

THE OCCURRENCE OF SHALLOW AQUIFERS IN PARTS OF SOUTHERN KADUNA METROPOLIS, NORTH-CENTRAL NIGERIA

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Abstract

The hydraulic characteristics of shallow aquifers in parts of Southern Kaduna Metropolis had been studied using geological mapping and inventory of hand dug wells as study approach. A total of one hundred and twenty-one (121) hand dug wells was investigated, taking static water level measurements each for the peak of dry season (March) and the peak of rainy season (August). The static water level in hand dug wells range from 0.48m to 11.68m and from 0.05m to 10.40m in dry season and raining season respectively. The contour pattern obtained from the static water level for the study area is characterized by isolated closures. The isolated closures are due to the discontinuous nature of aquifer systems found in crystalline basement areas. Groundwater flows from the recharge areas and moves towards the valley of Kaduna River and its main tributaries.

Keywords: geology, hydrogeology, shallow aquifers, Kaduna

Introduction

The term groundwater is usually reserved for the subsurface water that occurs beneath the water table in soils and geologic formation that are fully saturated. It supports drinking water supply, livestock needs, irrigation, industrial and many commercial activities (Egboka *et al.*, 1989).

In recent years, there have been rapid urbanization and population growth in the southern parts of Kaduna town as a result of migration of people to the area due to various crises in the northern part of the town. This resulted to an increased pressure on groundwater resources and increase in human activities such as establishment of industries, generation

of industrial waste, domestic sewage and other waste. The situation has resulted in increasing demand on shallow groundwater development as compliment to existing public supply which is surface water - based is inadequate for the ever increasing populace.

As a result of reliance on groundwater, there is indiscriminate and uncoordinated development in form of hand-dug wells, shallow drill- holes and deep wells. Lack of appropriate government policy and controls in respect of groundwater resource exploitation is responsible for this indiscriminate development. Consequently, such uncontrolled

developments have heightened the concern about impact on the

Description of Study Area

The study area is located in parts of Southern Kaduna Metropolis in Kaduna State, Nigeria (Figure 1). The area extent is defined by latitude $10^{\circ} 24.00'$ and $10^{\circ} 30.00'$ north of the Equator and longitudes $07^{\circ} 23.00'$ and $07^{\circ} 30.00'$ east of the Greenwich meridian. The area falls within 1:100,000 sheet 144 Kakuri topographical map with area coverage of about 135.70 square km. The project area falls within Kaduna South LGA and Chikun LGA of Kaduna State. Some of the notable settlements within the study area include Barnawa, Narayi, High Cost, Ungwan Television, Sabon Tasha, Ungwan Yelwa, Ungwan Romi, Goni Gora, Kakuri, Makera, Trikania, Nasarawa, Kinkinau, Juji, Kargi, Karuga and Kamazo.

total population of Kaduna South and Chikun LGA based on 2006 census is 402,390 and 368,250 people.

Therefore, the population of the study area is estimated to be about 500,250 people.



Figure 1: Location Map of the study area

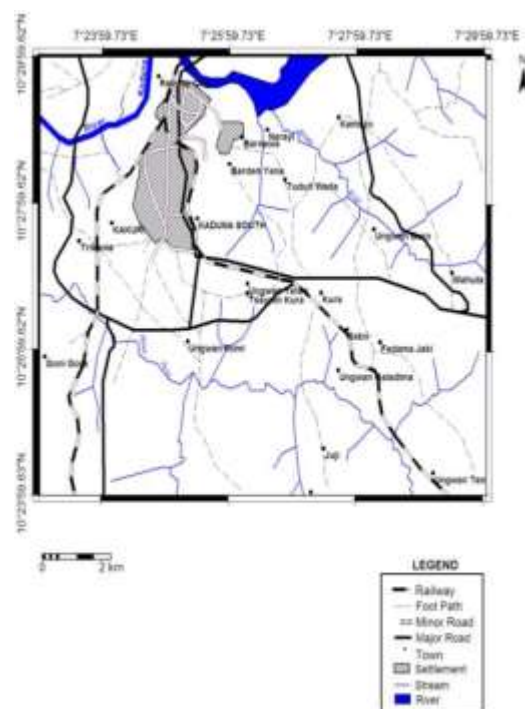
The study area is inhabited by the Gbagyi, the Kaje, the Adara, the Kataf (Atyap) and the non-indigenes. The area is moderately to densely populated. The

groundwater in the affected area.

The study area is accessible through both railway and by road. The railway systems are the Minna- Kaduna and Kafanchan-Kaduna rail lines. The road networks include the Abuja- Kaduna expressway from the south, the Kachia – Kaduna highway from the east, the Zaria – Kaduna road from the north and the Birnin Gwari- Kaduna road from the west (Figure 2). These major roads are linked with other minor roads, numerous footpaths and farm routes that enhance movement within the study area.

Figure 2: Accessibility and drainage map of the study area

The study area lies within the tropical continental climatic zone classified as A_w by Koppen (Mallo, 2001). The climate zone has distinct seasonal regimes oscillating between cold to hot dry and humid to wet. The two distinct climatic seasons experienced in the study area are raining season and the dry season. Raining season starts from April and lasts till October, with peak rainfall occurring in September (Abdullahi *et al.*, 2009). The dry season lasts between November and March. The second half



of the dry season, February - March, is the hottest period of the year when temperatures range from 33°C to 42°C.

The mean annual rainfall in the area is 1,263mm (Jasper, 2010). Temperatures vary between less than 15°C in December/January and 32°C in March/April (Abdullahi *et al.*, 2011). The maximum annual mean temperature (for 30 years from 1978 to 2008) ranged from 25.30°C $\pm$ 1.39 to 36.2°C, while the minimum temperature over the same period showed a minimum annual mean temperature

range of 28.45°C $\pm$ 3.27 to 34.38°C $\pm$ 2.43 (Abdullahi *et al.*, 2009).

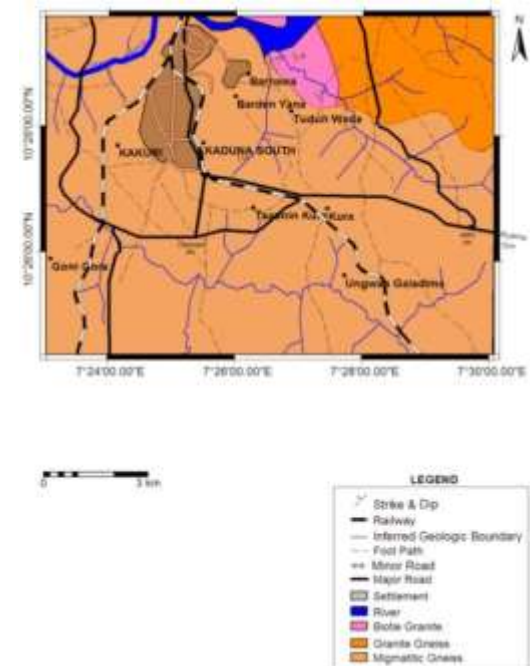
Africa Atlas (2002) indicated that the study area falls within the Northern Guinea savanna vegetation belt of Nigeria. The vegetation is characterized by grassland with scattered trees, scattered tall grasses and woody shrubs. The study area is drained by River Kaduna and its major tributaries (Figure 2). All the rivers exhibit dendritic pattern of flow. The rivers are all subjected to seasonal water level fluctuations due to influence of climate.

on the ratio of the mafic minerals to the felsic mineral in the rock.

Geology and Hydrogeology of the Area

The study area is part of northern Nigeria Basement Complex and is located within the Pan Africa Mobile belt. The study area is underlain by the rocks of the Migmatite-gneiss complex. The geological map (Figure. 3) of the study area showed that the area is underlain by migmatitic gneiss, granite gneiss and biotite/quartz gneiss. The migmatitic gneiss is the most abundant rock type in the study area (Figure 3) as it underlain over 90% of the study area, even though the soil cover obscures majority of them. The rock is a mixture of dark and light coloured rocks variety comprising paleosome and metasome. The metasome is the light coloured variety and is composed of quartzofeldspathic or granitic materials, while the paleosome is usually a biotite-rich gneiss and is dark in colour.

The granite gneiss represents about 4% of rock underlying the study area and is fine to medium grained. Its colour varies from light grey to dark grey depending



The biotite gneiss is dark grey in weathered sample, but light grey in fresh sample and is fine to coarse grained. The rock in the study area is moderately weathered and poorly to well fractured. These features enhance the aquifer potential of the rocks in the study area. Olugboye (1975) stated that the physical characteristics of the rocks in the area in terms of fractures are such that they form

moderate good aquifers. The two main types of aquifer in the study area are the weathered basement (the regolith) and joint/fractured basement aquifers. The joint/fractured Figure 3: Geologic Map of the study area.

basement aquifers generally occur below the regolith aquifer. The relative unconsolidated nature of the regoliths developed upon basement complex rocks enhances their porosity and permeability which facilitate substantial ingress and storage of water (Omorinbola, 1984). The Basement aquifers in the study area are essentially unconfined in nature. However, Wright (1992) stated that Basement aquifer can respond to localized abstraction in semiconfined fashion, if the rest water level occurs in a low joint/fractured basement aquifer permeability horizon, such as clayey regolith.

Methodology

A total of one hundred and twenty-one (121) hand dug wells was investigated, taking static water level measurements each for the peak of dry season (March) and the peak of rainy season (August). Other activities include description of the well location, well depth, water level in the wells and general environmental condition of each well. Generally, as a

standard the wells were chosen at random on the average distances between 300m to 500m to ensure an even distribution within the study area. The acquired field data were further evaluated using various software packages. Location map of the area was produced with ARCGIS software. ILWIS software was used to produce the geologic and accessibility maps, while Surfer 8 software was used to produce the hydraulic head distribution maps and 3-D model of the hydraulic head distribution maps of the area.

Results and Discussions

The summary of the results of the hand dug well inventory of the study area is presented in Table 1. Detailed measurement of static water level in hand-dug wells in the study area showed that the water table within the area is generally shallow. The static water level in the wells during the dry season ranges from 0.48m in Narayi (Loc. 6) to 11.68m in Kinkinau

(Loc. 98), with a mean value of 5.10m. The wet season value range from 0.05m in Railway Quarters (Loc. 94) to 10.40m in Kinkinau (Loc. 98), with a mean value of 2.40m. The table also indicated that the water column for the dry season varies from 0.02m to 6.73m, with a mean value of 0.98m, while that of the wet season varies from 0.19m to 7.32m, with a mean value of 3.64m. The wet season period indicated shallower static water level and higher value of water column than the dry

season. This is expected due to the influence of the climate. Olugboye (1975) in his work stated that the water level in wells of the study area at the depth range of 6.1m and 12.8m correspond to the estimated thickness of the saturated zone within the shallow laterite aquifer. This implied that majority of the shallow wells in the study area tap their water from the weathered overburden aquifer.

Table 1: Summary of the Hand dug well Inventory of the Study area during the dry and raining season periods.

S/N	Parameters	Dry season		Raining season	
		Range	Mean	Range	Mean
1.	Depth to water (m)	0.48 – 11.68	5.1	0.05 – 10.40	2.40
2.	Depth to 12.18	1.48 – 6.1	1.48 – 6.1 bottom (m)	12.18	
3.	Water 0.02 – 0.98	0.19 – 3.64	column (m)	6.73	7.32
4.	Hydraulic Head (m)	578.7 – 636.7	608.10	579.8– 641.6	610
5.	Elev. of 581 - 613	581 - 613	well (m)	645	645

Figures 4a and 4b shows the hydraulic head distribution of the study area in the dry and raining season periods respectively. The contour pattern obtained from the static water level for the study area is characterized by isolated closures. The isolated closures are due to the discontinuous nature of aquifer systems found in crystalline basement areas. This situation was observed in the field, whereby wells sited very close to each other showed varying depths of water levels. The static water level is relatively deeper in northeast, northwest, southeast, southwest and parts of the central parts of the study area around Karuga, Kamazo, Mahuta, Kinkinau, Kakuri, Nasarawa, Juji, Goni Gora, Ungwan Romi and parts of Ungwan Television

area. During the dry season period, the static water level in these areas vary from 2.98m (Loc. 12) to 8.08m (Loc. 16) in Ungwan Romi; 4.38m (Loc. 74) to 8.28m (Loc. 71) in Ungwan Maijero/ Karuga/ Kamazo/ Mahuta; 5.28m (Loc. 99) to 11.68m (Loc. 98) in Kinkinau; 2.48m (Loc. 90) to 8.18m (Loc. 61) in Nassarawa/ Kakuri; 5.13m (Loc. Loc. 17) to 8.58m (Loc. 103) in Goni Gora and 6.82m (Loc. 39) to 9.38m (Loc. 42) in Juji. Generally, in most of these areas the unweathered basement occurs at shallow depths or outcrops at the surface and thereby reduces the groundwater potential of the area. These areas are also found to be located at higher elevation and has deeper water level. Some of the wells in the area are seasonal. By contrast, the static water level is relatively shallow in the north central and some parts of the central parts of the study area where Baranawa, Narayi, Sabon Tasha are located. During the dry season period, the static water level in these areas vary from 0.48m (Loc. 6) to 4.18m (Loc. 52) in Narayi; 0.75m (Loc. 35) to 5.28m (Loc. 37) in Sabon Tasha and 0.89m (Loc. 45) to 4.82m (Loc. 50) in Barnawa. These areas has majority of their wells to be perennial and are found to be located at lower elevations and in the valley of Kaduna and its major tributaries. These areas generally have thicker weathered overburden.

The hydraulic head of the study area varies depending on the season. Table 1 and Figures 4a and 4b showed that the values range from 578.72m to 636.72m, with a mean value of 608.10m in dry season. In the wet season it varies from 579.80m to 641.58m and has a mean value of 610m. Naturally, groundwater flows perpendicularly from region of high head

(area of recharge) to that of lower head (points of discharge) such as stream, rivers and wells. Therefore, from the hydraulic head distribution map the study area, the directions of flow of the groundwater can be determined.

The hydraulic head between the dry season and wet season period did not show difference in the direction of flow. The distribution showed that water flow from the recharge area to that of the discharge area. The figures revealed that groundwater flows from the main recharge area at the central part of the study area (Kakuri, Ungwan Television, Ungwan Yelwa, Sabo Tasha) towards the valley of Kaduna River and its major tributaries of Romi, Gora, Kuyi and Rani Rivers. Other recharge zones occur in the northwest around Kinkinau, while in the northeast it occurs around Karuga, Kamazo, Mahuta area. In the southwest it occurs around Ungwan Romi, Goni Gora, while on the southeast part it occurs around JujiKakau area.

Figures 5a and 5b showed the hydraulic head distribution and 3-D model of the hydraulic head in the study area in the dry and raining season periods. The 3-D modelling of the area also showed the same trend as the hydraulic head distribution. In the 3-D model map, the recharge areas are located on highs and water flows from there down into the lower points of the discharge areas, which corresponds to Kaduna River valley and its major tributaries. These high points correspond to low (deeper) water table zones, while the low points correspond to high (shallower) water table zones.

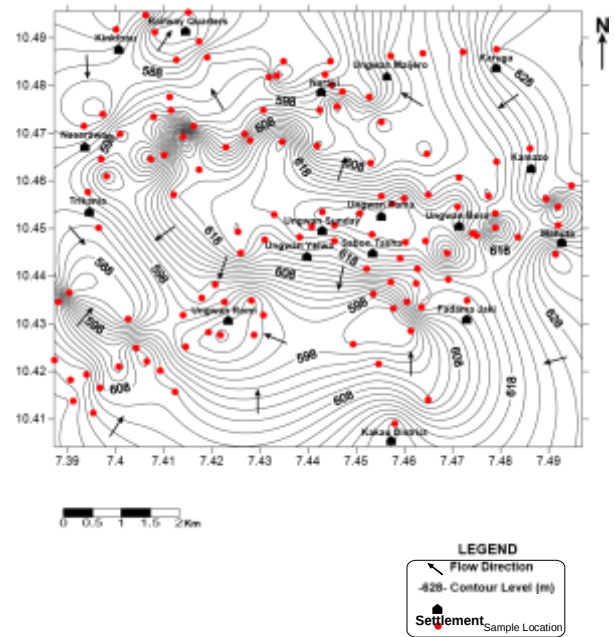


Figure 4a: Hydraulic Head distribution map of the study area during the dry season period.

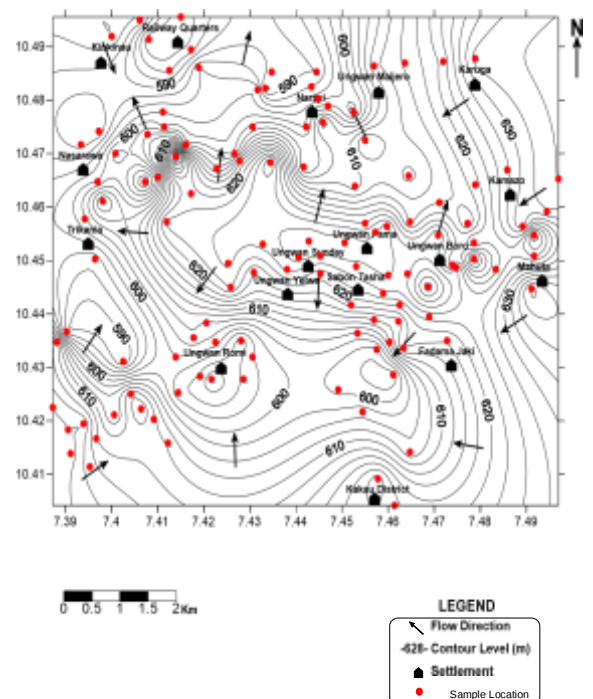


Figure 4b: Hydraulic Head distribution map of the study area during the raining season period.

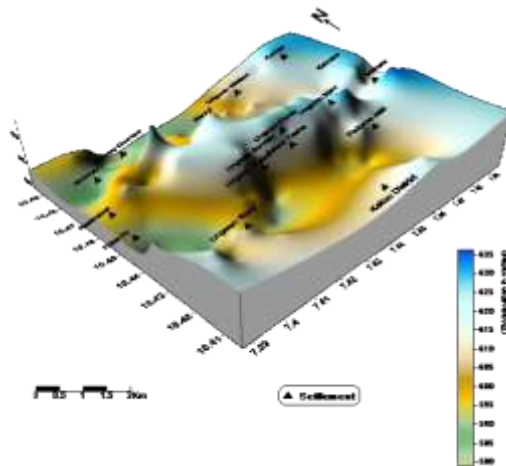


Figure 5a: 3-D model of the Hydraulic Head of the study area during the dry season period.

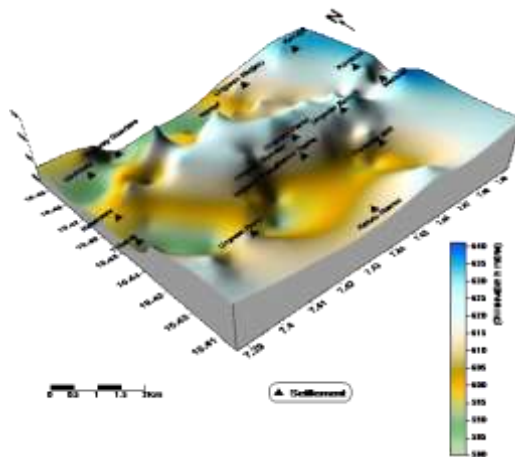


Figure 5b: 3-D model of the Hydraulic Head of the study area during the raining season period.

Conclusion

Groundwater in the study area occurs within the weathered overburden (regolith) aquifer and fractured basement aquifer. The water table within the area is generally shallow. The groundwater condition is that of unconfined aquifer that are discontinuous and their water levels fluctuate with percolation of precipitation with change of seasons. The static water level in hand dug wells range from 0.48m to 11.68m and from 0.05m to 10.40m in dry season and raining season respectively. The contour pattern obtained from the static water level for the study area is characterized by isolated closures. The isolated closures are due to the discontinuous nature of aquifer systems found in crystalline basement areas. The hydraulic head distribution of the study area revealed that groundwater flows from the recharge areas and moves towards the valley of Kaduna River and its main tributaries.

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