The use Of Resistivity Profiling Method In Grounwater Investigaton of a typical Basement Complex: A Case Study Of L.E.A Primary School-Dagiri In Gwagwalada Area Northcentral Nigeria

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Abstract: Geophysical technique involving resistivity profiling was used to map LEA Primary School-Dagiri in Gwagwalada Area of the Federal Capital Territory with a view to investigate the lateral variation in the subsurface resistivity. The qualitative interpretation results identified the presence of fractures across the surveyed area. Three traverses each measuring 500m, (representing an area of 250,000m^2) were mapped using wenner array configuration with electrode spacing of 50m for the profiling. Some prolific areas that can further be investigated for groundwater exploration using Vertical Electrical Sounding (VES) were delineated at the northeastern and Southern parts of the area. A resistivity range of 16Ωm - 1000Ωm was delineated, indicating a good groundwater potential area. Areas with resistivity values between 15Ωm and 265Ωm were however, marked as having good hydrogeologic significance in the region and consequently recommended for further investigation.

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1. Introduction

The rapid growing industrialization recently witnessed by the Gwagwalada metropolis has resulted in population increase and has resulted in urbanization of satellite villages and settlements of which the ancient Dagiri settlement is one (Figure 1). Rapid population growth of Dagiri occasioned by the influx of people from nearly congested city has made the sources of water inadequate for its dwellers, and the need for good quality and readily available portable groundwater in this area forms the basis for this research.

Dagiri town is underlying by Basement Complex rocks of the northcentral Nigeria and groundwater in this environment is usually contained in the weathered and/or fractured basement rocks or alluvial deposits within flood plains as mentioned by some authors among whom are Wright (1992) and Olorunfemi and Fasuyi (1993). The geophysical methods employed in the investigation of shallow features of the earth's crust vary according to the physical properties of the rocks, (Alile and Amadasun, 2008).

The basement aquifers are often limited in extent both laterally and vertically (Satpathy and Kanugo, 1976). This discontinuous nature of the basement aquifer system makes detailed knowledge of the subsurface geology, its weathering depth and structural disposition through geological and geophysical investigations inevitable (Adiat et. al., 2009).

Geophysical survey involving electrical resistivity, gravity, seismic and electromagnetic methods constitutes the most reliable means, outside direct mechanical drilling, through which basement structures such as ancient river channels, basement depressions and fractured zones that are of hydrogeological significance can be mapped (Eaton and Watkins, 1970; Vanderberghe, 1982). However, the most commonly applied geophysical technique for ancient river channel exploration is the electrical resistivity method (Minasian, 1979). This is a consequence of the usually significant resistivity contrast between the deposit within the channel and the underlying bedrock (Ako and Olorunfemi, 1989).

The resistivity profiling method has found useful application in groundwater investigation in basement terrain, most especially in understanding the lateral variation (Amadi and Nurudeen, 1990; Olorunfemi et. al., 1995; Mallam, 2004). Therefore, the aim of this research is to determine the lateral variation in the subsurface resistivity of a segment within the study area with a view to determining the presence or otherwise of structures such as fractures, faults, fissures and crack which may harbor the accumulation of groundwater. Their presence May thus furnish information on the groundwater potentials in the area at shallow depths of relatively uniform overburd.

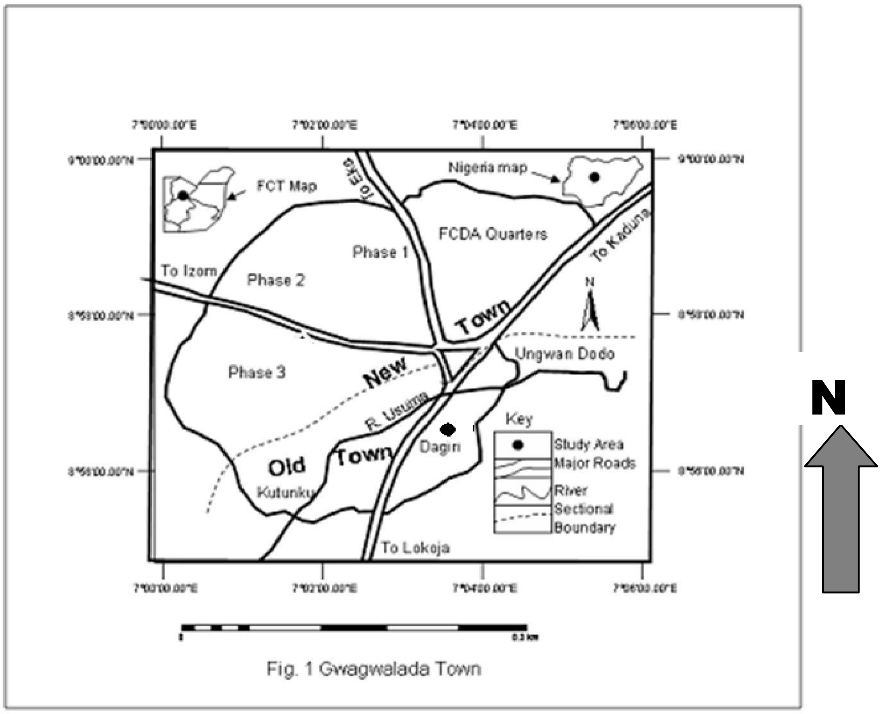

Figure 1: Location Map of Gwagwalada Showing the Study Area (Adopted from Galouchko, 2005)

Figure2: Geological Map of Nigeria (Galouchko, 2005; FCDA, 1997)

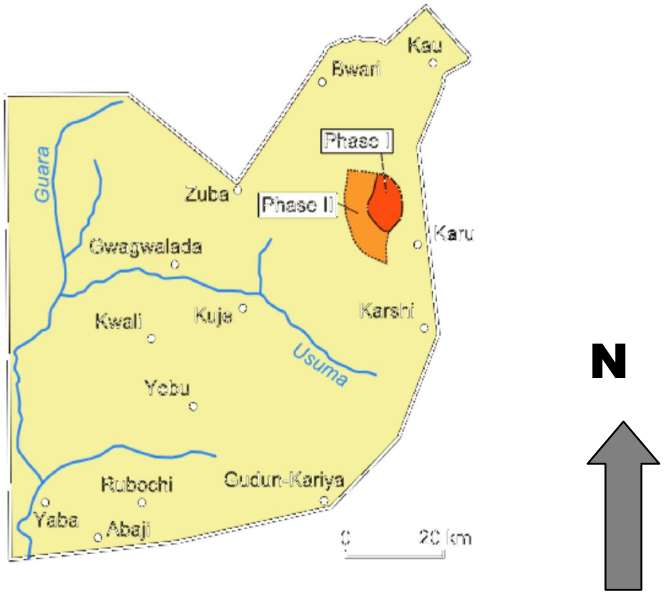

Figure 3: Geological Map of Federal Capital Territory Abuja (Galouchko, 2005; FCDA, 1997)

Site Description and Geology

The study area is in L.E.A Primary School in Dagiri Area of Gwagwalada Area Council. Gwagwalada is a suburb of Federal Capital Territory, Abuja. It is situated along Abuja – Lokoja road, about 55km Southwest of the Abuja City Centre, between Latitudes $8^{0}\,55'$N to $9^{0}\,77'$N and Longitude $7^{0}\,04'$ E to $12^{0}\,07'$ E (Figure 1). The topography is undulating with surface elevation ranging from 200m – 450m above sea level. According to Olugboye (1977), these hills are formed by outcropping basement rocks. Several mature profile rivers drain the area westward to the River Usuma that runs south to join River Gurara, the major river running through the territory and whose contents empty into river Niger (Olugboye, 1977). The geologic setting of the area is typical of the Metaigneous and older granite group; and Metasedimentary group complex rocks of the Precambrian Basement Complex of northcentral Nigeria (Murat, 1998), comprising of granite, gneiss, migmatite, biotite, granodiolite, quartzite, amphibolites, banded gneiss, mica, schist quartzite schist and amphibolites schist. According to USGS (1999), sharp escarpment clearly visible on both scales of aerial photographs of the area, separate the two rock group, which has been interpreted as shear zone. The vegetation in the study area lies in the tropical savannah, characterised by complete soil and vegetation cover with high annual rainfall of about 1,400mm. Annual mean temperature is between 19^{0C} and 38^{0C} with relatively high humidity (Galouchko, 2005).

Methodology

The equipment employed for the resistivity profiling field data measurements is the 3000 SAS Terrameter. Three (3) profiles spaced 50m apart and spanning a dimension of 500m by 500m representing an area of 250,000m^2 were investigated for lateral variation in resistivity using a wenner array configuration with electrode spacing varying from 0-500m.

Consider a point electrode on the surface of a homogenous isotropic earth extending downwards to infinity, and having a resistivity, ρ (Figure 4). If we describe a hemispherical shell of radius, r and thickness δr around the electrode then by symmetry, the current at any point of the surface will be along the radius, provided the conductivity of the air above is zero (Parasnis, 1986; Telford, 1978)

If I (A) is the total current passing through the electrode into the ground then the current flows through a hemispherical surface in the ground. By solving the Laplace Equation $\nabla^2 V = 0$ the potential drop, δV across the surface will be:

$$\delta V = -\frac{I\rho\delta r}{2\pi r^2} \ldots\ldots\ldots\ldots\ldots(1)$$

Where,
δr = thickness around the electrode.

The negative sign indicates that potential decreases in the direction of current flow.

Integrating equation (1), we get the potential, V(r) at a distance r(m), from point current source as:

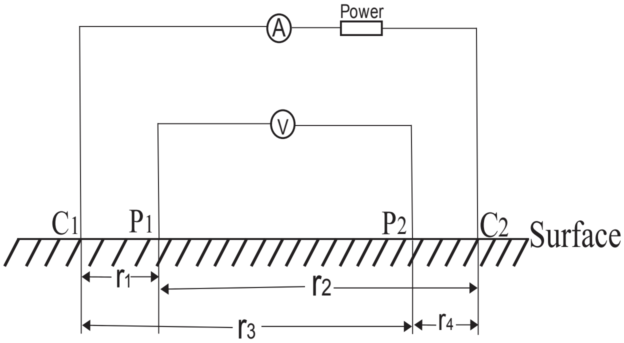

Figure 4: Current and potential electrodes of a typical wenner array configuration (Parasnis, 1986).

$V(r) = \frac{I\rho}{2\pi r} + c$……….……. (2)

As $r \rightarrow \infty, V \rightarrow 0\ and C = 0$

So that:

$V(r) = \frac{I\rho}{2\pi r}$ ………………….. (3)

In practice, we have two current electrode one positive C_1 sending current into the ground and the other negative C_2 receiving the returning current from the ground. The total potential at any point, Pin the ground will then be given as:

$V(r, r') = \frac{I\rho}{2\pi}\left(\frac{1}{r} - \frac{1}{r'}\right)$ ……….(4)

Where,

r, r' are distance of P from the two electrodes.

The potential due to C_1 at P_1 is then given as:

$V_1(r) = \frac{I\rho}{2\pi r^1}$……..……………. (5)

Similarly, the potential at P_1 due to C_2 is given as:

$V_2(r) = \frac{-I\rho}{2\pi r_2}$………..………. (6)

The total potential due to C_1 and C_2 is therefore given as:

$V_1(r) + V_2(r) = \frac{I\rho}{2\pi}\left(\frac{1}{r^1} + \frac{1}{r^2}\right)$ …………(7)

Note: the current at the two electrodes are equal and opposite in direction.

If we now introduce a second potential electrode at P_2 then the potential difference will be:

$\Delta V = \frac{Ip}{2\pi}\left\{\left(\frac{1}{C_1P_1} - \frac{1}{C_2P_1}\right) - \left(\frac{1}{C_1P_2} - \frac{1}{C_2P_2}\right)\right\}$…….(8)

This arrangement corresponds to the four electrodes spreads usually used in resistivity fieldwork (Parasnis, 1986; Telford, 1978)

Rearranging the terms in equation (8), we obtain:

$$\rho = \frac{2\pi\left(\frac{\Delta V}{I}\right)^1}{\left[\left(\frac{1}{C^1P^1} - \frac{1}{C^2P^1}\right) - \left(\frac{1}{C^1P^2} - \frac{1}{C^2P^2}\right)\right]} = 2\pi\left(\frac{\Delta V}{I}\right).\frac{1}{G}$$

$$= 2\pi R.\frac{1}{G}\text{…….(9)}$$

Where, $G = \left(\frac{1}{C^1P^1} - \frac{1}{C^2P^1}\right) - \left(\frac{1}{C^1P^2} - \frac{1}{C^2P^2}\right)$ is a parameter that is a function only of the geometry of the electrodes arrangement.

$G_w = \frac{1}{a} - \frac{1}{2a} - \frac{1}{2a} + \frac{1}{a}$……… (10)

This implies that

$\boldsymbol{G_w = \frac{1}{a}}$.................................. (11)

Using this result in (2), we obtain the apparent resistivity for Wenner array as:

$\rho_a = 2\pi aR$…………………(12)

The equation above (12) was used in computing the apparent resistivity values.

The profiling was conducted on the three layout traverses which cover the entire studied area. The profiles data presented as profiles and table. The results of the qualitative interpretation of the resistivity profile data are summarized in table 1.

DISCUSSION OF RESULTS

Profile 1(Figure 5) shows the zigzag nature of the area, and indication of the presence of cracks, fissures, fractures or faults, which are associated with the study area. It begins with a low apparent resistivity value, increase sharply and then falls almost at the same rate to it minimum value. The general trend of the apparent resistivity values in the surveyed area is low, ranging from 16 - 1000Ωm. This suggests that the area may contain groundwater at relatively shallow depth. Profile 2(Figure 5) also shows some features. It has relatively low resistivity from the beginning and fall considerably to their lowest values. Profile 3 (Figure 5) also shows some

A careful look at the profiles indicates the extremely high resistivity values are predominantly visible at about 50m, 50m and 300m on the first, second and third profiles respectively. These are area with values greater than 600Ωm. Places with the lowest resistivity value on the other hand are essentially noticed at about 150m on the first profile, 200m on the second and third profiles. These are area characterized by resistivity value less than 200Ωm. Apart from the two extremes cases mentioned above, there are commonly low resistivity values ranging between 200Ωm and 600Ωm spread across the entire area. The area can thus, convincingly be said to be good for groundwater exploration. The higher resistivity values observed in some parts of the area may likely be done to the presence of intrusions in the subsurface whose origin is thought to be the results of tectonic activities within the mantle. Lithlogic information obtained near the area indicates that overburden consists of four (4) subsurface layers which include top soil, clay/ sandy clay, weathered/fractured basement and fresh basement. The data obtained supports this, as the range of resistivity value in most parts of the area lies within the range for these soil types.

Table 1: Resistance and Corresponding Apparent Resistivity Values

		First Profile		**Second Profile**		**Third Profile**	
Distance (m)	**Probe No**	**Resistance R (Ω)**	**ρa = 2πaR (Ω m)**	**Resistance R (Ω)**	**ρa = 2πaR (Ω m)**	**Resistance R (Ω)**	**ρa = 2πaR (Ωm)**
0	1	0.830	261	1.066	335	1.342	422
50	2	2.324	730	2.089	656	1.480	465
100	3	1.064	334	0.820	258	1.034	325
150	4	0.050	16	0.988	310	1.256	395
200	5	1.200	377	0.611	192	0.460	145
250	6	0.889	279	1.111	349	1.625	510
300	7	0.534	168	0.973	306	3.183	1000
350	8	1.432	450	1.503	472	1.066	335
400	9	1.534	482	1.084	341	1.084	341
450	10	1.432	450	1.257	395	1.043	328
500	11	1.344	422	1.263	397	1.242	390

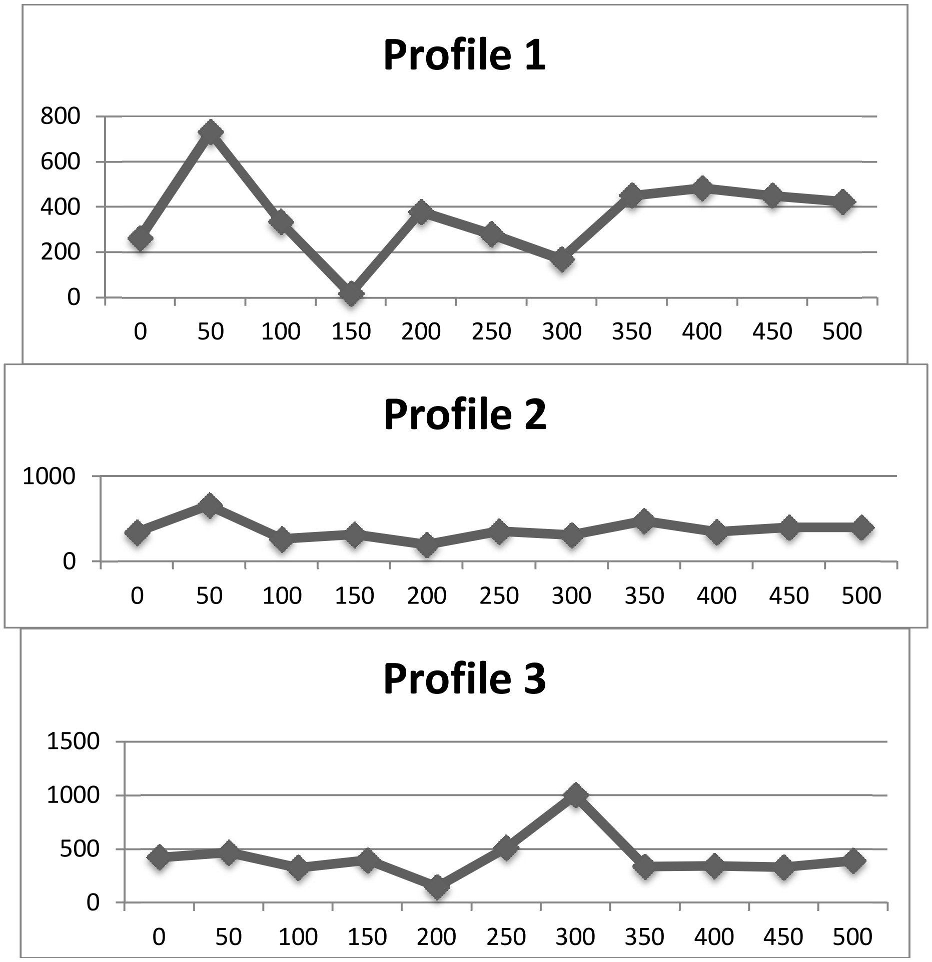

Figure 5: Typical profiles along the three traverses

Conclusion

The study area is generally underlain by four (4) geo-electrical / geologic layer with an average low resistivity of 382Ωm.The study area can be concluded to have very good groundwater potential. This statement derives its supportive evidence from the relatively low resistivity value obtained from the area (15 - 1000Ωm), coupled with the presence of cracks, fissures and fractures as evidence by the nature of the profiles drawn across the area. However, this study can be investigated further through quantitative approach using vertical electrical sounding.

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