Hydrogeologic Conditions of Crystalline Basement Aquifers in Kauru Area of Kaduna, Nigeria

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ABSTRACT: The paper assessed the hydrogeologic conditions of the crystalline basement rocks underlying the Kauru Area of Kaduna using data obtained from 26 producing wells in the area. Certain hydrogeologic characteristics of the aquifer which affect well productivity were investigated and analyzed. The minimum, maximum and the averages of the range of values of the hydrogeologic parameters were presented. The water table contour map of the area was prepared from the static water level data, and it shows that water table is generally deeper around the northwest-southeast axis of the middle section of the study area than at the southwest and northeast flanks of the LGA boundary. Graphical representation of screen lengths and specific capacities revealed that screen length has a direct effect on the specific capacity. Regolith thickness and saturated thickness showed a near-parallel variation from one well location to the other. The Pearson Product Moment Correlation analysis showed a strong positive correlation value of 0.746 between yield and drawdown, a weak correlation value of 0.48 between pumping rate and drawdown, and a very weak correlation value of 0.071 between yield and regolith thickness in the study area. The Regression Analysis, on the other hand showed that while drawdown rate has very strong and fairly strong linear relationships with yield and pumping rate respectively, yield has a very weak linear dependence on regolith thickness.

Keywords: basement aquifer, hydrogeologic conditions, statistical analysis, regolith, yield

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1.0 INTRODUCTION

The study area is the Kauru Local Government Area of Kaduna State, Nigeria. It is located in the north central part of Nigeria between latitudes 10° 03'N and 10° 33'N and longitudes 7° 33' E and 8°13'E. Groundwater development in the area has been stimulated due to continued increase in demand for water, especially for individual and rural supplies, leading to the rapid expansion of knowledge of groundwater hydrology and better means of extracting groundwater. Despite this, groundwater potential in the Basement rocks is not well defined as it occurs in a complex manner. Thus, borehole productivity is often associated with certain characteristics of the aquifer such as regolith thickness, bedrock type and structure, saturated thickness and measured hydraulic parameters like hydraulic conductivity, specific capacity, drawdown, transmissivity and storativity, among others (Chilton and Smith-Carington, 1984; Omorinbola, 1984 and McCann, 1991).

Figure 1 shows the geologic map of Kauru Local Government Area (LGA) of Kaduna State, while Figure 2 shows the major rivers

and tributaries draining the LGA. The geology consists mainly of typical Basement complex rocks found in most parts of Kaduna State. The igneous and metamorphic rocks are mostly crystalline and they occur as granites, gneisses, migmatites, schists, phyllites, pegmatites or quartzites. They also include metasediments and volcanic rocks of different ages and petrography. Crystalline rocks weather more easily and deeply under humid conditions, and more water is available for storage under favourable rainy environments. But in arid and semi-arid conditions, the extent of weathering, fracturing and erosion is generally limited (McCann, 1991; Offodile, 1992). Despite this limitation, the prolonged in-situ weathering under tropical conditions has produced a lithologic sequence of unconsolidated material whose thickness and lateral extent vary extensively. The localization of groundwater within the lithologic zones is controlled by a number of factors such as type of parent rock, depth, extent and pattern of weathering, thickness of the weathered materials, the sand/clay ratio and the degree of fracturing, fissuring and jointing (Amadi and Teme, 1987; Odusanya, 1990; Eduvie and Olaniyan, 2013). Groundwater exploration in the crystalline basement complex areas of Nigeria requires good understanding of the lithologic characteristics of the area. In the northern and semi-arid climatic conditions of Nigeria, almost entirely underlain by crystalline formations, groundwater and surface water availability are scarce and problematic (Olabode et al, 2012). The vegetation of the area is characterized by the northern Guinea Savanna type, characterized by patches of woodland, herbs and grasses with few widely scattered deciduous trees, although continuous cultivation, bush burning and grazing activities have greatly modified the natural vegetation cover and composition.

The main purpose of this paper is to assess the hydrogeologic conditions of the study area vis-a-vis the water supply for rural and semi-urban population by comparing, evaluating and analyzing the hydrogeologic properties obtained from production data of some producing wells drilled through the Basement rocks in the area.

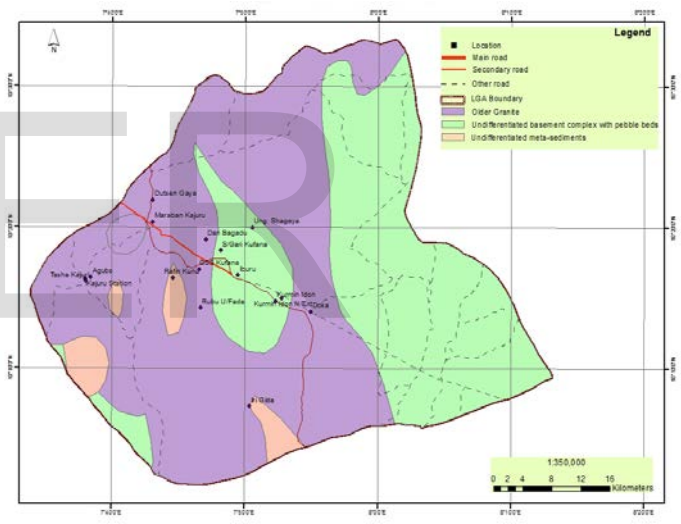

Fig. 1. Geologic Map of Kauru Local Government Area of Kaduna State

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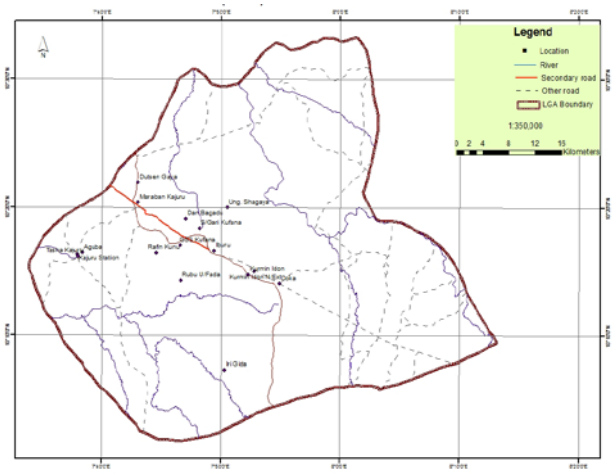

Fig. 2. Drainage Map of Kauru Local Government Area of Kaduna State

2.0 METHODOLOGY

Under the rural water supply programme of the Kaduna State Government of Nigeria, several boreholes were drilled into the crystalline basement complex rocks, and out of the successful ones, relevant hydraulic data were obtained for the 26 that were located within the Kauru LGA. Such data include static water level, depth to basement, pumping rate, drawdown, yield, screen length, regolith thickness and saturated thickness and were used to determine secondary data such as specific capacity and for further analysis and interpretation toward determining the hydrogeologic conditions of crystalline basement aquifers in the area.

3.0 RESULTS AND DISCUSSION

3.1 Aquifer Hydraulic Parameters

Table 1 below shows the summary of the aquifer hydrogeologic parameters for twenty-six producing wells in the study area. From the table, the static water level across the area varies from 3.3m to 9.3m with an average value of 5.85m. The depth to crystalline basement rocks range from 7m to 27m with mean depth of 16.61m. The average pumping rate is 34.54 l/min with minimum value as10 l/min and max value as 70 l/min. Drawdown is the difference between static and pumping water levels, and it averages 15.98m in the area. Well yield is the volume of water discharged per unit time from a well. Average yield of wells in the area is 51.69 l/min. The screen length and specific capacity have average values of 14.69m and 3.40 l/min respectively. The regolith thickness ranges from 7m to 27m while saturated thickness has a minimum value of 23.7m and a maximum value of 50.5m.

Table 1: Aquifer Hydraulic Parameters for Kauru LGA

Parameter	Unit	Min Value	Max Value	Mean
Static Water Level	m	3.3	9.3	5.85
Depth to Basement	m	7.0	27.0	16.61
Pumping Rate	l/min	10.0	70.0	34.54
Drawdown	m	3.4	22.6	15.98
Yield	l/min	21	270	51.69
Screen Length	m	6	18	14.69
Specific Capacity	l/min/m	0.44	20.47	3.40
Regolith Thickness	m	7	27	16.62
Saturated Thickness	m	23.7	50.5	39.42

3.2 Water Table Contour Map

The water table contour map (Figure 3) was prepared from the static water level data at the well points, and it shows the lateral variation in the depth to water table across the study area. The levels were generally affected by the subsurface geology. The figure shows that water table is generally deeper around the northwest-southeast axis of the middle section of the study area than at the southwest and northeast flanks of the LGA boundary.

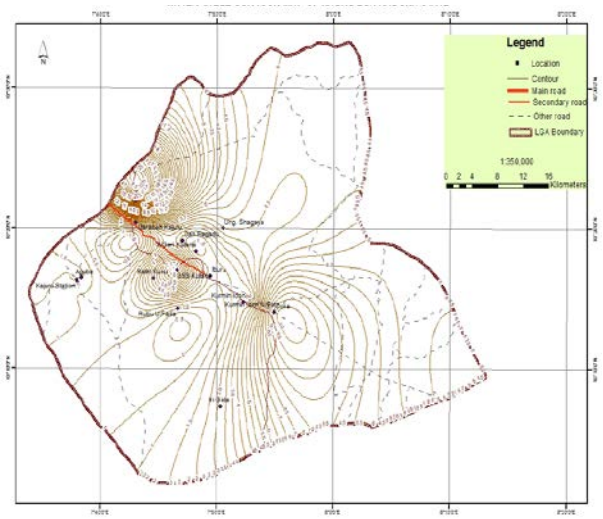

Fig. 3. Water Table Contour Map of Kauru Local Government Area of Kaduna State

3.3 Relationship between Screen Length and Specific Capacity

The screen length determines the amount of pathway available to groundwater for suction into a pumping well. Specific capacity is defined as the yield of a well per unit of drawdown, provided that the two quantities are measured at the same time. Specific capacity gives a better indication of aquifer performance than yield since it also reflects aquifer transmissivity and thickness (Uma and Kehinde, 1994; Olaniyan and Tsuzom, 2014). Figure 4 shows plots of screen lengths and specific capacities at the well locations. The figure shows a fairly related pattern of variation from one well location to the other. It can, therefore, be inferred that screen length has a direct effect on the specific capacity.

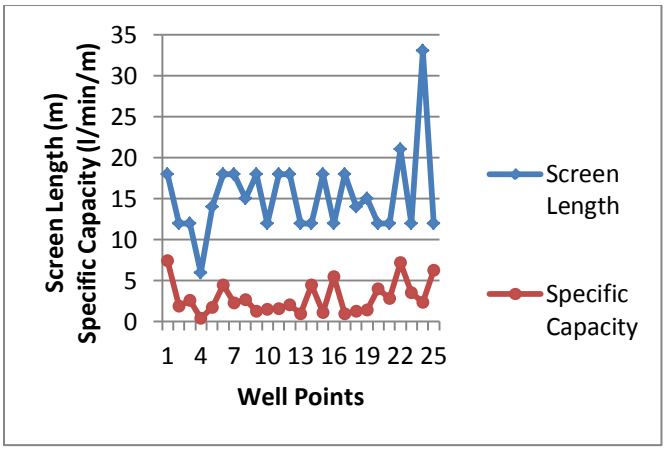

Fig. 4. Relationship between screen length and specific capacity

3.4 Variation of saturated thickness and regolith thickness

The saturated thickness in a water well generally refers to that portion of the well below the water table in which all the pore spaces are fully saturated with water. Its value is determined based on the depth penetrated by the well. The regolith thickness, on the other hand, refers to the thickness of the overburden soil above the basement rocks. Hazell et al (1992) classified the regolith according to grades of weathering from silty clay with no relict textures (Grade IV) down to the fresh rock (Grade I). The weathered or fractured Basement horizons are the principal targets for groundwater abstraction. The contributions of these two thicknesses to well productivity or yield will depend on the variations in grain-size, texture and degree of fracturing of the bedrocks and of the regolith. Figure 5 shows a graphical comparison of the two thicknesses. The figure shows a near-parallel variation in the two thicknesses from one well location to the other.

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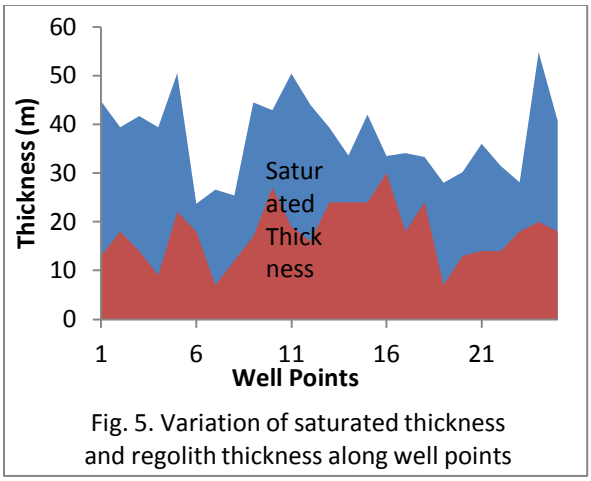

Fig. 5. Variation of saturated thickness and regolith thickness along well points

3.5 Statistical Evaluation of Some Hydrogeologic Conditions

The extent of interrelationship among some hydrogeologic conditions in the study area was investigated using the Pearson Product Moment Correlation analysis. The result showed a strong positive correlation value of 0.746 between yield and drawdown, a weak correlation value of 0.48 between pumping rate and drawdown, and a very weak correlation value of 0.071 between yield and regolith thickness in the study area. The evaluation further considered the linear relationship between the hydrogeologic conditions using Regression Analysis. The regression line of yield on drawdown gave a coefficient of 0.864 (figure 6); pumping rate on drawdown has a coefficient of 0.693 (figure 7), while yield on regolith thickness gave a coefficient of 0.266. The deduction that could be made from this analysis is that while the rate of drawdown has very strong and fairly strong linear relationships with yield and pumping rate respectively, yield has a very weak linear dependence on regolith thickness as far as the data could reveal for the study area. However, a more detailed relationship between these hydrogeologic conditions may require more than such a simplified linear model if desired.

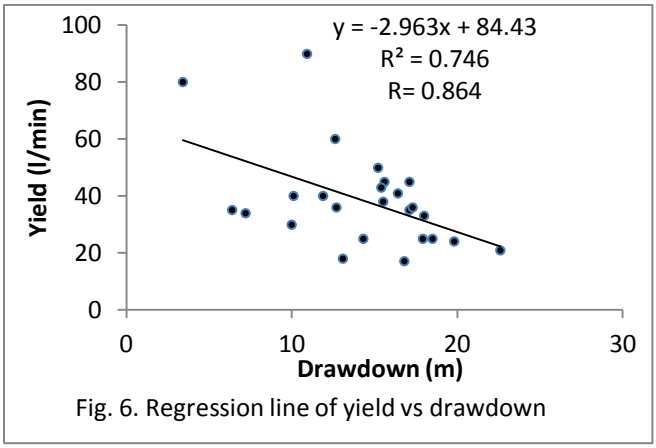

Fig. 6. Regression line of yield vs drawdown

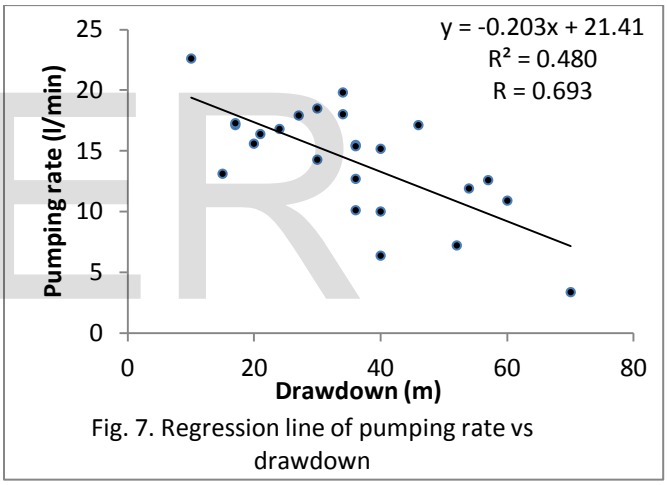

Fig. 7. Regression line of pumping rate vs drawdown

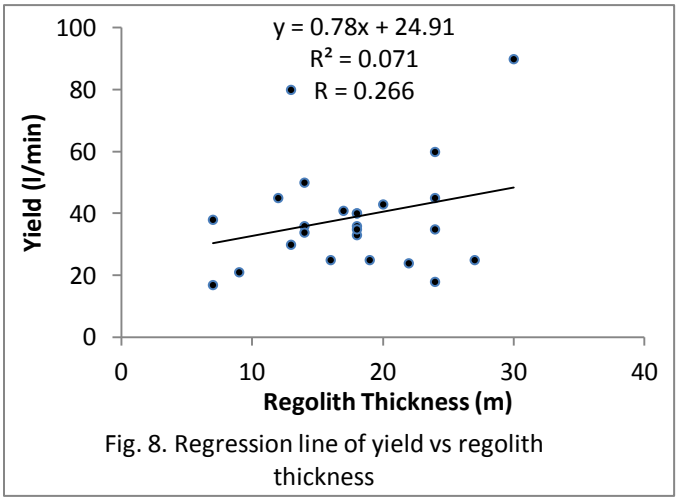

Fig. 8. Regression line of yield vs regolith thickness

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4.0 CONCLUSION

The hydrogeologic conditions of the study area have been assessed. Water table is generally found to be deeper around the northwest-southeast axis of the middle section than at the southwest and northeast flanks of the study area. It was observed that screen length has a direct effect on the specific capacity due to the observed pattern of variation between them. There exists a near-parallel variation between saturated and regolith thicknesses from one well location to the other. Further analysis revealed that while the rate of drawdown has very strong and fairly strong linear relationships with yield and pumping rate respectively, yield has a very weak linear dependence on regolith thickness.

REFERENCES

Amadi, U.M.P. and Teme, S.C. (1987). The engineering characteristics of soils around Abuja. Nigerian Journal of Mining and Geology. Vol. 23.

Chilton, J.P. and Smith-Carington, A.K. (1984). Characteristics of the weathered basement aquifer in Malawi in relation to rural water supplies. Challenges in African hydrology and water resources. IAHS Publ. No.144, pp.57-72.

Eduvie, M.O. and Olaniyan, I.O. (2013). Groundwater quality appraisal in southern parts of Kaduna State, Nigeria. *American Journal of Environmental Engineering* **3**(1): 77-83, Scientific & Academic Publishing, U.S.A. http://journal.sapub.org/ajee

Hazell, J.R.T., Cratchley, C.R. and Jones, C.R.C. (1992). The hydrogeology of crystalline aquifers in northern Nigeria and geophysical techniques used in their exploration. In: Wright, E.P. and Burgess, W.G. (Eds.) The hydrogeology of crystalline basement aquifers in Africa. *Geological Society Special publication No. 66, London*.

McCann, B. (1991). Pump solution to North Nigeria water shortage. *World Water and Environmental Engineer*. Jan/Feb 1991:29-30.

Odusanya, B.O. and Amadi, U.M.P. (1990). An empirical resistivity model for predicting shallow groundwater occurrence in the basement complex. Water Resources -Journal of the Nigerian Association of Hydrogeologists. 2(1): 77-87.

Offodile, M.E. (1992). *An approach to groundwater study and development in Nigeria*. Mecon Services Limited, Jos. pp. 67-68.

Olabode, T.O., Olaniyan, I.O. and Onugba, A. (2012). Optimum Drilling Depth of Boreholes in the Crystalline Basement Rocks of Nigeria. *Journal of Mechanical and Civil Engineering* **4**(2): 23-26, www.iosrjournals.org

Olaniyan, I.O. and Tsuzom, J.N. (2014). An appraisal of certain characteristics of aquifer in Chikun Local Government Area of Kaduna, Nigeria. *International Journal of Engineering Science & Advanced Technology* (*IJESAT)* **4**(6): 554-559, http://www.ijesat.org

Omorinbola, E.O. (1984). Groundwater resources in tropical African Regolith. Challenges in African Hydrology and Water resources. *IAHS Publication*, No.144, pp.15-23.

Uma, K.O. and Kehinde, M.O. (1994). Potentials of regolith aquifers in relation to water supplies to rural communities: A case study from parts of Northern Nigeria. *Journal of Mining and Geology*, 30 (1): 97-109.

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