquitards (sandy-clay and clayey-sand) and sandstone aquifer with fine to medium grained. The failure of most boreholes in the area was the inability to delineate aquifer from aquitard in the area. A minimum depth of 50-60m was recommended for borehole and 20-25m for hand-dug well in the study area. Siting of boreholes and hand-dug wells away from soakaway, toilet and dumpsite is advocated. Good hygiene practice is also suggested for the people of the area to avoid water borne disease in the future.

Keywords: *geoelectrical properties, characterization, electrical resistivity survey, aquifers types, agaie area, north-central Nigeria*

Cite This Article: Olasehinde P. I., Amadi A. N., Idris-Nda A., Katu M. J., Unuevho C. I., and Jimoh M. O., "Aquifers Characterization in Agaie, North-Central Nigeria Using Electrical Resistivity Method and Borehole Lithologs." *American Journal of Environmental Protection*, vol. 3, no. 3 (2015): 60-66. doi: 10.12691/env-3-3-1.

1. Introduction

Water is a vital resource for human existence and the growth of any community is a function of availability of basic infrastructures such as potable water, good road, electricity and industries (Ajibade, 2003; Mac Donald, 2005; Amadi, 2010). Groundwater is of significant importance to northern Nigerian where the amount of rainfall is limited to very few months of the year with annual rainfall of 1000-1500m and surface water sources are usually inadequate (Eduvie, 1998). The concept of groundwater management centers on establishment of norms leading to optimization of factors necessary for economic utilization of the resources without disturbing the system irrevocably (Alao, 2000; Amadi and Olasehinde, 2010; Nwankwoala *et al*., 2004).

Despite the favorable and large groundwater occurrence reported globally, the Northern Nigerian situation appears to be critical due to the fact that majority of the area is underlain by crystalline rocks which are either igneous or metamorphic in origin and lack primary porosity and permeability (Adeleye, 1976; Adeleye and Desauviagie, 1972; Offodile, 2002; Oluyide *et al*., 1998; Olasehinde et al., 2010). Numerous abortive boreholes have been drilled in Agaie and environs in search of groundwater thus necessitating the need for scientific identification and quantification of parameters governing groundwater resources exploration, exploitation and management in Agaie and its environs. The present study tends to provide answer to the high rate of boreholes failure in Agaie and provide scientific based solution to the problem.

2. Study Area Description

Agaie is situated between Longitude 6º16'16"E and 6º25'18"E of the Meridian and Latitude 8º59'01"N to 9º5'00"N of the Equator (Figure 1). It is accessible through Paiko-Lapai road, Lambata-Lapai road and Bida-Agaie road. The area alternate between dry and rainy seasons and fall within the Guinea Savannah which comprises of different species of shrubs and becomes forest like along stream channels (Falconer, 1971; Kogbe, 1979; Truswell and Cope, 1963; Ajibade, 1982). The maximum daylight temperature is about 34ºc in the month of March while a minimum temperature of about 24ºc is recorded in December (Braide, 1992; Mc Curry, 1976; Shekwolo, 1983). The mean annual temperature is about 31ºc (Department of Meteorology, Minna Airport, 2004). The study area is well drained by River Tankpolo and its tributaries. These streams are seasonal and are dry in most part of the year except during the rainy season, hence the need for a groundwater source as a good alternative in the area. The study area stands at an elevation of between 140m and 150m above sea level in the East and drops slightly to about 125m in the Northwest and Southwest (Figure 1). The study area is low lying with some hills at the northeastern portion, around Ebugi and Mashina (Figure 2).

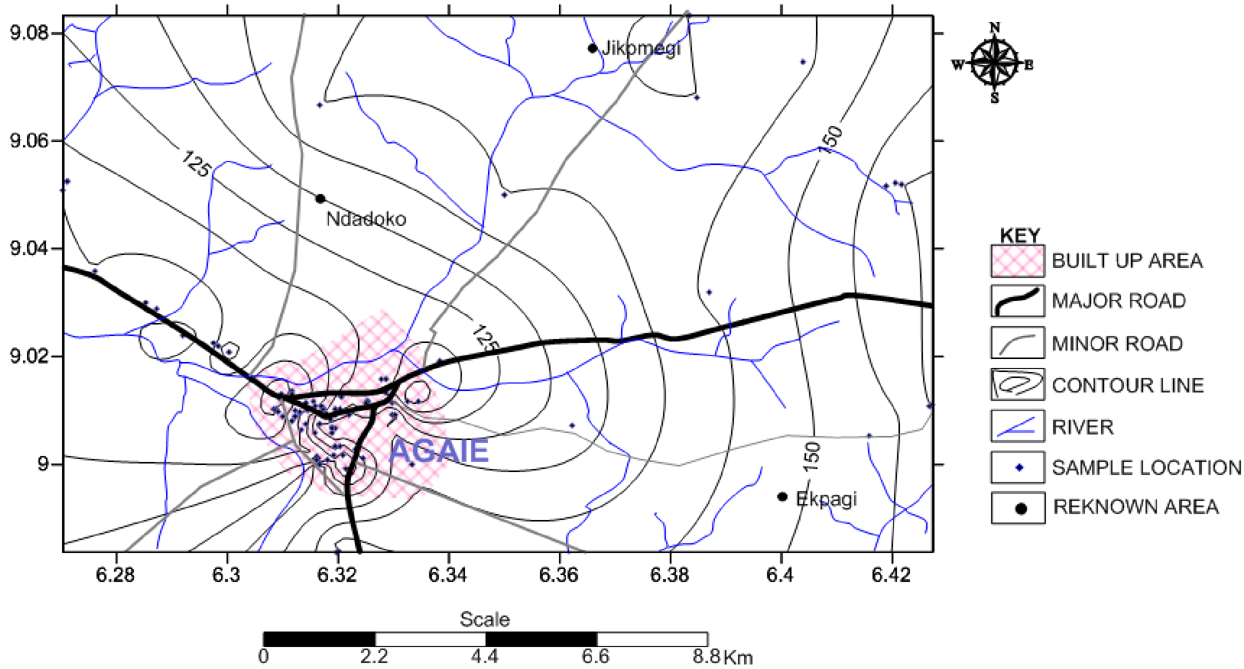

Figure 1. Topographical Map of Agaie and environs

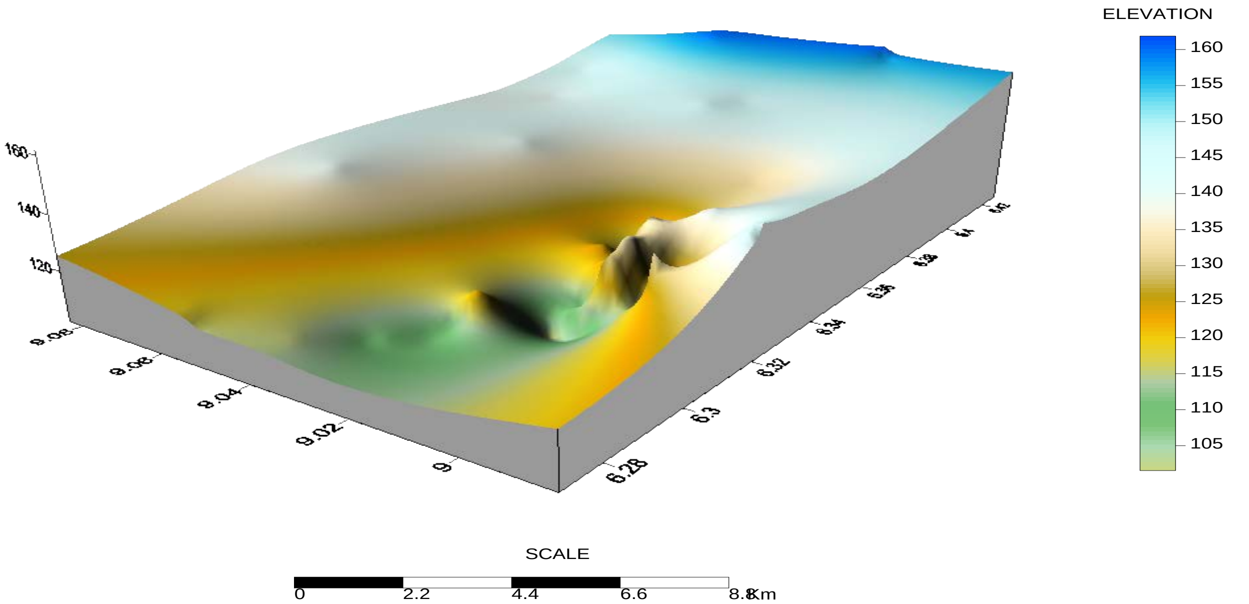

Figure 2. 3D Relief map of Agaie and environs

3. Electrical Resistivity Method

The principle of the resistivity methods is that an electric current is passed into the ground through two electrodes (C_1 and C_2) and the resulting potential difference is measured by another two electrodes (P_1 and P_2) as illustrated in Schlumberger Figure 3 and Wenner arrays (Telford *et al.*, 2001; Zohdy *et al.*, 1974; Virba, 1999; Selemo et al., 1995). The electrode spacing is progressively increased, keeping the center point of the electrode array fixed (Olasehinde and Taiwo, 2000; Oteze, 1989; Schwarz, 1986). At small electrode spacing, the apparent resistivity is nearly the resistivity of the surface material, but as the current electrode spacing increases the current penetrates deeper within the ground and so the apparent resistivity reflects the resistivity of the deeper layers (Olarewaju *et al.*, 1996; Olashinde and Awojobi 2004; Olugboye, 2008).

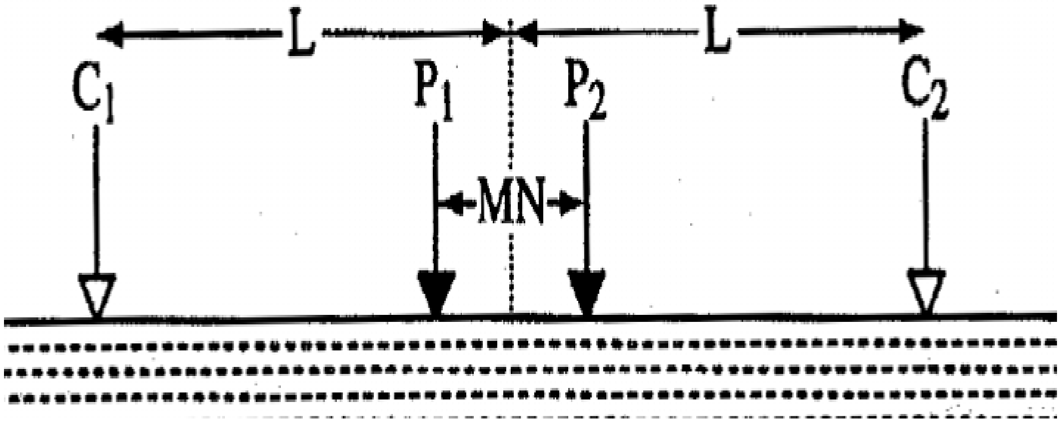

Figure 3. Schlumberger Array

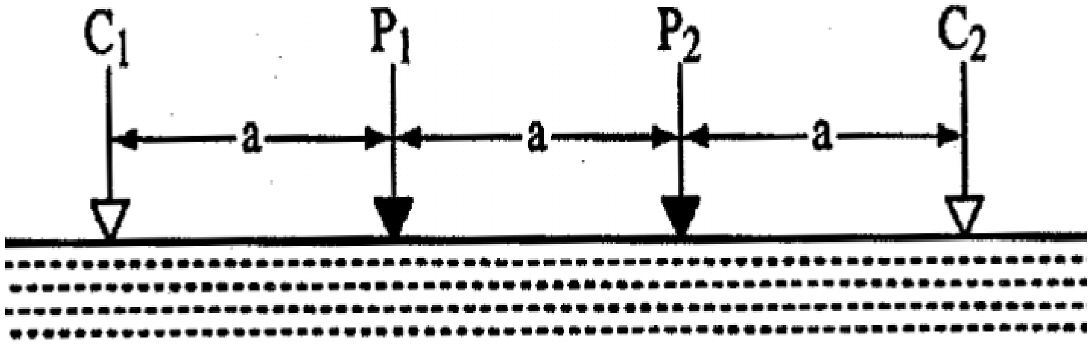

Figure 4. Wenner Array

4. Inventory of Boreholes and Hand Dug Wells

The inventory of hand-dug wells and boreholes were taken in Agaie town and neighboring communities in the study area. A total of 89 hand-dug wells were measured in Agaie town while 19 boreholes were drilled in Agaie and environs by the researcher during the period of investigation and these values where used to generate the groundwater flow direction of the area (Figure 5).

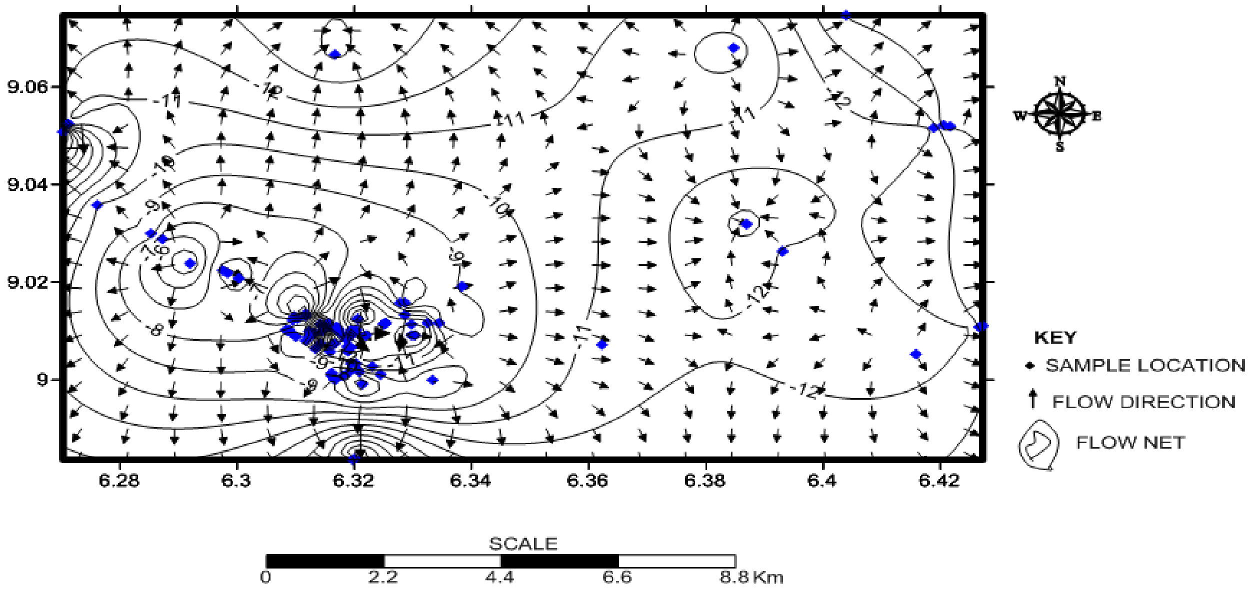

Figure 5. Groundwater flow direction of Agaie and environs

5. Geophysical Investigation

Geophysical Investigation provides information on the subsurface geology, stratigraphy and structural signatures as well as aquifer properties of the study areas (Singh, 1984; Shekwolo, 1993; Amadi *et al.*, 2010; Olasehinde, 2010). The electrical resistivity method was used in this research because it is the most effective and economical means of groundwater investigation.

6. Data Acquisition

Pre-drilling geophysical investigation involving vertical electrical sounding (VES) and horizontal resistivity profiling (HRP) was carried out in Agaie and environs using schlumberger (Figure 3) and Wenner (Figure 4) arrays respectively. A total of 19 VES and HRP were carried out in the study area. For schlumberger electrode configuration, maximum current electrode separation (AB/2) was 60 m while two current and two potential electrodes having equal intra and inter electrodes separation of 40 m interval moved together at the same time in leap frog method was used for Horizontal Electrical Resistivity Profiling.

7. Data Interpretation

Resistivity VES data was interpreted by plotting apparent resistivity against electrode spacing (Figures 6 and Table 1; Figure 7 and Table 2). The data was interpreted qualitatively by examining the curve shape and quantitatively by using computer modeling. Quantitative analysis involves identifying from the apparent resistivity curve the number of layers, their thickness and resistivity interpretation using Winresist modeled subsurface resistivity interpretation software. This interpretation was compared with the field curve matching in order to ensure high accuracy.

EBUGI VES DATA
Schlumberger Array

AB/2	RES
1.00	463.0000
2.00	481.0000
3.00	350.0000
5.00	264.0000
6.00	260.0000
6.00	225.0000
8.00	104.0000
10.00	126.0000
10.00	75.0000
15.00	125.0000
20.00	125.0000
25.00	123.0000
30.00	111.0000
35.00	62.0000
40.00	54.0000
40.00	175.0000
45.00	103.0000
50.00	38.0000

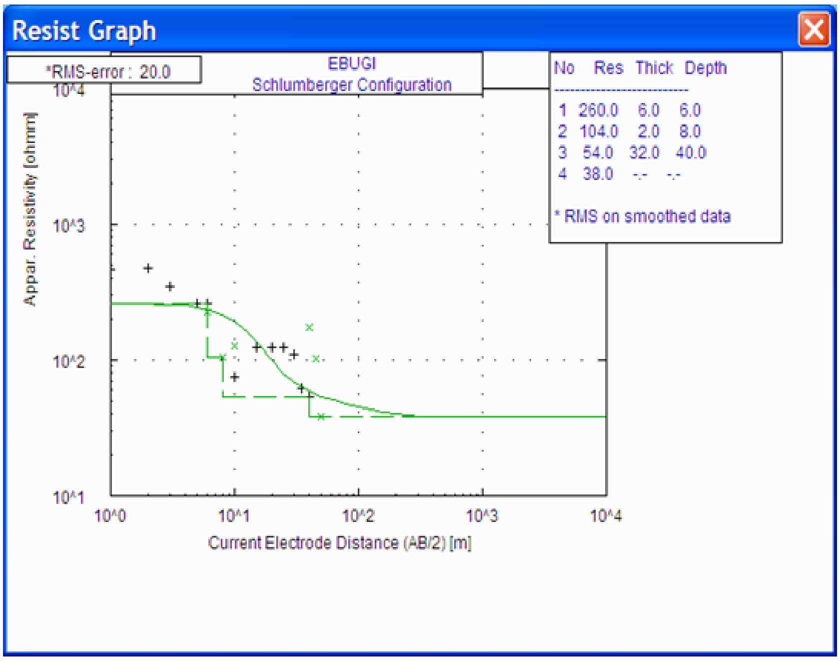

Figure 6. A representative VES curve in Ebugi village, Agaie

ESSANGI VES DATA
Schlumberger Array

AB/2	RES
1.00	130.0000
2.00	250.0000
3.00	147.0000
5.00	194.0000
6.00	147.0000
6.00	109.0000
8.00	95.0000
10.00	100.0000
10.00	91.0000
15.00	76.0000
20.00	80.0000
25.00	73.0000
30.00	71.0000
35.00	86.0000
40.00	98.0000
40.00	32.0000
45.00	20.0000
50.00	20.0000

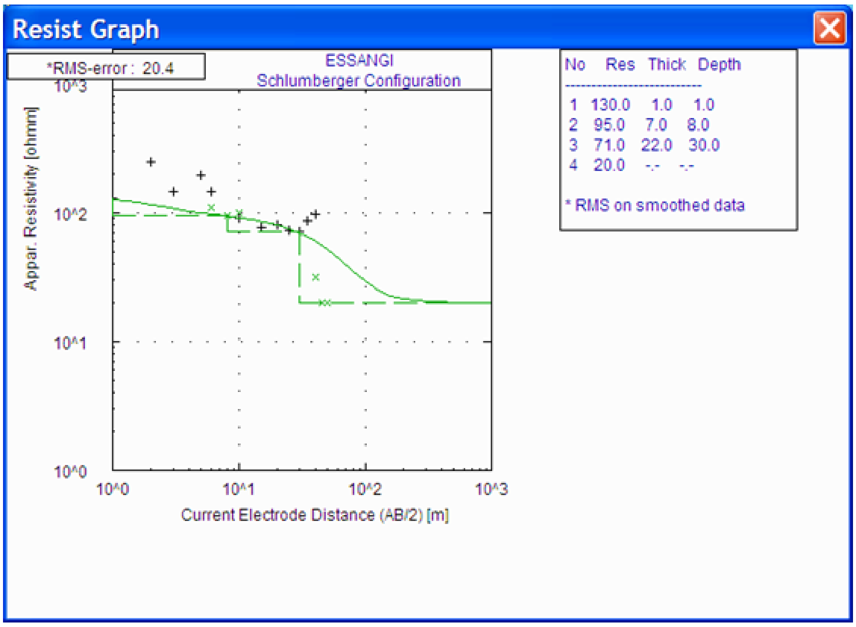

Figure 7. A representative VES curve in Esangi Village, Agaie

Table 1. Interpreted geoelectric section of Figure 6

Depth	Resistivity	Lithology	Remark
3	350	Top soil	Overburden water
15	125	Sandstone	Aquiferous
40	54	Sandy clay	Aquiferous

Table 2. Interpreted geoelectric section of Figure 7

Depth	Resistivity	Lithology	Remark
3	147	Top soil	Contain no water
10	100	Clayey sand	Aquiferous
35	86	sandstone	Aquiferous
50	20	Clay	Aquiclude

8. Geoelectric Section

One of the outcomes of VES is the generation of geoelectric sections which is a reflection of the subsurface lithologic signatures. The result revealed five geoelectric sections for the area which include: top soil, clay, sandy-clay, clayey-sand and sandstone (Figure 8). It can be deduced that the top soil generally has a thickness of about 3m in all the locations except in Emi-Alhaji Nusa, Emi-Ndanshimu and Emi Gozan where the thickness is about 2m. The thickness of clay in the study area ranged between 40-50m in many locations and also between 8-10m in few locations. The two aquitards which are clayey-sand and sandy-clay varied between 15-35m in most locations while the aquifer in the area (sandstone) ranged between 20-35m in the study area.

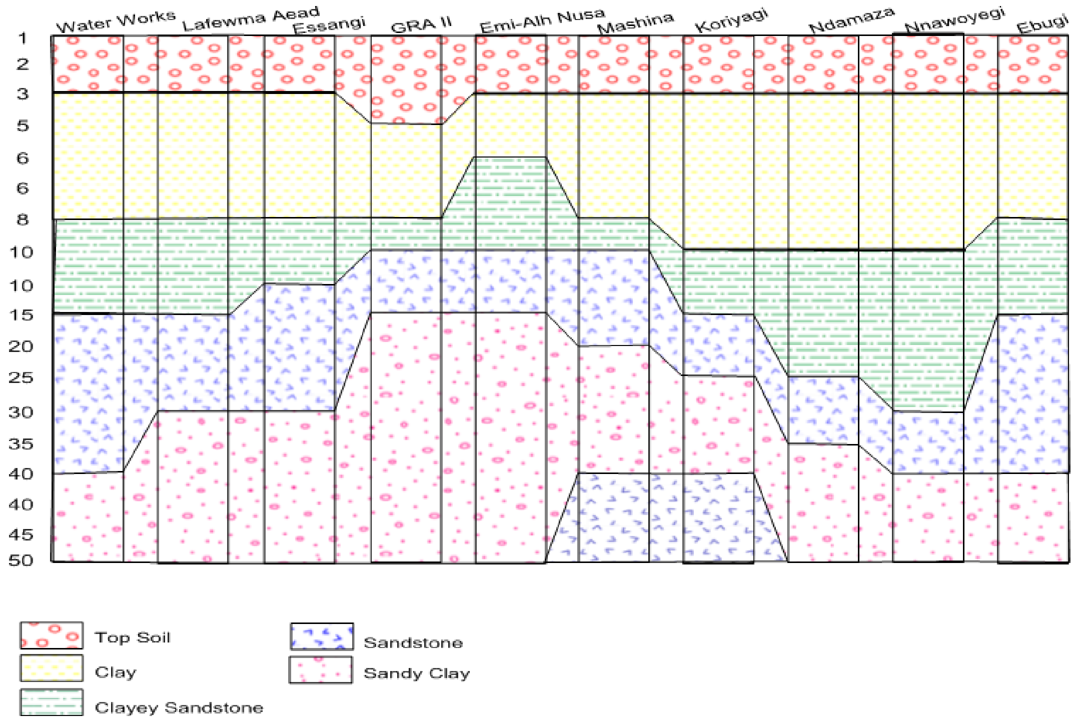

Figure 8. Geoelectric section of Agaie and environs

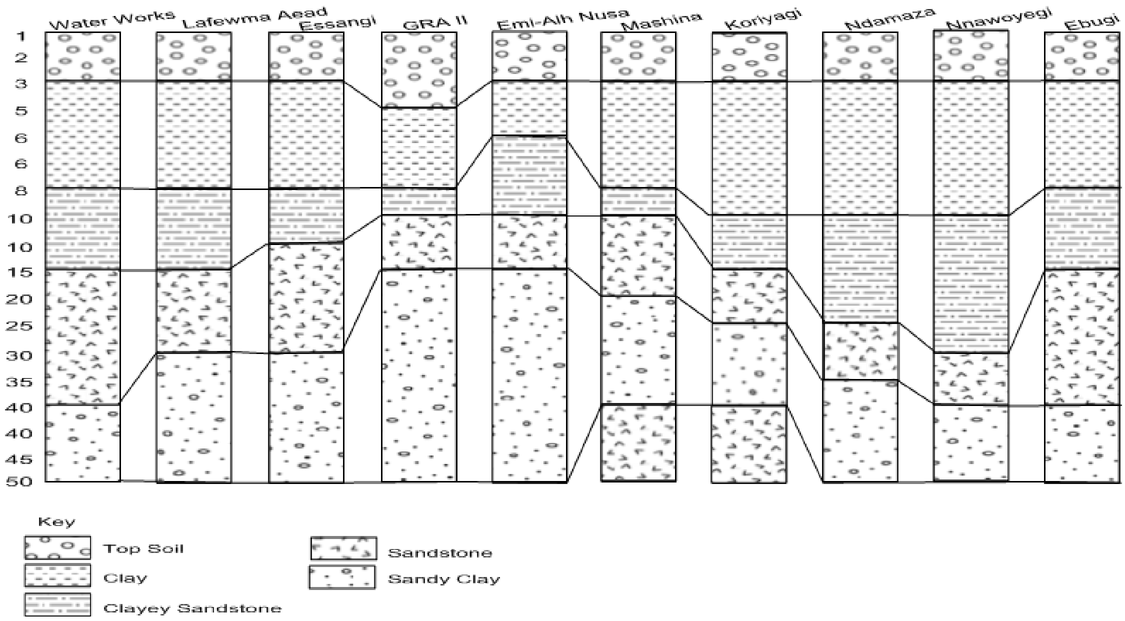

Figure 9. Borehole litholog of Agaie and environs

This indicates that the depth to aquifer and aquiclude varies across the sounding stations. The corresponding lithologs obtained from drilled boreholes in the area is shown in Figure 9. A strong correlation exists between the geoelectric section (Figure 8) from the geophysical investigation and the lithologs from the drilled boreholes (Figure 9). This is a good development for characterizing the aquifer system in the area.

9. Groundwater Potential Evaluation in the Area

The groundwater potential of the study area was evaluated by taking the inventory of some hand-dug wells in Agaie and environs. At each location, static water level, total depth of the well, longitude, latitude and elevation were taken. The study revealed the area with shallow and deep wells and conforms to the groundwater flow direction of NE and SW as areas with high groundwater potential (Figure 10) while the southern part of Agaie has medium groundwater potential. The ground water potential of the study was also evaluated using Horizontal Electrical Profiling (HEP) and Vertical Electrical sounding (VES) of the electrical resistivity to investigate the resistivity signatures of the subsurface. The data obtained from the survey was used to generate geoelectric sections were drawn to determine the existing relationship between the lithologic and the geoelectric section so as to delineate areas with high water bearing potential. Litho sample obtained while drilling were also used to evaluate groundwater potential of the study area. The lithologs obtained presents two aquitards (sandy-clay and clayey-sand) and sandstone aquifer which is fine to medium grained. About 85% of the aquiferous unit in the study area is semi-confined and or confined. Pumping test was carried out in each of the drilled boreholes in the area and the result used to evaluate the groundwater potential of the study area. The boreholes pumped 8 litres/sec for more than an hour except boreholes at Ebugi and Essangi Communities where the pumping lasted for less than an hour.

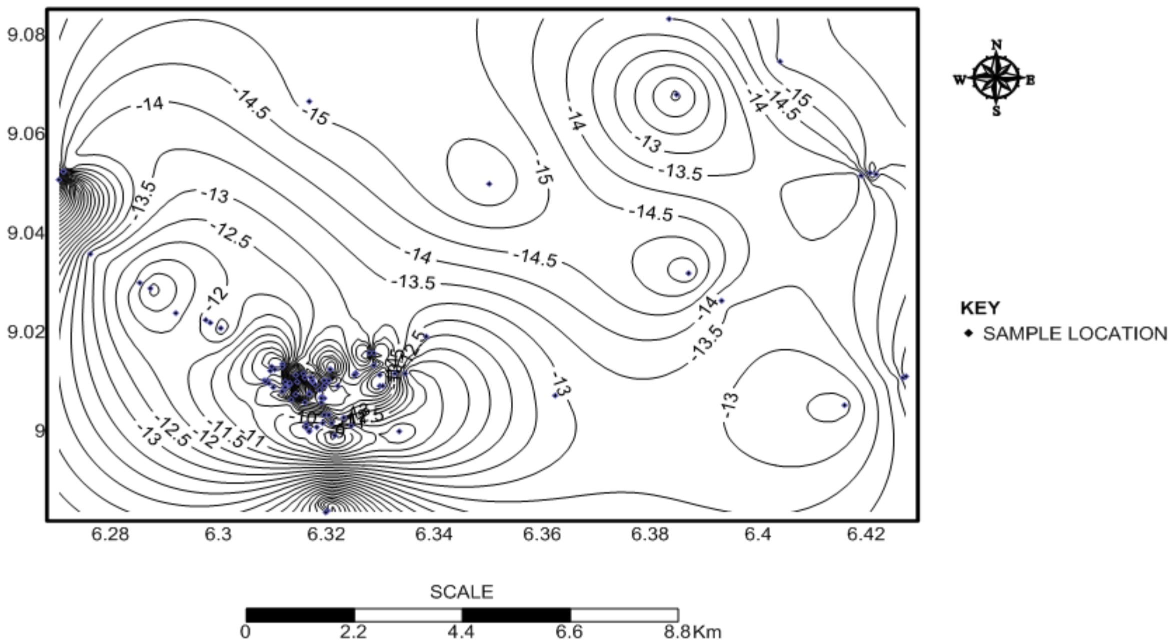

Figure 10. Well depth contour map of the study area

10. Conclusion and Recommendation

In the present study, geophysical, geological, hydrogeophysical and structural investigation have been found useful in elucidating the groundwater potential of Agaie and environs, North central Nigeria. The study has also given an insight to the causes of abortive boreholes and dry hand dug wells in the area. Numerous unsuccessful boreholes have been drilled in the area and such causes have been adequately analyzed and scientific based solution proffered. The anomalies identify have been overcome in the present study by integrating geophysical investigation with geological, structural and hydrogeological mapping. Qualitative and quantitative interpretation of the obtained data were carried out, via visual inspection of the field curve, traditional curve matching involving the master and auxiliary curves as well as the computer interpretation using Winresist software to generate resolution curves. Geoelectric section correlates positively with the borehole lithologs. The thickness and depth to the sandstones aquifers in the study area varies from one location to another. The subsurface electrical resistivity trends coincide with sub-regional lineament trends and the groundwater flow direction of the area. Siting of boreholes and hand-dug wells away from soakaway, toilet and dumpsite is advocated. Good hygiene practice is also suggested for the people of the area. A minimum depth of 50-60m for borehole and 20-25m for hand dug well is recommended for the study area.

References

[1] Adeleye, D.R. (1976). The Geology of Middle Niger Basin. In C.A Kogbe (Ed.) *Geology of Nigeria* (PP. 283-87). Lagos, Elizabethanpublication co.

[2] Adeleye, D.R., & Dessauvagie, T.F.J. (1972).Stratigraphy of the Embayment near Bida, Nigeria. In T.F.J. Dessauvagie, A.J. Whiteman, (Eds), *African Geology*.(PP 181 -185). Ibadan, University of Ibadan Press.

[3] Ajibade, A.C. (1982). The Origin of Older Granite of Nigeria: some evidence from the Zungeru region, Nigeria. *Journal of mining and Geology*, 19(1), 223-230.

[4] Ajibade, D.O. (2003). Hydro geochemical studies of Ground Water Resources in Agaie and Lapai L.G.A of Niger State. Unpublished B. Tech thesis, Federal University of Technology, Minna, Nigeria.

[5] Alao, D.A. (2000). Geophysical Investigation of Structural Controlled Ground Water Aquifer in the South Western Nigeria. *International Journal of Urban and Regional Affair*, 4(2), 42-50.

[6] Amadi, A.N. (2010). Hydrogeological and Geophysical Study of Bosso area of Minna, North-Central Nigeria. *BayeroJournal and Mathematical science*, 3 (1), 66-73.

[7] Amadi, A.N., & Olasehinde, P.I. (2010).Application of Remote Sensing Techniques in Hydrogeological Mapping of part of Bosso area, Minna, North-Central Nigeria.*International journal of physical science*, 5(9), 1465-1474.

[8] Amadi, A.N., Olasehinde, P.I., Okunlola, I.A., Okoye, N.O., & Waziri, S. (2010), A Multidisciplinary Approach to Subsurface Characterization in Northwest of Minna, Niger state, Nigeria. *Bayero Journal of Physics and Mathematical Science*, 3(1), 74-82.

[9] Braide, P.S. (1992).Syntectonic Fluvial Sedimentation in the Central Bida Basin.*Journal of Mining and Geology*, 28(1), 55-64.

[10] Edvuvie, M.O. (1998). Groundwater Quality data in the Yola arm Sedimentary Basin of Adamawa state, North Eastern Nigeria. *Water Resources Journal* 8(1), 31-39.

[11] Falconer, D.I. (1971).The Geology and Geography of Northern Nigeria. Macmillian, Lagos.

[12] Kogbe, C.A. (1979). Geology of the South-Eastern (Sokoto) Sector of the Lullemmeden Basin. *Bulletin of Department of Geology, Ahmadu Bello University, Zaria*, 2 (1), XV + 420PP.

[13] Mac Donald, A., (2005). Developing Groundwater.A guide for rural water supply ITDG PUBLISHING warwickshine CV 23 9QZ, UK www.itdgpublishing.org. UK.

[14] McCurry, P. (1976). The Geology of the Precambrian to Lower Paleozoic rocks of Northern Nigerian, a Review InC A,Kogbe (Ed.), *Geology of Nigeria (*pp. 15-39). Lagos, Elizabethan Publishing Co.

[15] Nwankwoala, H.O., Odero, D.R., Semu, E., & Kamau, G. (2004).Estimating Aquifer Parameters in parts of the PortHarcourt and environs using pumping test data. Unpublished M. Phil thesis, Rivers state University of Science and Technology, PortHarcourt, Nigeria.

[16] Offordile, M.E (2002). Groundwater Study and Development in Nigeria 2nd Edition published by Mecon Geology and Engineering Service Limited, Jos, Nigeria.

[17] Olarewaju, V.O., Olorunfemi, M.O., &Alade, O. (1996). Chemical Characteristics of Ground Water from some parts of the Basement Complex of Central Nigeria. *Journal of Mining and Geology.* 33(2)135-139.

[18] Olasehinde, P.I., & Taiwo, K.A. (2000). A Correlation of Schlumberger Array Geoelectric log with Borehole Lithologic log in South Western part of Nigeria Basement Complex Terrain. *Water resources journal*, 11, 55-61.

[19] Olasehinde, P.I., & Awojobi, M.O. (2004). Geologic and Geophysical Evidences of a North South Fracture System, East and West of the upper Gurarariver in Central Nigeria. *Water Resources Journal*, 15(1), 33-37

[20] Olasehinde, P.I. (2010). An integrated Geological and Geophysical Exploration Techniques for Groundwater in the Basement Complex of West Central part of Nigeria. *Journal of National Association of Hydrogeologists (water resources)*, 10(1), 46-49.

[21] Olasehinde, P.I., Amadi, A.N., Okunola, I.A., & Ejiofor, I.C. (2010).Assessment of groundwater transmissivity, yield and quality in parts of Niger State. *Bayero Journal of Physics and Mathematical Science*, 4(2), 23-30.

[22] Olugboye, M.O. (2008). Hydrogeological Practices with Application to Nigeria ground water terrain, PIOS publications, Ilorin.

[23] Oluyide P.O., Nwajide, C.S., & Oni, A.O. (1998). The Geology of Ilorin with Exploration on the 1:250,000 series, sheet 50 (Ilorin). Geological Survey of Nigeria bulletin 42, 1-84.

[24] Oteze, G.E. (1989). The Hydrogeology of the North-Western Nigeria Basin In C A,Kogbe (pp. 455-472) Jos, RockviewNig Ltd.

[25] Schwarz, S.D. (1986). Application of Geophysical Ground Water Exploration in Tssolt River Basin. *Water Resources Journal*, 2, 23-28.

[26] Selemo, A.O., Okeke, P.O., & Nwankwo, G.I. (1995).An Appraisal of Usefulness of VES in Ground Water Exploration in Nigeria. *Water resources Journal* 6(1 & 2), 61-67.

[27] Singh, C.L. (1984). Role of Surface Geophysical method for Ground Water Exploration in Hard rocks areas. *Proceedings of International workshop on Rural Hydrology and Hydraulics in fissured Basement Zones*, 59-68.

[28] Shekwolo, P.D. (1983). Structural Influence on Ground Water Occurrence in the Crystalline rocks of North West and North Central Nigeria and the proposed use for inclined drilling to improve it Exploitation. *Water resources Journal*, 11 (1), 87-95.

[29] Shekwolo, P.D. (1993). Regional Hydrogeology of Bida Basin, Central Nigeria. Unpublished Ph.D Thesis, Ahmadu Bello University, Zaria.

[30] Telford, W.N., Geldart, L.P., & Shriff, R.E. (2001). Applied Geophysics (2ndEd.) Cambridge 770pp.

[31] Truswell, J.F., & Cope, R.N. (1963).The Geology of parts of Niger and Zaria province, Northern Nigeria, Bulletin No. 29 Published by the Nigeria Geological Survey.

[32] Virba P. (1999). An Evaluation of Ground Water Potential of Arid and Semi-arid Region of North African using Isotope Technique. *Water Resources Journal* 10(1), 68-73.

[33] Zohdy, A.A., Eaton, C.P., & Mabey, D.R. (1974).Application of Surface Geophysical to Ground Water Investigation Technology. Water Resources Investigation, Washington, U.S Geological survey.