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The Use of Electrical Resistivity Survey in Locating Aquifers in Ilorin Area of Kwara State, Nigeria.

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Abstract

This research involved the use of electrical resistivity survey method for groundwater exploration in Ilorin area of Kwara State, Nigeria. The Vertical Electrical Sounding (VES) using Schlumberger array with maximum spread of 200m and partial curve matching /computer iteration techniques were used to interpret the data obtained with the aim of accurately predicting the depth to basement and aquifer. A total of ninety five VES were carried out and thirteen boreholes constructed. The predicted depths to basement from VES and the actual depths from the drilling log show a good agreement with each other and with results obtained from literature.

The results of the research also confirmed the already known geological units of the western Nigerian Basement Complex Terrain and the drilling exercise was successful.

Keywords: Groundwater, aquifer, iteration, geoelectric measurement and fractured zone

1.0 Introduction

Groundwater is one of the most important natural resources. It is normally used to augment the supplies from surface sources and sometimes it is the main source of water supplies. To harness groundwater for domestic and industrial usage usually require the drilling of boreholes which is quite expensive and is prone to failure when there is no prior knowledge of the subsurface geology, hence the need for thorough geophysical studies.

The study area includes: Ilorin West, Ilorin South and a part of Ifeodun Local Government Areas (LGAs) of Kwara State, Nigeria (Figs. 1 and 2). It is underlain by Precambrian rocks of the south-western Nigerian Basement Complex where groundwater occurs either in the weathered mantle or in the joint and fracture systems in the un-weathered rocks [1]. The highest groundwater yield in the basement terrains is found in areas where thick overburden overlies fractured zones [2]. These zones are often characterized by relatively low resistivity. Omosuyi, *et al.* [3] opined that, because of the discontinuous (localized) nature of basement aquifers, drilling programmes for groundwater development should generally be preceded by detailed hydro-geophysical investigations. Various authors have suggested the use of electrical resistivity method, especially the VES for geophysical exploration [4].

The VES method is a depth sounding galvanic method and has proved very useful in groundwater studies due to simplicity and reliability of the method. The electrical resistivity of rock is a property which depends on lithology and fluid contents. The ultimate objective of VES at some locality is to obtain a true resistivity log similar to the induction log of a well at the locality, without actually drilling the well [5]. In this study, the Electrical Resistivity method, i.e. VES technique was used to delineate the different subsurface geo-electric layers, the aquifer units and their hydrogeologic properties.

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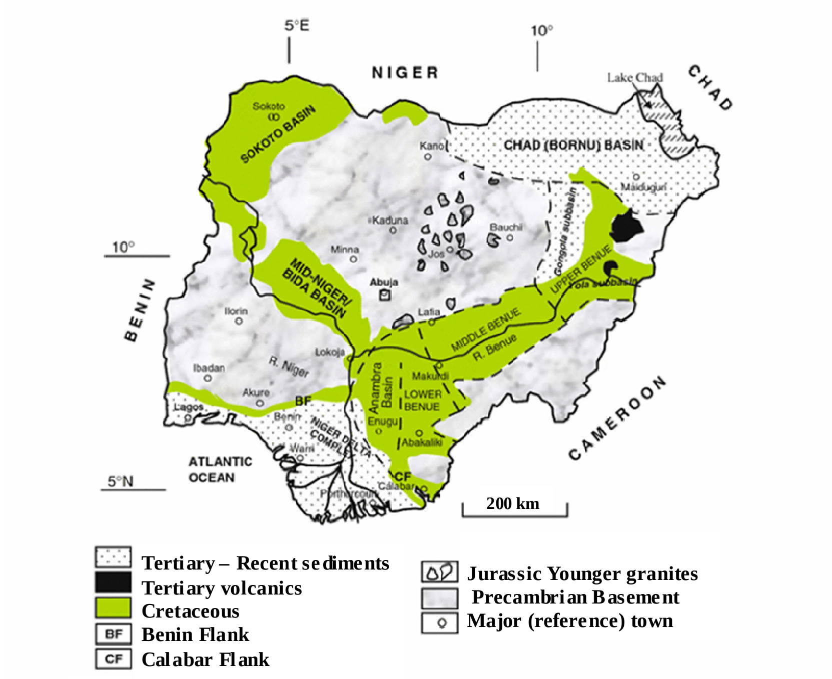

Fig.1: Geological sketch map of Nigeria showing the major geological components (Basement, Younger Granites and Sedimentary basins) and Ilorin, the capital of Kwara state (After Obaje [6]).

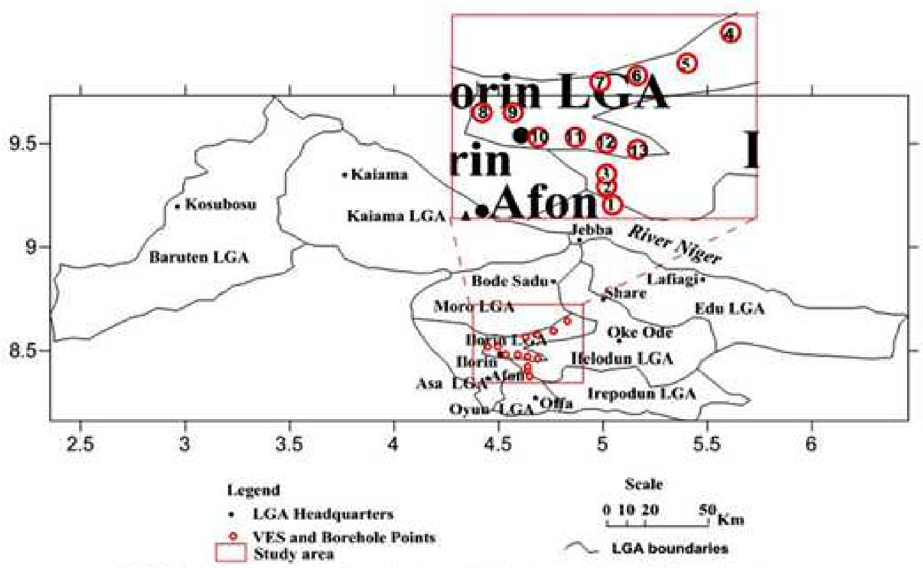

Fig.2: Map of Kwara State showing the chosen VES locations and the drilled boreholes (Inset is the map of the study area)

2.0 Geology and Hydrogeology of the Study Area.

The study area is bounded by longitude 4^0 24' and 4^0 48' E and latitude 8^0 18 ' and 8^0 42' N in the topographical map of Nigeria. It falls within the Crystalline Basement Complex rock of Kwara state, West Central Nigeria and range in age from Precambrian to probably Paleozoic [7]. About 90 percent of the State is covered by Precambrian rocks (basement complex) and the remaining area by Cretaceous and Quaternary formations (sedimentary and Alluvia). Oyawoye [8] classified the Basement Complex into four main rock groups using lithology. These include; (i) the older granites (ii) the migmatite complex (iii) the metasedimentary series and (iv) Miscellaneous rock types.

Three main aquifer types identifiable in the study area occur in the weathered and fractured Basement Complex and Alluvial sediments while most of the boreholes drilled are very productive and in the range of 0.5 to 5.0 litres per second. The highest groundwater yield in the basement terrains is found in areas where thick overburden overlies fractured zones [2]. Frequency plots of borehole yields, depth to water level and total depth show that median yields in both the Basement rocks and sedimentary rocks in Kwara State are between 1 and 3 litre per second. More than 75 per cent of boreholes in the basement have water levels between 0 and 10m. Some hydrogeological parameters are summarized in Table 1, based on 312 boreholes with recorded geological information [9].

Table 1: Average Hydrogeological Parameters in Kwara State (Geoexploration Nig. Associates [9]).

Aquifer	Number of Bore-holes	SWL (m)	Q (l/s)	Specific capacity (l/sm.)	Drawdown (m)	Total depth (m)
Basement	271	9	2.0	0.11	19	57
Cretaceous	31	42	2.2	0.1	21	110
Alluvium	10	7	11.8	2.7	4	55

3.0 Materials and Methods

The electrical resistivity method involving VES technique and the Schlumberger electrode configuration with maximum current electrode separation (AB/2) of 100 m was employed in this work. The electric current (I) is passed into the ground by means of two electrodes and the potential difference (ΔV) is measured between another pair of electrodes. The apparent resistivity (ρa) for the Schlumberger configuration is given by equations (1) and (2) [10]:

$$\rho a = \frac{\Delta V}{I} G \qquad (1)$$

$$\rho a = \frac{\pi R (AB/2)^2}{MN} \qquad (2)$$

Where: G is the geometric factor, AB is current-electrode spacing, MN is the potential-electrode spacing, I is the input current, R is electrical resistance and π *is a constant* (3.142 or 22/7).

Ninety five VES were carried out and thirteen boreholes constructed(Fig. 2). The VES data were utilized in generating field curves (Fig. 3) that were interpreted using partial curve matching technique of Kearey *et al*. [11]. The layer resistivities and thicknesses obtained served as layered model parameters input for the computer iteration algorithm [12]. The VES data was used for producing the resistivity maps (Figs. 4 and 5) drawn for 15 and 50 m (AB/2) electrode spacing respectively within the study area.

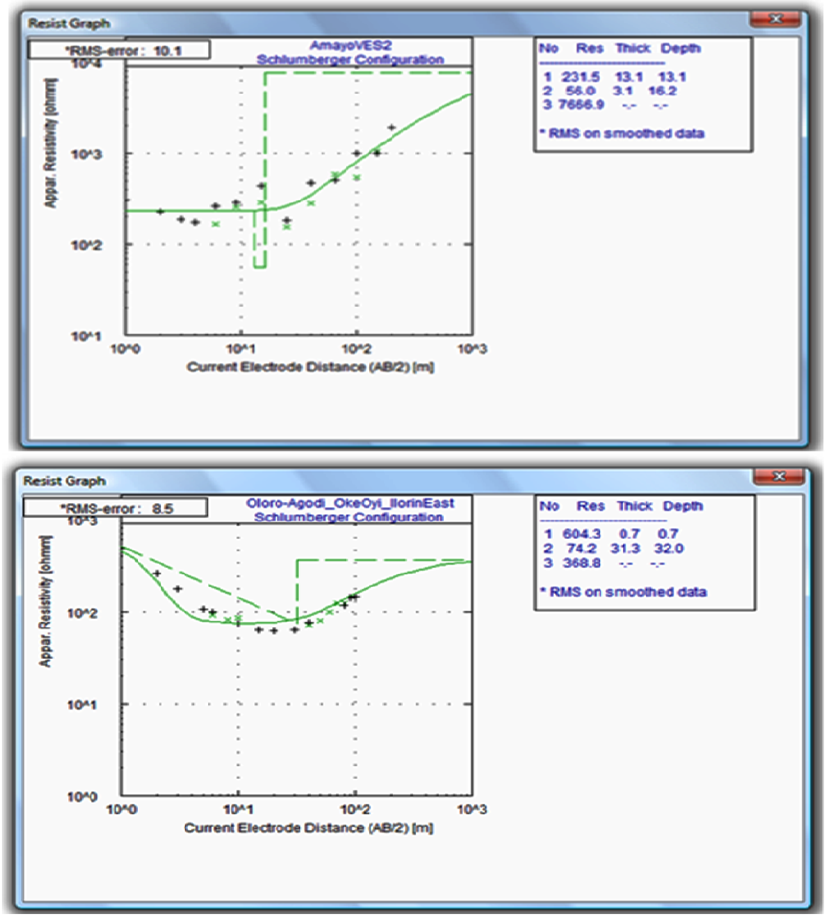

Fig. 3: Typical Schlumberger sounding curves obtained in the study area

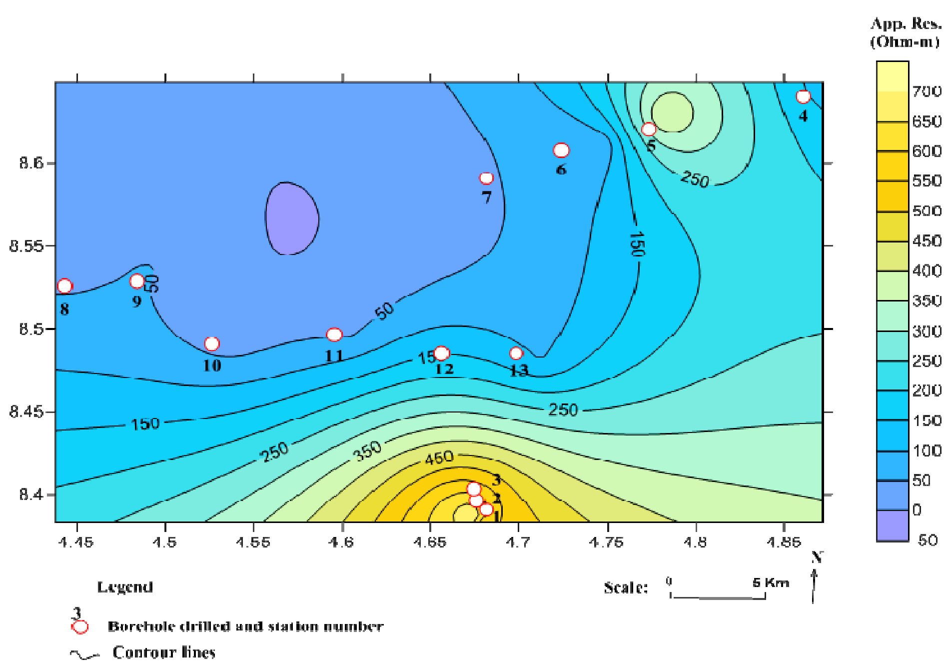

Fig.4: Apparent resistivity map of the study area (AB/2=15m)

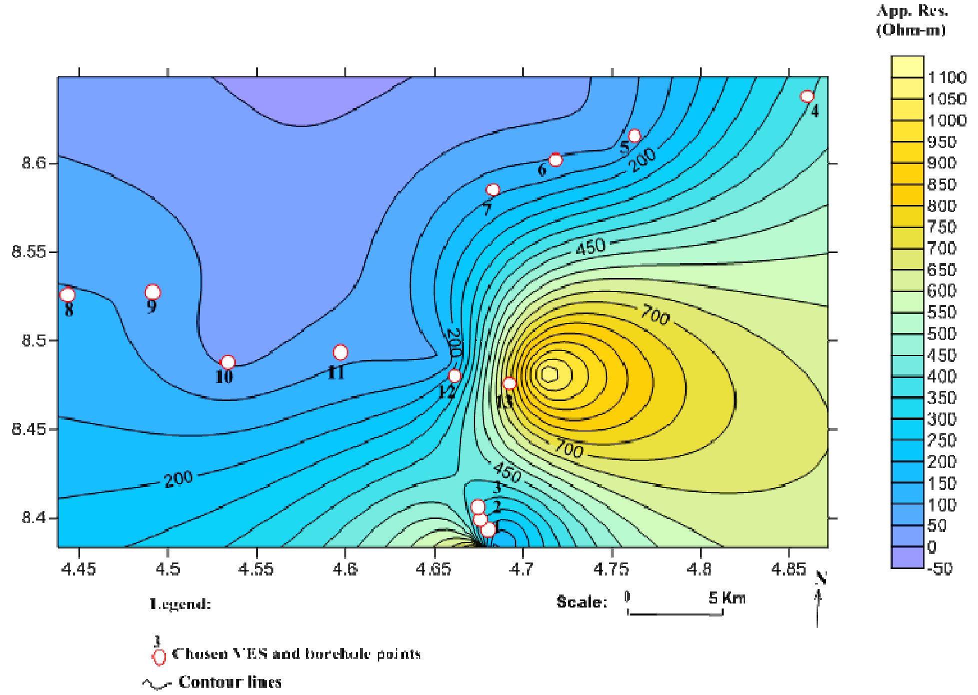

Fig.5: Apparent resistivity map of the study area (AB/2=50m)

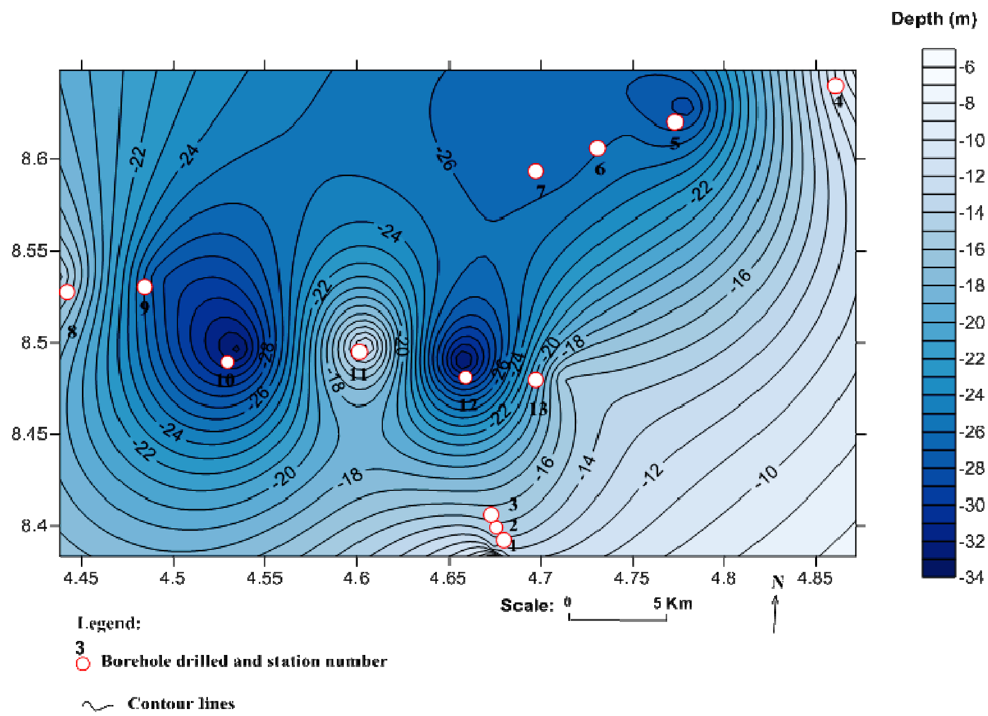

Fig.6: Map of depth to bedrock (Fresh basement)

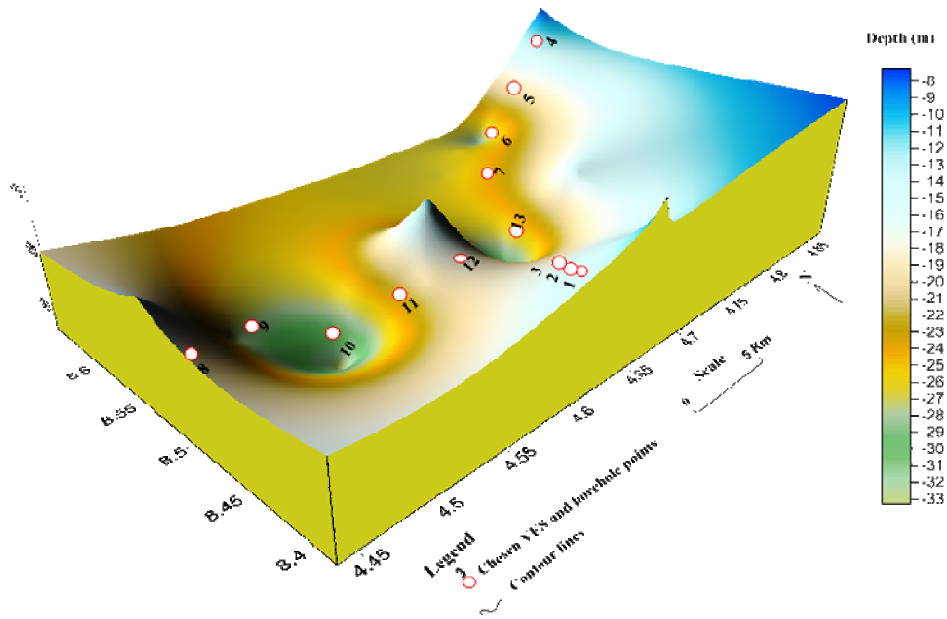

Fig.7: 3-D surface map of bedrock topography in the study area

4.0 Results and Discussion

4.1 VES data and drilling log

The typical VES curves and interpreted geoelectric models are displayed in figure 3. The geoelectric models delineated three subsurface layers composed of topsoil/ lateritic layer, weathered/ fractured layer and the fresh basement or bedrock. The topsoil/lateritic layer composed of silt, clayey sand and sand; its thickness ranged between 0.4 and 4.5 m while resistivity ranged from 119 to 1,350 Ωm. The weathered/ fractured layer which constitutes the main aquifer unit, has a thickness ranging between 2.5 and 33m; resistivity ranging between 7.6 and 270 Ωm. The fresh basement constitutes the bedrock and had resistivity ranging from 26 – 5,500 Ωm. The depth to the top of fresh basement ranged from 5.6 to 34.5 metres. Table 2 shows a comparison between the VES and the drill log results. The data shows a good agreement between the two methods of depth measurement and hence a successful outcome of the drilling exercise whereby all the boreholes drilled was productive.

4.2 Apparent resistivity map

The apparent resistivity (iso-resistivity) contour maps for 15 and 50 m (AB/2) current electrodes are displayed in Figures 4 and 5 while Figures 6 and 7 are the depth to bedrock and 3-D surface map of bedrock topography respectively produced from the VES data. The maps display high resistivities 350-700 and 450 -1100 Ωm (typical of fresh basement) at the southern (Fig. 4) and eastern (Fig. 5) parts respectively and very low to low resistivity (<200 Ωm) (characteristic of fractured basement and clayey environment) from the west to the northern parts of the study area.

5.0 Conclusion

This study has shown the successful application of electrical resistivity survey in locating aquifers which are necessary for groundwater development in the Crystalline Basement Complex Terrain of Ilorin, the capital of Kwara State, Nigeria. The VES method used to predict the depths to basement and the actual depths recorded from the drilling log show a good agreement with each other while the VES curves obtained exhibit a three-layer (H type) characteristic; showing a resistive first layer, followed by a less resistive weathered basement and finally, the highly resistive fresh basement. In all the boreholes, the second geoelectric layer, that is, weathered basement, form the main aquifer and none of the thirteen boreholes drilled was abortive. The 3-D surface map obtained from the inversion of the geo-electric parameters of the VES has shown the nature of the basement topography and the area most suitable for groundwater exploration. Whenever VES is to be carried out, the Schlumberger array is recommended because of its several advantages over other array types.

Acknowledgement

The authors gracefully acknowledge the contributions of Mr Oluwole V. O. for making available some VES data on Agricultural and Rural Management Training Institute (ARMTI), Ilorin, Kwara State, Nigeria.

Table 2 : VES Interpretations and Drilling Results

			Auxiliary Curve Matching Results		Drill Results	
S/No	**Location**	**L.G.A.**	**Resisistivity (Ωm)**	**Depth (m)**	**Depth(m)**	**Estimated Yield of BH (l/s)**
1.	ARMTI 1	Ifelo-dun	$\rho_1 = 460$ $\rho_2 = 30.54$ $\rho_3 = 2300$	$d_1 = 3.40$ $d_2 = 8.10$ $d_3 = \infty$	d_1 = N.A d_2 = N.A $d_3 = \infty$	2.4
2.	ARMTI 2	Ifelo-dun	$\rho_1 = 220$ $\rho_2 = 8.80$ $\rho_3 = 5500.$	$d_1 = 3.20$ $d_2 = 3.20$ $d_3 = \infty$	d_1 = N.A d_2 = N.A $d_3 = \infty$	2.6
3	ARMTI 3	Ifelo-dun	$\rho_1 = 119$ $\rho_2 = 7.60$ $\rho_3 = 47.50.$	$d_1 = 3.20$ $d_2 = 9.60$ $d_3 = \infty$	d_1 = N.A d_2 = N.A $d_3 = \infty$	3.5
4.	Aloko-laro	Ilorin East	$\rho_1 = 290$ $\rho_2 = 58$ $\rho_3 = 1,260$	$d_1 = 1.2$ $d_2 = 6.3$ $d_3 = \infty$	$d_1 = 1.6$ $d_2 = 5.0$ $d_3 = \infty$	0.8
5.	Matanmi	Ilorin East	$\rho_1 = 235$ $\rho_2 = 70.5$ $\rho_3 = 1,240$	$d_1 = 2.8$ $d_2 = 25.8$ $d_3 = \infty$	$d_1 = 1.8$ $d_2 = 28.0$ $d_3 = \infty$	2.5
6.	Oloro Agodi	Ilorin East	$\rho_1 = 640$ $\rho_2 = 44.8$ $\rho_3 = 420$	$d_1 = 0.77$ $d_2 = 25$ $d_3 = \infty$	$d_1 = 0.4$ $d_2 = 15.0$ $d_3 = \infty$	2.5
7.	Abidolu	Ilorin East	$\rho_1 = 640$ $\rho_2 = 44.8$ $\rho_3 = 420$	$d_1 = 2.4$ $d_2 = 24.1$ $d_3 = \infty$	$d_1 = 4.5$ $d_2 = 30.0$ $d_3 = \infty$	30
8.	Dada-Sobi	Ilorin East	$\rho_1 = 640$ $\rho_2 = 44.8$ $\rho_3 = 420$	$d_1 = 1.6$ $d_2 = 12.1$ $d_3 = \infty$	$d_1 = 2.5$ $d_2 = 15$ $d_3 = \infty$	23
9.	Muyideen Arabic Sch.-Kulende	Ilorin East	$\rho_1 = 330$ $\rho_2 = 33$ $\rho_3 = 540$	$d_1 = 3.0$ $d_2 = 24.6$ $d_3 = \infty$	$d_1 = 1.8$ $d_2 = 23.0$ $d_3 = \infty$	1.5
10.	Ansar-Deen Mosq.	Ilorin West	$\rho_1 = 142$ $\rho_2 = 7.6$ $\rho_3 = 26$	$d_1 = 3.45$ $d_2 = 30$ $d_3 = \infty$	$d_1 = 0.4$ $d_2 = 28.0$ $d_3 = \infty$	3.0
11.	Police Barrack 'A' Div.	Ilorin South	$\rho_1 = 140$ $\rho_2 = 70$ $\rho_3 = 140$	$d_1 = 0.8$ $d_2 = 10.4$ $d_3 = \infty$	$d_1 = 1.0$ $d_2 = 8.5$ $d_3 = \infty$	2.2
12	ITC Quarters	Ilorin South	$\rho_1 = 270$ $\rho_2 = 108$ $\rho_3 = 1,240$	$d_1 = 0.75$ $d_2 = 33.0$ $d_3 = \infty$	$d_1 = 0.8$ $d_2 = 28.0$ $d_3 = \infty$	2.6
13.	Tanke-Mark	Ilorin South	$\rho_1 = 1,350$ $\rho_2 = 270$ $\rho_3 = 1095$	$d_1 = 2.0$ $d_2 = 13.0$ $d_3 = \infty$	$d_1 = 4.0$ $d_2 = 10.0$ $d_3 = \infty$	0.6

(N.A. $\Rightarrow$ Not Available).

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