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Full Length Research Paper

Estimates of Aquifer Transmissivity from Specific capacity data in Sandstone Aquifers in Enugu State, Southeastern Nigeria

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ABSTRACT

Estimates of aquifer transmissivity from specific capacity data of water wells from seventy (70) locations in Enugu state has been carried out. The simulation by Razack and Huntley was utilized. The area is underlain by the Nsukka and Ajalli Formations. Large data on specific capacity of water wells in these areas exists. Aquifer transmissivity values range from 66.08m^2/day to 1478.93m^2/day with the average indicating a high potential aquifer transmissivity, when compared with the Gheorghe aquifer transmissivity classifications. Various contour maps of aquifer transmissivity, specific capacity, yield, static water level and aquifer depth were produced to show these parameter variations in the study area. This could be a better exploration model in future. A better idea of the groundwater potentials and disposition of the area has also emerged from this study.

Keywords: Aquifer transmissivity, Specific capacity, Borehole yield, Static water level.

INTRODUCTION

The study area lies within latitude $6^{0}\ 02^{I}$ N to $6^{0}\ 59^{I}$ N and longitude $7^{0}\ 2^{I}$ E to $7^{0}\ 31^{I}$ E with an area extent of about 5,657.39sqkm. The area is composed of (figure 1) the Udi, Ezeagu, Nsukka, Igbo-etiti, Oji River and Isi Uzo local government areas of Enugu state. The area is characterized by several water wells which have been drilled by the state water board and by the federal government, under its last “National Borehole Programme”. Ninety-seven percent (97%) of these boreholes tap the Ajalli Sandstone aquifers. The prolific nature of the Ajalli Sandstone as an aquifer has been known for a longtime (Offodile, 2002, Ezeigbo and Obiefuna, 1995, Ofomah and Ezeigbo, 1997). Pump tests analysis of these water wells produced the drawdown, aquifer yield and specific capacity. Data on the aquifer transmissivity of these water wells largely does not exist. Aquifer transmissivity is an integral part of aquifer hydraulics characterization. It is a concept that assumes flow through the aquifer to be horizontal (Fetter, 2001). The present study computes the aquifer transmissivity from the specific capacity, using the relation by (Razack and Huntley, 1991). Computed values indicates high aquifer transmissivity which are required for irrigation, municipal and industrial purposes (Gheorghe, 1978). The present work also contributes to the overall management programme which will culminate in the future in a sophisticated mathematical model for managing the water resources of the Anambra Basin.

GEOLOGY

The study area is underlain by two geologic formations: the Nsukka and the Ajalli Formation (Figure 2). The Nsukka Formation consists of fine-medium grained sandstones, carbonaceous shale, clay, siltstone and bands or seams of impure coal. Eroded remnants of this formation constitute outliers and numerous springs issue out from the flanks of the outliers. The springs are mainly contact springs emerging at the contact of the sandy units of the Nsukka Formation. It has a thickness which varies from over 200m around Aku to a mean of about 100m further south (Ofomah and Ezeigbo, 1997). The basal shale units generally confine the Ajalli Sandstone. The Ajalli Sandstone conformably underlies the Nsukka Formation (Reyment, 1965). It consists of friable,

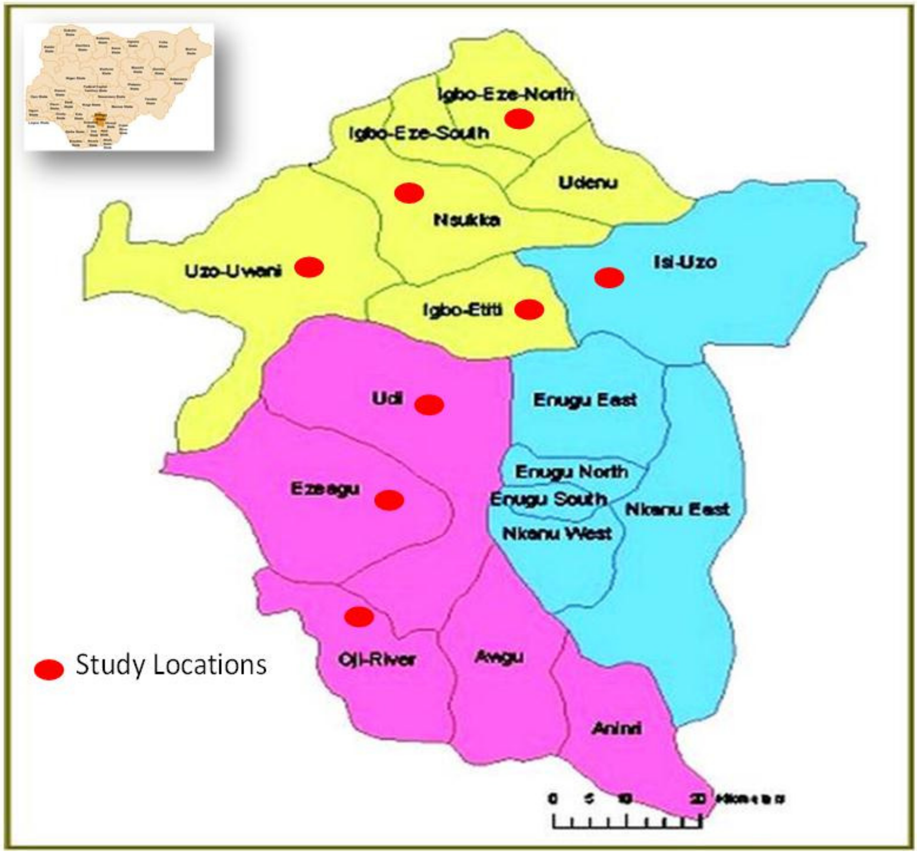

Figure 1: Map of Enugu state showing study area locations (insert: map of Nigeria). (World Gazette, 2011).

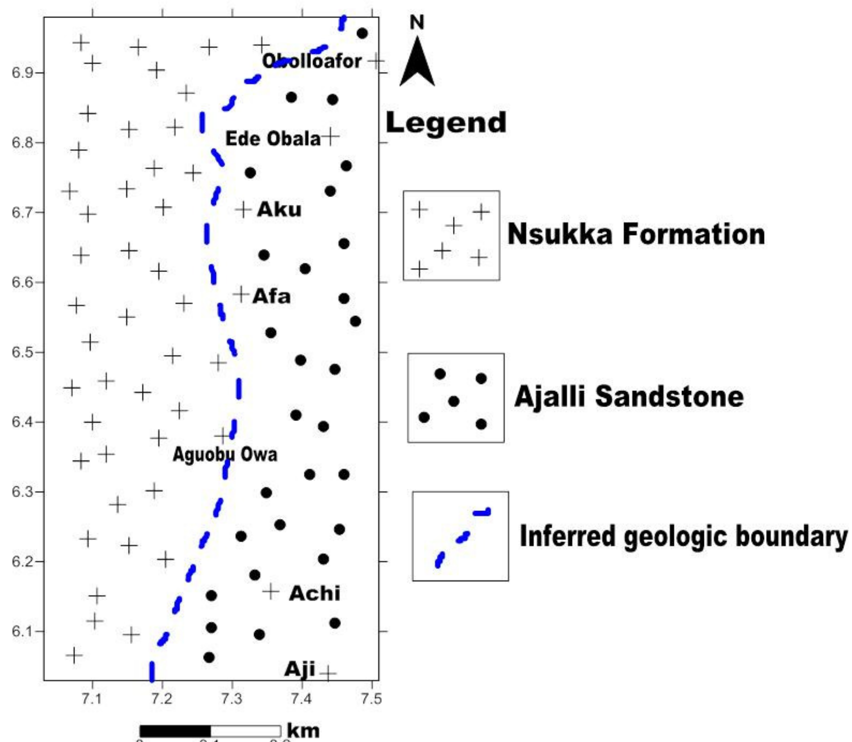

Figure 2: Geological map of the study area

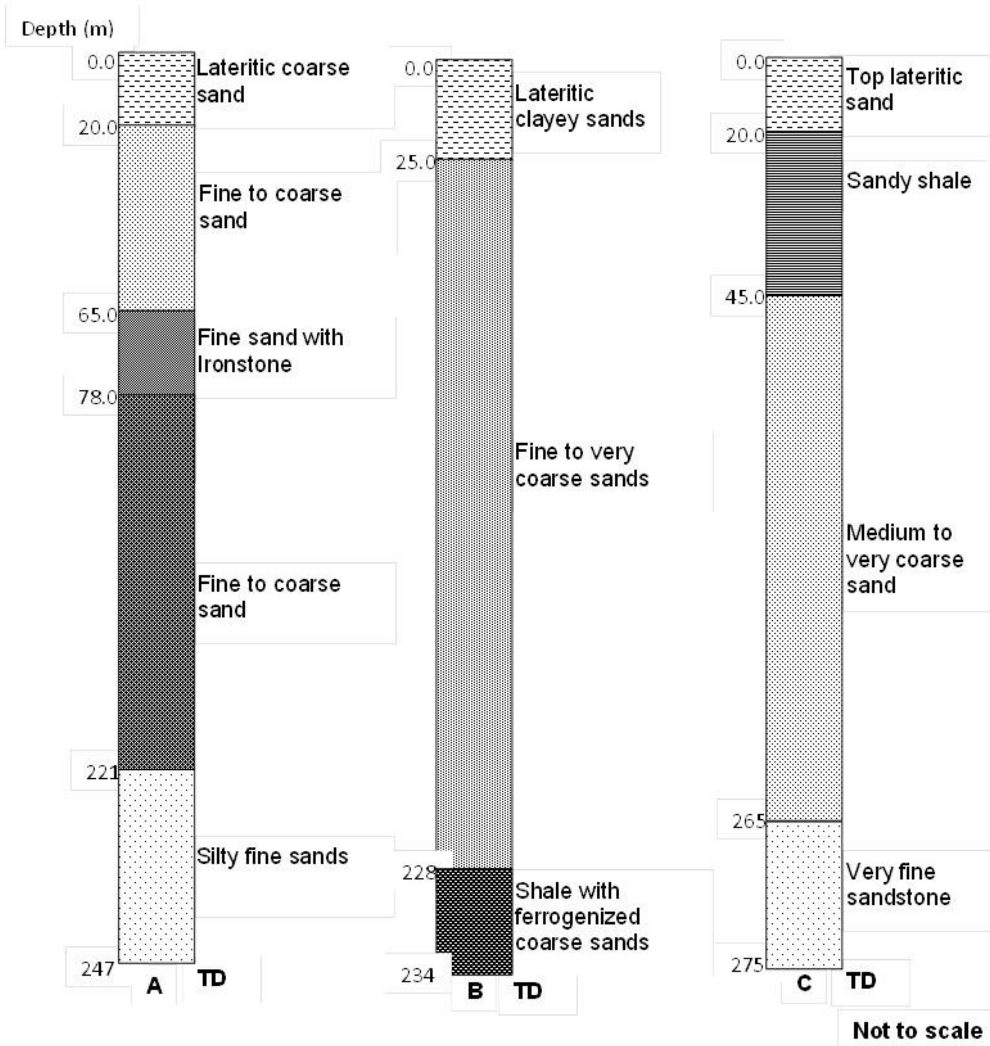

Figure 3: Well logs of water wells from the study area (**A**) Umulumgbe, (**B**) Ekwegbe and (**C**) Ede-oballa. TD (Total Depth)

cross-bedded, fine-medium, coarse grained sandstone that is very permeable. It is generally white in colour but it is sometimes iron-stained. Intercalations of mudstone and shale occur creating semi-confining conditions in places. Its thickness averages 300m with most of it saturated. It is the most aquiferous rock type in the study areas.

HYDROGEOLOGY

Surface water is very uncommon in the study areas and infiltration of rain water into the subsurface is very rapid due to the very porous and unconsolidated nature of the underlying Ajalli Sandstone. In groundwater terms, the most aquiferous geologic formation in the study areas is the Ajalli Sandstone and the sandy units of the Nsukka Formation. Well logs in figure 3 indicate that the aquifer is predominantly sands/sandstones with sandy clay and clay/shale as semi-confining aquitards or confining aquicludes. Confining condition has been reported in areas like Mgbagbuowa, Obinofia Ndiuno, Umumba Ndiagu, Adani, Aguobu Umumba and Oji River which produced artesian water profusely. (Ofomah and Ezeigbo, 1997). Water table condition largely exists in areas like Nsukka, Ukehe, Okpatu, Ngwo, Ngwo, Umulumgbe and Awhum. Variations in the static water levels are quiet significant.

METHODOLOGY

Many empirical relationships exist between aquifer transmissivity and specific capacity. Theis (1963) proposed a way of estimating the aquifer transmissivity from the specific capacity of a well by using this equation.

$$T = \frac{Q}{(h_0 - h)} \; \frac{2.3}{4\pi} \; \text{Log} \, \frac{2.25Tt}{r^2 s} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1) \quad \text{(Confined Aquifer)}$$

where $Q/h_0 - h)$ is the specific capacity of the well (m^2/day/m)

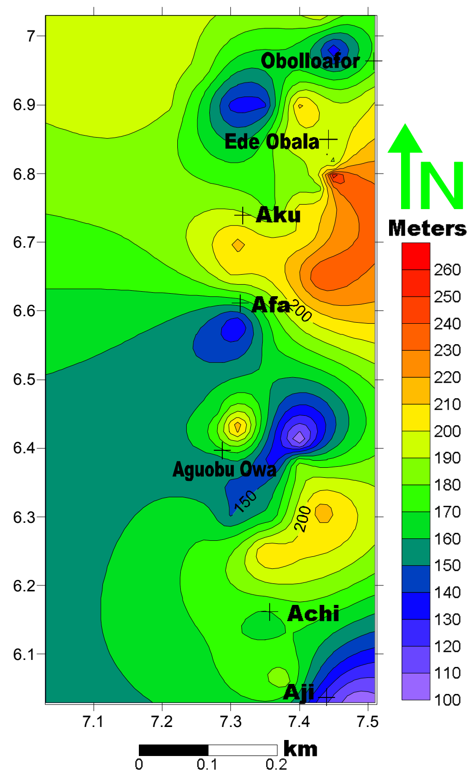

Figure 4: Aquifer depth map of the study area.

t is the period of pumping (T; day)
r is the radius of the pumping well (L; ft or m)
T is the aquifer transmissivity (L^2/T; ft^2/day or m^2/day)
S is aquifer storativity (dimensionless).

This formula has two flaws according to Theis (1963). First, estimate of T and S are made at the Log side of the equation which is a dubious situation. Second, the well is assumed to be 100% efficient, which in practical term is not feasible because there must be turbulent friction losses as the water passes into the well. Bradbury and Rothschild (1985) found a reasonable agreement between T determined by aquifer tests and T estimated from specific capacity data by using a computer program to estimate T from specific capacity data. Razack and Huntley (1991) developed an empirical relationship between T and specific capacity. The relationship was used in both continental and alluvial aquifers in Morocco. This relationship can be expressed as

$$T = 15.3\left(\frac{Q}{h_0 - h}\right)^{0.67} \quad \ldots\ldots (2)$$

where T is aquifer transmissivity (m^2/day)
Q is pumping rate (m^3/day)
$h_0 - h$ is drawdown (m)

or

$$T = 33.6\left(\frac{Q}{h_0 - h}\right)^{0.67} \quad \ldots\ldots (3)$$

where T is aquifer transmissivity (ft^2/day)
Q is pumping rate (m^3/day)
$h_0 - h$ is drawdown (ft).

Mace (1997) developed a similar approach to the analysis of specific capacity data with transmissivity data for karstic aquifers in Texas.

$$T = 0.76\left(\frac{Q}{h_0 - h}\right)^{1.03} \quad \ldots\ldots (4)$$

where T is aquifer transmissivity (m^2/day)
Q is pumping rate (m^3/day)
$h_0 - h$ is drawdown (m)

In this study, the simulation by Razack and Huntley (1991) Equation 2 utilized in estimating aquifer transmissivity from specific capacity data.

RESULTS AND DISCUSSION

Using the relation (equation 2) by Razack and Huntley (1991), the aquifer transmissivity was estimated from the specific capacity. The estimated aquifer transmissivities range from 66.08 m^2/day to 1478.93 m^2/day. Using the Gheorghe (1978) of aquifer transmissivity classification, the transmissivity values range from moderate to high potential. This however proves that the Ajalli Sandstone is a prolific aquifer. Various contour maps were constructed for a clear understanding of the area. Aquifer depth (figure 4) varies, showing highest depth of 263m at Edeoballa with lowest at Ngwo, 96m. The aquifer depth in most cases is a function of the topography. The static water level (figure 5) is highest at Edeoballa. The aquifer yield (figure 6), specific capacity (figure 7) and the estimated aquifer transmissivity (figure 8) show similarities. Areas with high transmissivity, has a

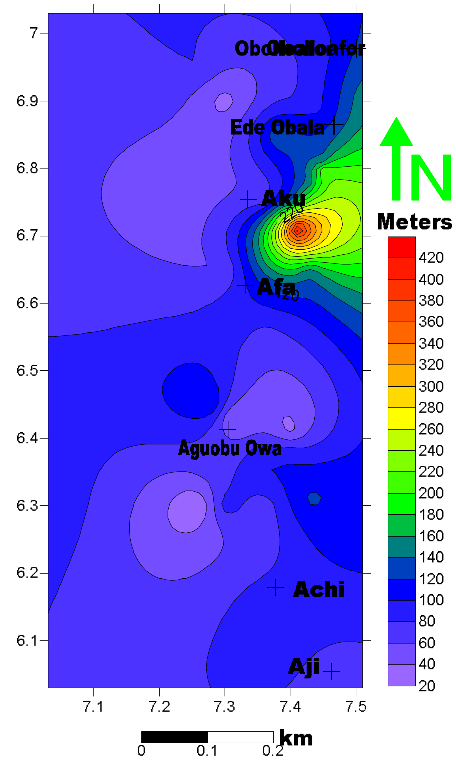

Figure 5: Static water level map of the study area

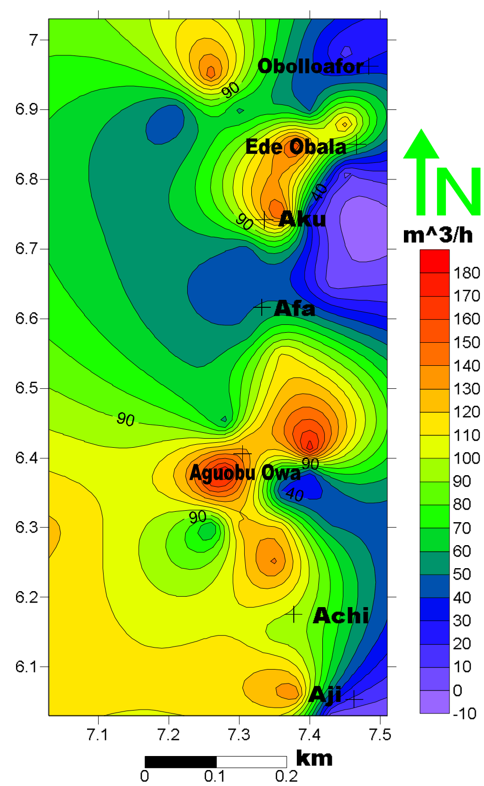

Figure 6: Aquifer yield map of the study area.

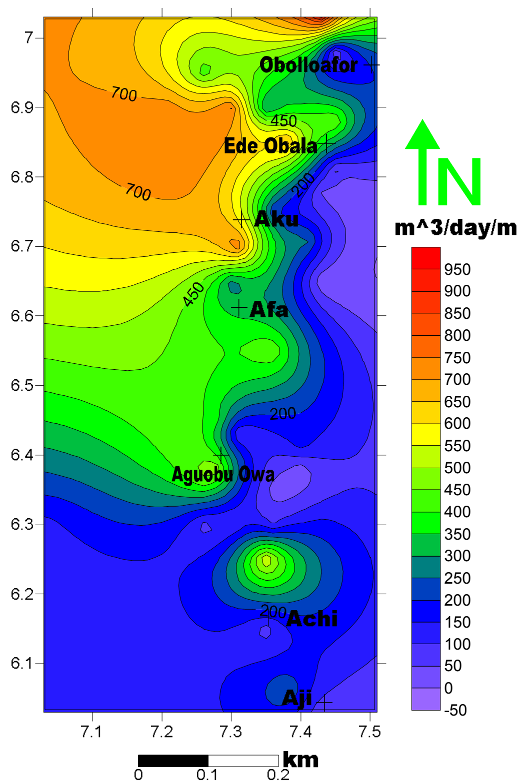

Figure 7: Specific capacity map of the study area

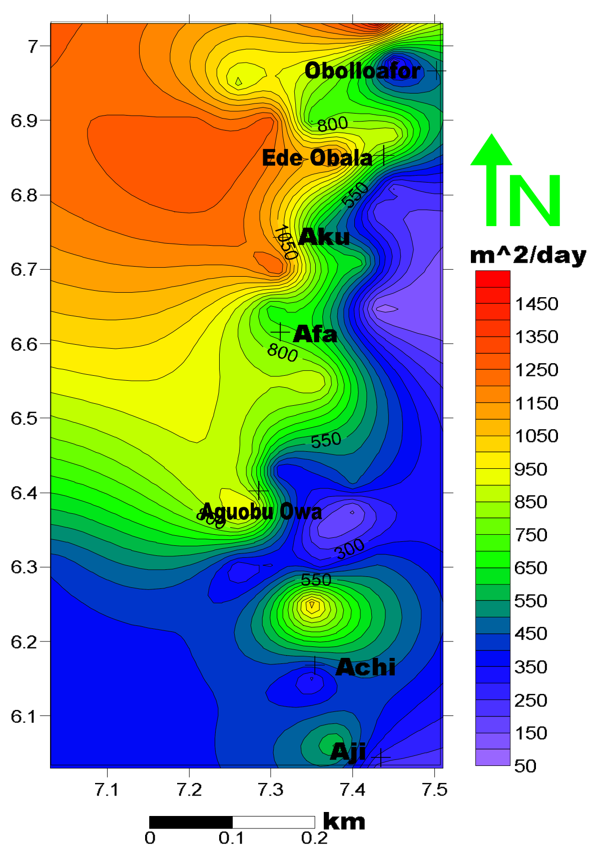

Figure 8: Estimated Aquifer transmissivity map of the study area.

corresponding high values of specific capacity and high aquifer yield. A marked trend running roughly NE-SW indicates the trend of the Ajalli Sandstone (Ezeh, 2011) or the escarpment (Reyment, 1965). This rock unit is predominantly sandy with less sandy clay/clay/shale laminae (figure 3).

CONCLUSION

The simulation by Razack and Huntley (1991) Equation 2 has proved plausible for estimating the aquifer transmissivity based on the available data on specific capacity in the study area. Theis (1963) Equation 1 has under predicted transmissivity values in areas of application because friction losses in the well. However, high aquifer transmissivity values in the study area have satisfied the perception that the Ajalli Sandstone is a prolific aquifer.

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