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BASEMENT AQUIFER HYDROLOGIC EVALUATION IN SOBA AND ENVIRONS, NIGERIA

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ABSTRACT

This study evaluates the hydrologic properties of basement aquifer in Soba area of Kaduna State in north central part of Nigeria, especially because hydrology, among other things, studies the occurrence, properties and behavior of water at any location. The data obtained from 56 producing wells in the area were used to evaluate the basement aquifer in the study area. Hydrologic properties of the aquifer which have significant effect on borehole productivity were investigated and analyzed. The maximum, minimum and the mean of the range of values of the hydrologic parameters are provided. The transmissivity values of the wells were computed and compared using three different methods, namely Babuskin, Jacob and Logan methods. The transmissivity values obtained using Babuskin method ranged from 1.27 to 26.19 $m^2.day^{-1}$, those from Jacob method ranged from 1.18 to 4.68 $m^2.day^{-1}$, while Logan method gave transmissivity values ranging from 1.66 to 31.23 $m^2.day^{-1}$. The values from Babuskin and Logan methods compared closely but far higher than the values obtained from Jacob method. The highest values were obtained at three locations, namely Kwalliga with 30.11 $m^2.day^{-1}$, Angwan Liman with 31.00 $m^2.day^{-1}$ while Karofi has 31.23 $m^2.day^{-1}$. The minimum values of transmissivity converged at Madarzai from each of the three methods used. The hydrologic data were further used to generate the basement isochore map and the water table map for Soba and environs.

KEYWORDS: Hydrologic evaluation, basement aquifer, transmissivity, water table, hydraulic conductivity, Soba.

1.0 INTRODUCTION

Groundwater resources in Nigeria are vast and extensively abundant. The availability and potential for development of groundwater in a particular area depend on the subsurface geologic formations. Formation or strata within the saturated zone below the ground surface from which groundwater can be obtained for beneficial uses are called aquifers. Most aquifers cover large areas and may be visualized as underground storage reservoirs. In addition to performing storage function, aquifers also perform conduit function. The ability of an aquifer to perform these functions effectively depends on certain hydrologic properties, namely hydraulic conductivity, transmissivity, storage coefficient and specific yield (Olabode and Eduvie, 2006). These properties also affect, to a large extent, the productivity of the borehole penetrating the aquifer. A critical evaluation of these properties will assist in achieving sustainable groundwater development.

The area under investigation is Soba and environs in Soba Local Government Area of Kaduna State, in the north central part of Nigeria (Figure 1). It has its headquarters in Maigama, and covers a total area of 2,234 km2, with a population of 293,270 at the 2006 census. The study area is situated approximately between latitudes 10º 43' and 11º 15'N, and between longitudes 07º 53 and 8 24'E in the Galma Basin. It is generally underlain by the Basement rocks of the Precambrian age and the rocks consist mainly of the migmatites, granites, gneisses, schists, the metasediments and the Older Granites (Figure 2). Granitic intrusions form a suite of batholiths, while the gneisses are found as small belts within the granite intrusions (McCurry, 1976; Jones, 1957). These rocks are hard, with low permeability and generally not water-bearing. The rocks are aquiferous only when they are weathered or fractured, otherwise they are dry or at best contain just little amount of water (Oluyide, 1995; Olabode *et al*, 2012). The weathered Basement rocks therefore provide the most widespread source of groundwater in the basin. Basement aquifers occur within the weathered residual overburden (the regolith) and the fractured bedrock. Development of the regolith aquifer component is by wells and shallow boreholes which can be drilled by lightweight percussion rigs, while prospecting into the fractured bedrock will require more powerful drilling rigs, preferably using hammer. Basement aquifers are essentially phreatic in nature, but may respond to localized abstraction in semi-confined fashion if water level occurs in a low-permeability horizon, such as clayey regolith (Wright, 1992; Olaniyan et al, 2011).

The aim of this study is to evaluate the aquifer system in Soba and its environs. The study is pertinent due to the increasing rate of large scale development of groundwater going on in the area. Several boreholes have been drilled in the area; while some of them have low yields, some have failed resulting in lack of water supply to meet the needs of the people. The result of this study will provide insight into the aquifer system with a view to ensuring sustainable groundwater development in the study area.

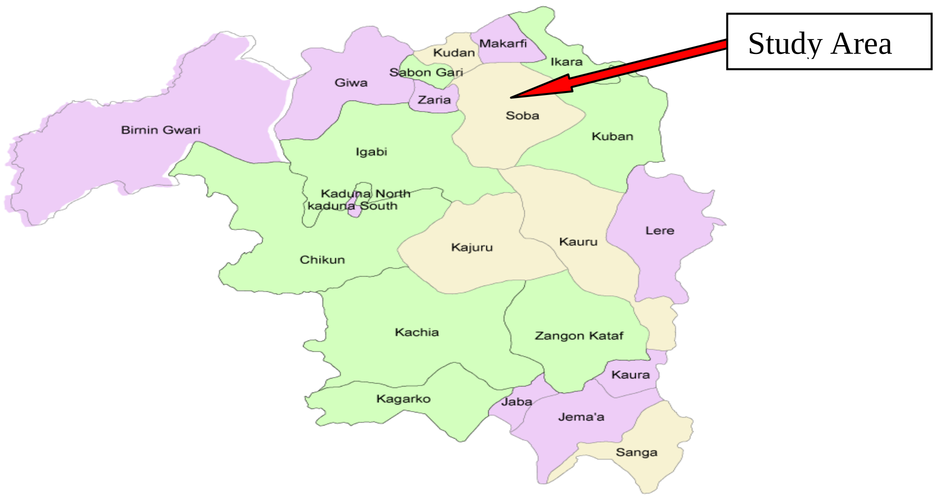

Figure 1: Map of Kaduna State by Local Government Area.

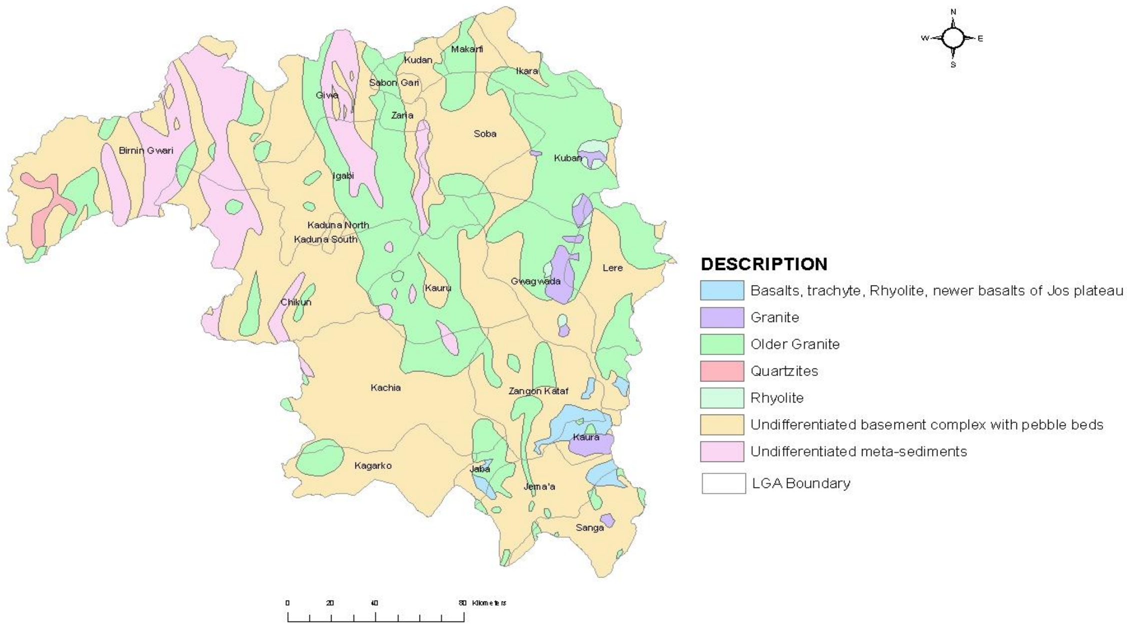

Figure 2: Geological Map of Kaduna Sta.

2.0 MATERIALS AND METHODS

The study requires conducting an inventory of existing and producing boreholes within Soba and its environs. The inventory consisted of a total of 56 boreholes which were mostly drilled during various government-sponsored water supply programmes in Kaduna State. The borehole data were obtained from Kaduna State Water Board. Aquifer hydrologic parameters such as hydraulic conductivity, specific capacity and transmissivity were computed from the basic pumping test data. Transmissivity is the rate of flow of water through a vertical strip of an aquifer of unit width and full depth under a unit hydraulic gradient (Garg, 2011). It indicates how much water will move through the water-bearing formation.

Transmissivity was calculated using three different methods, namely the semi-equilibrium Jacob analysis (Cooper and Jacob, 1946), Babuskin approximate method (Babuskin, 1954) and Logan method (Logan, 1964). The Jacob method of analysis is represented by the following equation:

$$T = \frac{2.3Q}{4\pi\,\Delta S} \tag{1}$$

Where T is the transmissivity in $m^2.day^{-1}$, Q is the discharge in $m^3.day^{-1}$, and ΔS is the drawdown over one log cycle in metres. Babuskin evolved a relationship for determining the hydraulic conductivity, K, given as:

$$K = \frac{0.366\,Q}{LS}\log\frac{1.32\,L}{r_w} \tag{2}$$

Where K is measured in $m.day^{-1}$, Q is borehole discharge in $m^3.day^{-1}$, L is the length of screen (m), S is the drawdown (m) and r_w is the radius of the borehole (m). Using the calculated value of K from the above equation (2), transmissivity can then be calculated from the relationship $T = Kb$, where b is the thickness of the aquifer. The Logan method of computing transmissivity, T ($m^2.day^{-1}$) is expressed by the equation:

$$T = \frac{1.22\,Q}{S_m} \tag{3}$$

Where Q is the discharge in $m^3.day^{-1}$, and S_m is the maximum drawdown.

The depths to basement rock were extracted from the drilled well data, and were used to plot the basement isochore map of the area, while the depths to the water table at the well locations were obtained to prepare the piezometric surface contour map of the study area. The two maps were plotted using Surfer 12 software.

3.0 RESULTS AND DISCUSSION

3.1 Hydrologic Parameters

The summary of groundwater hydrologic parameters of the study area is presented as Table 1.

Table 1: Summary of Groundwater Hydrologic Parameters of Soba Area.

	Depth to Water Table	Depth to Basement	Pumping Rate	Draw down	Specific Capacity	Hydraulic Cond.	Transmissivity *($m^2.day^{-1}$)*		
Unit	*m*	*m*	*l/min*	*m*	*l/min/m*	*m/day*	**Babuskin**	**Jacob**	**Logan**
Max.	14.7	70	132	20.8	17.6	2.25	26.19	4.68	31.23
Min.	3.4	18	15	1.8	1.01	0.064	1.27	0.25	1.66
Mean	7	36.7	41	11.5	4.5	0.46	6.06	1.18	7.89

The pumping rate ranges from 15 to 132 lit/min with corresponding drawdown varying between 1.8m at Karofi to 20.8m at Ungwan Jide. Drawdown is the difference between static and pumping water levels, and it has been reported that the rate of drawdown has strong linear relationships with yield and pumping rate of an aquifer (Olaniyan and Gwari, 2015). The drawdown in the study area ranged from 1.8 to 20.8m with an average value of 11.5m.

The Specific capacity generally gives a better indication of aquifer performance than yield since it also reflects aquifer transmissivity and thickness (Uma and Kehinde, 1994). The range of values for specific capacity in the area is 1.01 to 17.6 lit/min/m, with an average value of 4.5 l/min/m, while the hydraulic conductivity ranges from 0.064 to 2.25 m/day. These values may be attributed to the variations in degrees of fracturing, grain-size and texture of the bedrock. It is noteworthy that the lowest values of specific capacity and hydraulic conductivity occurred at Ungwan Jide while the highest values were found to occur at Angwan Liman.

The transmissivity values computed using Babuskin method ranged from 1.27 to 26.19 $m^2.day^{-1}$, while that of Jacob method vary from 1.18 to 4.68 $m^2.day^{-1}$. Logan method gave transmissivity values ranging from 1.66 to 31.23 $m^2.day^{-1}$. The values from Babuskin and Logan methods are closely comparable, and are far higher than the values generated from the Jacob method. The maximum values peaked at Kwalliga (30.11 $m^2.day^{-1}$), Angwan Liman

(31.00 $m^2.day^{-1}$) and Karofi (31.23 $m^2.day^{-1}$). However, the minimum values of transmissivity from each of the three methods being compared converged at Madarzai.

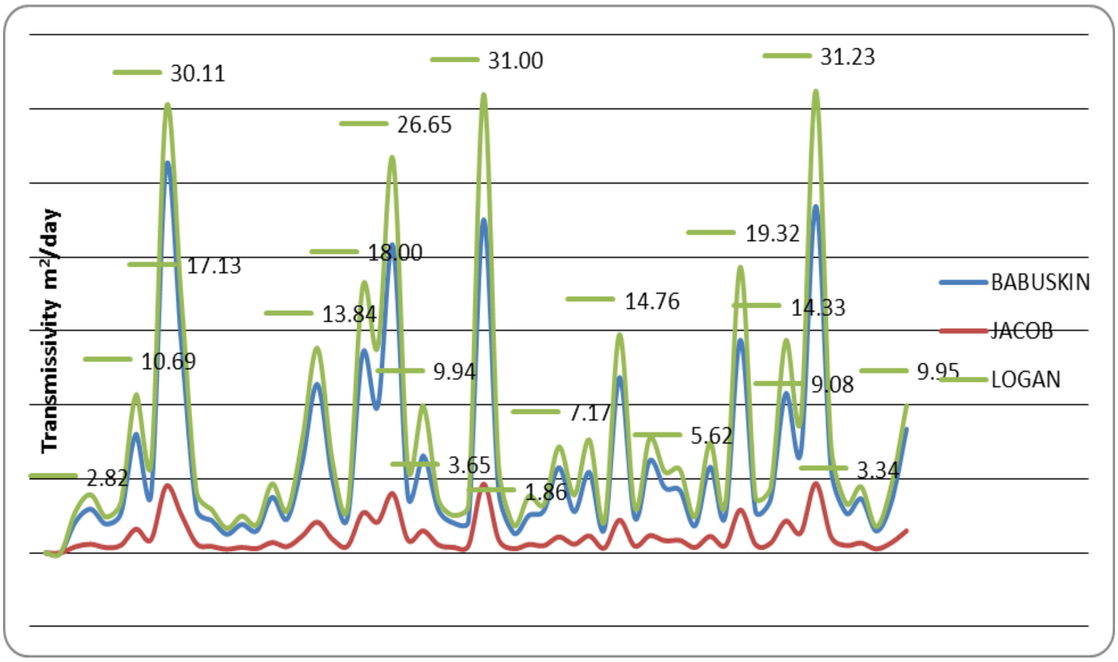

Figure 3: Graphical Comparison of Transmissivity Values.

Figure 3 shows the graphical comparison of the computed transmissivity values using the three methods. From the figure, although the values of transmissivity from each method vary, they generally assume a near-parallel relationship. According to the classification given by Gheorghe (1978), transmissivity range of 5 - 50 $m^2.day^{-1}$ can be regarded as low potential in terms of yield. This is, however, typical of basement complex aquifers which are essentially phreatic in character with typical low storativity of fracture systems, but increase in yield may require interaction with storage available in overlying or adjacent saturated regolith or alluvium (Wright, 1992).

3.2 Basement Isochore Map and Piezometric Surface Map

The depth to basement isochore map and the water table surface map of the study area are presented as Figures 4 and 5 respectively. The Basement isochore map shown as Figure 4 was prepared by using the data obtained for the depths to Basement complex rocks at each of the 56 well locations, and the figure shows the depth of occurrence of the basement rock at different locations within the study area. The depth to the Basement rock is shallowest at Gurbabiya (18m) and deepest at Bakura (70m) and the average depth is 36.7m.

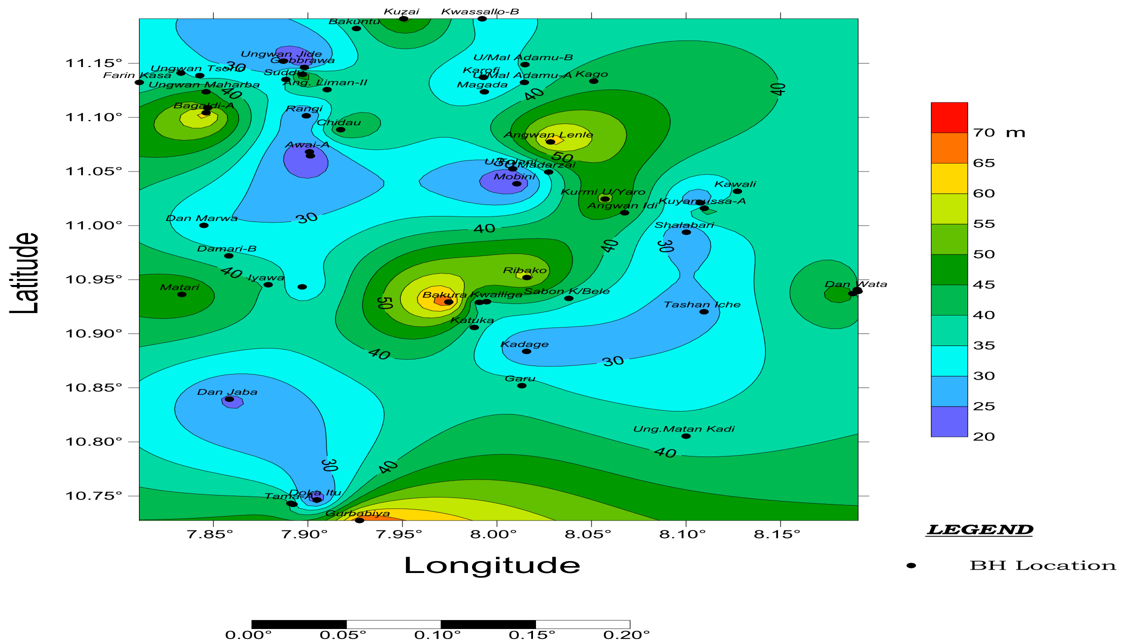

Figure 4: Depth to Basement Isochore Map of the Study Area.

The depth to water table contour map (Figure 5) was similarly prepared from the static water level data at the 56 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 depth to the water table was found to be shallowest (3.4m) at Angwan Idi and deepest at Rangi (14.7m) with an average value of 7m.

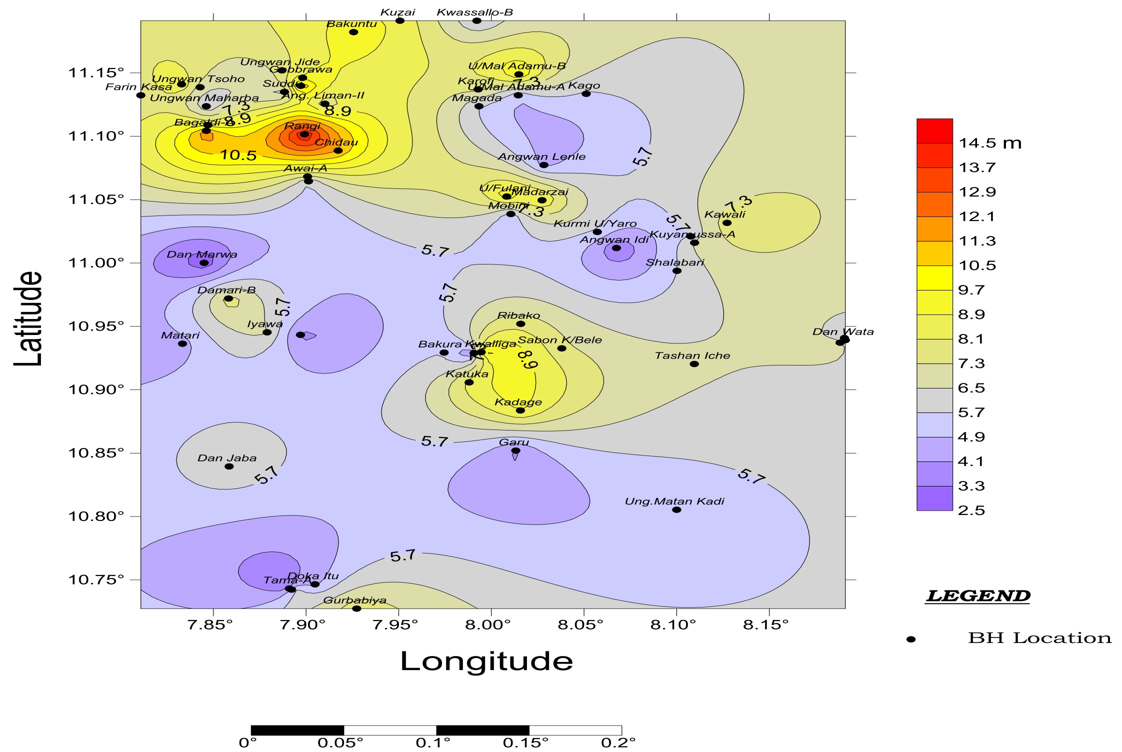

Figure 5: Depth to Water Table Map of the Study Area.

4.0 CONCLUSION

The hydrologic evaluation of the Basement aquifer of Soba and environs has been carried out using data obtained from 56 drilled and completed boreholes in the area, with a view to determining their potential for the supply of adequate portable water for the semi-urban communities in the area. The transmissivity values computed from the Babuskin and Logan methods are closely comparable, and are far higher than the values generated from the Jacob method, although the values from the three methods assume a near-parallel relation. The maximum values of transmissivity peaked at Kwalliga, Angwan Liman and Karofi, while the minimum values from each of the three methods converged at the same location, Madarzai. The depth to basement map and the depth to water table map were generated for the study area using the hydrological data obtained from 56 wells located in the area, thus providing valuable data for groundwater prospecting, monitoring and research.

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