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Variations in Groundwater Flow Potential in Parts of Imo State, Niger Delta Basin, Southeastern Nigeria

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ABSTRACT: *Groundwater flow potential of ten water boreholes in parts of Imo State were determined principally from their transmissivity values. The results indicates that the aquifer thickness range from 36 to 50m while the hydraulic conductivity varies from 10^{-1} to 10^{-4} m/s. The transmissivity values of the aquifer rocks varies from 311.04 to 388,072m^2/ day. Although the study area is underlain by the same geological formation (Benin Formation), the groundwater flow potential varies from moderate to high. The highest groundwater flow potential (388,800m^2 /day) was obtained at Futo while the lowest (311.04m^2/day) was obtained at Uratta. The groundwater flow potential of the study area in decreasing order is: Futo 5> Nekede 1 > Ihiagwa 4 > Aba Rd>8 > Njoku sawmill > Concorde > Aladinma > Naze > Amazu > Uratta 3. The study area is segmented into two: areas characterized by moderate potential and those that has high groundwater flow potential. Uratta- 3 and Amazu wells are characterized by moderate groundwater flow potential while the rest are characterized by high potential.*
The groundwater flow potential can be employed in sustainable groundwater management and development in the study area.
Keywords: *Aquifer Rock, Transmissivity, Hydraulic Conductivity, Borehole and Groundwater Potential*

I. INTRODUCTION

The study area (Figure 1) is located in Imo State,Niger Delta Basin, Southeastern Nigeria. The area lies within the equatorial rain forest belt of Nigeria which has a mean annual rainfall of 3,100mm (National Root Crop Research Insitute,2012). Nigeria is blessed with abundant surface and groundwater resources. The water resources master plan for Nigeria which was prepared by the Japan International Co-operation Agency (JICA) in 2006 indicates an estimated surface water resources of 2.67 x 10^{11} m^3/year groundwater storage of about 0.52 x 10^{11} m^3/year (Oteze,2006). These figures greatly outweigh the Country's total water demand of about 0.40 x 10^{11} m^3/year (Oteze,2006). . However, many Nigerians are yet to have access to groundwater resources. This is partly becausemost borehole contracts are awarded on the basis of political expediency rather than geological or engineering considerations. Aquifer parameters such as well yield, draw down, hydraulic conductivity, aquifer thickness and transmissivity are rarely determined. Some studies (Iduma and Abam, 2010; Ahiarakwem and Ejimadu, 2002; Ezeigbo, 1989; Uma, 1984 Etu-Efeotor and Odigi, 1983) have been carried out on some aspects of the hydrogeology of Southeastern Nigeria of which the study area is a part, the flow potential of the groundwater resources in the area is yet to be studied. The flow potential of groundwater is a measure of the transmissivity or transmibility of the aquifer. The transmissivity is the product of the aquifer thickness and hydraulic conductivity. The flow potential of groundwater resources is essential in the planning of Regional water supply projects. It is also essential for private groundwater development.

Transmissivity values can vary within short intervals in a particular geological formations; this calls for careful monitoring of transmissivity values. In groundwater exploration, areas with higher transmissivity values are usually preferred to areas with lower values in citing satelliteborehole projects. Private borehole construction in the study area is on the increase; indiscriminate sinking of boreholes can result in the interference of water table as the safe distance to the next borehole (radius of influence) are rarely determined (Offidile, 1983). This can effect the draw down of the groundwater resources as well as wide spread water-borne epidemic. One approach to putting in place appropriate mitigation measure to guard aains this problem is the monitoring of the groundwater flow potential in the study area.

II. GEOLOGY AND HYDROLOGY

The Teriary Nger Delta Basin of which the study area is a part consists of three major stragraphic Formations, namely (from top to bottom) :Benin, Agbada and Akata Formations. (Short and Stauble, 1967;). However, the study area is precisely underlain by the Benin Formation (Figure 1) which consists of friable sands, conglomerates, very coarse sandstone and isolated gravel units and intercalations of shale/clay lenses of Pliocene to Miocene age(Horton, 1965; Short and Stauble, 1967; Ananaba et al., 1993)). The mean thickness of the formation in the study area is about 800m while the mean depth to water table is about 18.3m (Avbovbo, 1978). The formation is overlain by Alluvium deposits and underlain by the Ogwashi-Asaba Formation which consists of lignite, sandstones, clays and shale (Figure 2). The Benin Formation provides the aquifer for groundwater storage because of its high porosity and permeability. The incidence of high porosity and permeability as well as shallow water table makes the groundwater in the area very vulnerable to pollution.

The stuy area is drained by Otamiri, Oramiriukwa and Nworie Rivers. The Otaimiri and Oramiriuka rivers have a confluence at the southern part (Figure 2) from where both flows together into the Atlantic ocean. The Nworie river on the other hand is the tributary of the Otamii River. These rivers re used for domestic and commercial water supply as well as for recreation, fishing and sand mining activities. They also serve as research and tourist and are also used for transportation. The rivers have deposited large deposits at their banks over the years most of which now serve as aquifer rocks.

III. MATERIALS AND METHODS

Ten boreholes (Nekede, Aladinma, Uratta, Ihiagwa, FUTO, Naze, Njoku sawmill, Eziobodo, Concorde and Amuzu) were investigated. The static water table of the boreholes were measured using water level indicator while the strata logs were cproceww3d using Strata software (version 3) and subsequently used to determine the aquifer thickness. The hydraulic conductivity was determined using method described by Hubbert (1956) while the Transmissivity values were calculated using equation 1 described by Todd (1980).

T = KD………………………………………………………….. (Equa. 1)

Where

T= Transmissivity,

K= Hydraulic Conductivity

D= Aquifer Thickness

Contour maps of the aquifer thickness, hydraulic conductivity and transmissivity were carried out with the aid of Surfer 11 software. The computed transmissiviy values were interpreted using the chart described by Offidile (1983).

IV. RESULTS AND DISCUSSION

The results of this investigation is summarized in Table 1. The transmmissivity values varies from one borehole to another although the boreholes are located within the same geological formation (Benin Formation).This implies variations in the groundwater potential of the study area.

4.1 Nekede 1

The lithlogical succession of this borehole shows that it consists essentially of lateritic cover, sandy clay, sands and gravel (Table1and Figure 2) . The total depth of the borehole is about 60m while the aquifer thickness and static water table are 44.8 and 18.2m respectively. The aquifer is unconfined with a hydraulic conductivity of 0.1m/s and a transimmissivity of387, 072m/day (Table1). The transmissivity value indicates high groundwater flow potential (Table2). The groundwater potential is favorable for sustainable groundwater development.

4.2 Aladinma

The total depth and static water level of this borehole are 80 and 30m respectively while the aquifer thickness is about 50m (Table 1). The aquifer is unconfined and has a hydraulic conductivity and transmissivity values of 10^{-3} m/sand 4,320m'/day respectively. The lithologic succession in the borehole consists of lateritic cover, sands and sandstone (Table 1 and Figure 2). The transmissivty value although lower than that of Nekede is high and thus indicates high groundwater flow potential (Table 2).

4.3 Uratta -3

The total depth of the borehole is about 90m while the aquifer thickness is about 36m. The aquifer is unconfined with a static water level of about 54m. The lithologic succession include laterite, sands and gravel (Table 1 and Figure 2). The hydraulic conductivity and transmissivity of the aquifer are 10^{-4} m/s and $311.04m^2$/day respectively. This borehole has the lowest groundwater flow potential in the study area, The groundwater flow potential is considered moderate (Table 2).

4.4 Ihiagwa -4

The total depth of the borehole is about 65m while the aquifer thickness is about 39m. The aquifer is unconfined with a static water table of about 26m. The lithologic succession in the well include laterite, silts, sands, sandy clay and gravel (Table 1 and Figure 2). The hydraulic conductivity and transmissivity are 10^{-1} m/s and $336,960m^2$/day respectively and this implies high groundwater flow potential (Table 2).

4.5 FUTO - 5

The total depth of the borehole is about 60m with an aquifer thickness of about 45m (Table 1). The aquifer is unconfined with a static water table of about 15m. The lithologic succession consists essentially of laterite, silts, sands and gravel (Table 1and Figure 2). The hydraulic conductivity is about 10^{-1} m/s while the transmissivity is about 388,800m^2/day and this is the highest in the study area.The groundwater flow potential is also high (Table 2).

4.6 Naze

The total depth of this well is about 60m with an aquifer thickness of about 38m. The static water table is 22m. The strata log of this well shows that it consists of laterite,silt, sandy clay and gravel (Table 1and Figure 2). The hydraulic conductivity and transmissivity value are 10^{-3} m/s and 3,283.2m^2/day respectively. This also indicates high groundwater flow potential (Table 2).

4.7 Njoku sawmill

This well has a total depth of about 70m and aqufer thickness of about 49m (Table 1). The static water table is about 21m while the lithologic succession include laterite, sands , clay and gravel (Table 1and Fjgure 2). It has an unconfined aquifer.The hydraulic conductivity is 10^{-2} m/s while the transmissivity value is 42,366m^2/day. This well is also characterized by high groundwater flow potential (Table 2) and thus quite suitable for sustainable groundwater development. The aquifer is unconfined.

4.8 Aba Rd. -8

The total depth of this well I is about 80m while the aquifer thickness is about 50m. The static water table js about 30mand the aquifer is unconfined . The strata log of this well consists of laterite,silt, sandy clay and sands (Table 1 and Figure 2). The hydraulic conductivity and transmissivity values of the well are10^{-2} m/sand 43,200m^2/day respectively and this indicates high groundwater flow potential (Table 2).

4.9 Concorde 9

The total depth of this well is 70m while the thickness of the aquifer which is unconfined is is about 40m. The static water table is about 30m. The strata log of well include lateterite, sandy clay, sand and gravel (Table 1and Figure 2). The hydraulic conductivity and transmissivity values are 10^{-2} m/s and 34,560m^2/day. The groundwater flow potential is also high (Table 2).

4,10 Amuzu

The total depth of this borehole is about 80m while the aquifer thickness is about 45m. The aquifer is unconfined and the static water table of the well is about 35m. The lithologic succession include laterite, sandy clay and sand (Table 1 and Figure 2). The hydraulic conductivity is 10^{-4} m/s while the transmissivit is 388.8m^2/day. However, the groundwater flow potential of this well is moderate (Table 2).

V. GROUNDWATER FLOW POTENTIAL MODEL

The groundwater flow potential of thestudy area in decreasing order is: Futo 5> Nekede 1 > Ihiagwa 4 > Aba Rd>6 > Njoku sawmill > Concorde > Aladinma > Naze > Amazu > Uratta 3 (Table 3). The study area is segmented into two: areas characterized by moderate and high groundwater flow potential. Uratta- 3 and Amazu wells are characterized by moderate groundwater flow potential while the rest are characterized by high potential (Figure 3). The groundwater flow potential trend depends on the aquifer thickness (Figure 4) and the hydraulic conductivity (Figure 5). Generally, the flow potential decreases with decrease in hydraulic conductivity (Table 3). Contour maps of aquifer thickness (Figure 6) and hydraulic conductivity (Figure 7) is consistent with the groundwater flow potential model (Figure 3) of the study area. The model indicates that the groundwater flow potential generally increases from North to South.

VI. CONCLUSIONS

The results of this study indicates that hydraulic conductivity varies from 10^{-4} to b10^{-1}m/s while aquifer thickness varies from 36 to 50m. The static water table varies from 15 to 54m while the transmissivity range from 311.04m^2/day (at Uratta 3) to 388,800m^2/day (at Futo 5). tAlthough the study area is underlain by the same formation (Benin Formation), the groundwater flow potential varies from moderate to high. The groundwater flow potential at Uratta 3 and Amazu are moderate while those of Futo 5, Nekede 1, Ihiagwa 4, Aba Rd.6, Njoku sawmill, Concorde, Aladinma and Naze have high potential. The transmissivity values in decreasing order follow the trend: Futo 5 > Nekede 1 > Ihiagwa 4 > Aba Rd.6 > Njoku sawmill > Concorde > Aladinma >Naze > Amazu > Uratta 3. The transmissivity values obtained depends on the hydraulic conductivity and aquifer thickness. The wells with low ttransmissivity values were observed to have the lowest hydraulic conductivity (10^{-4}m/s). Accordingly, the transmissivity values increases with increase in hydraulic conductivity. The transimissivity values values are suitable for sustainable groundwater development.

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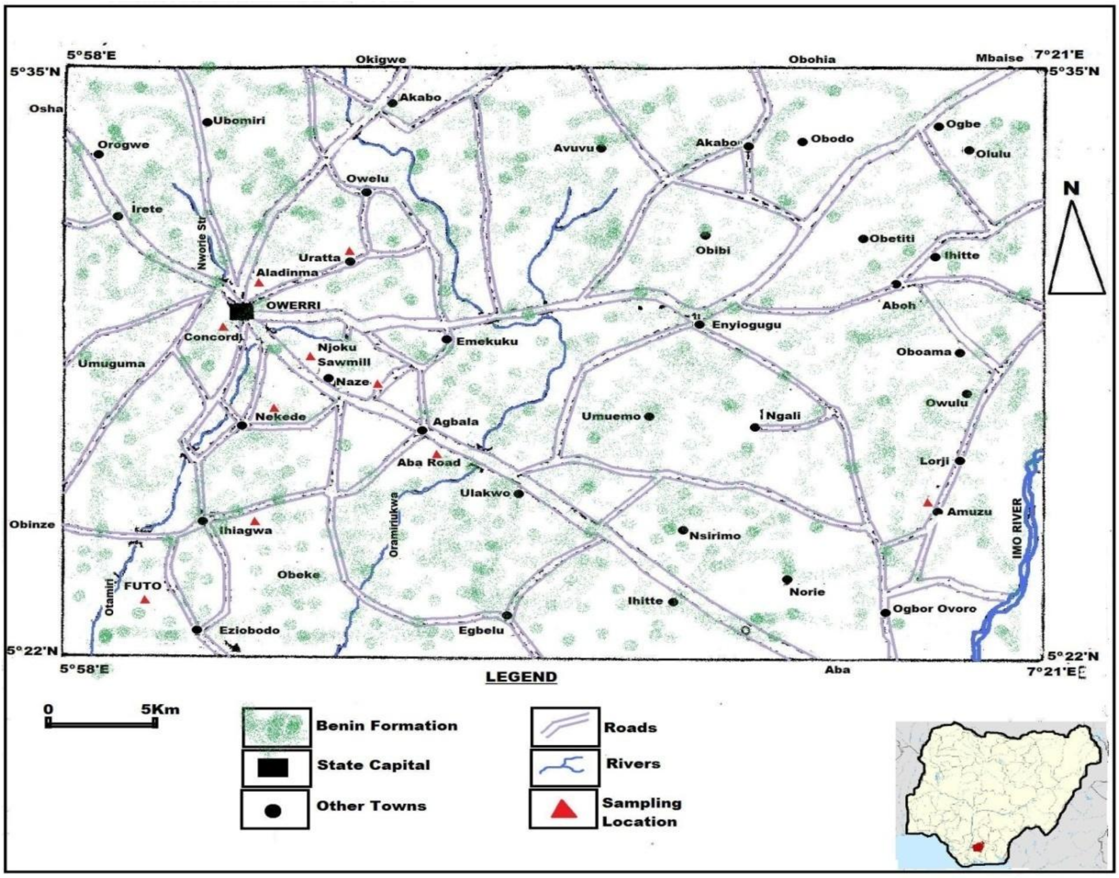


Figure 1. Geological map of the study area showing sampling locations

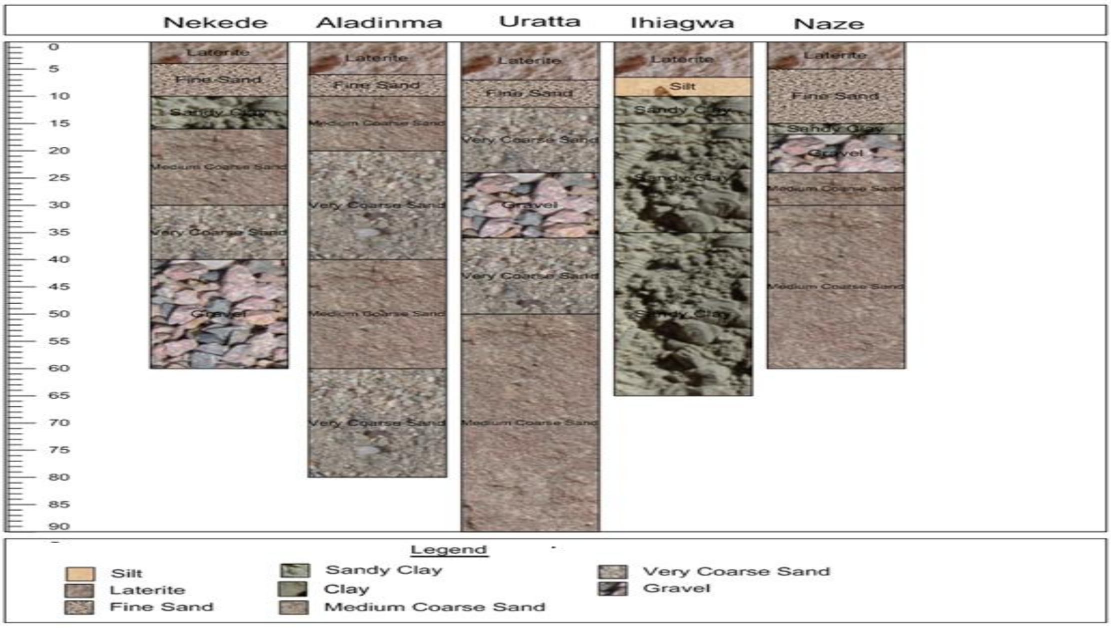


Figure 2. Strata logs of the wells in the study area

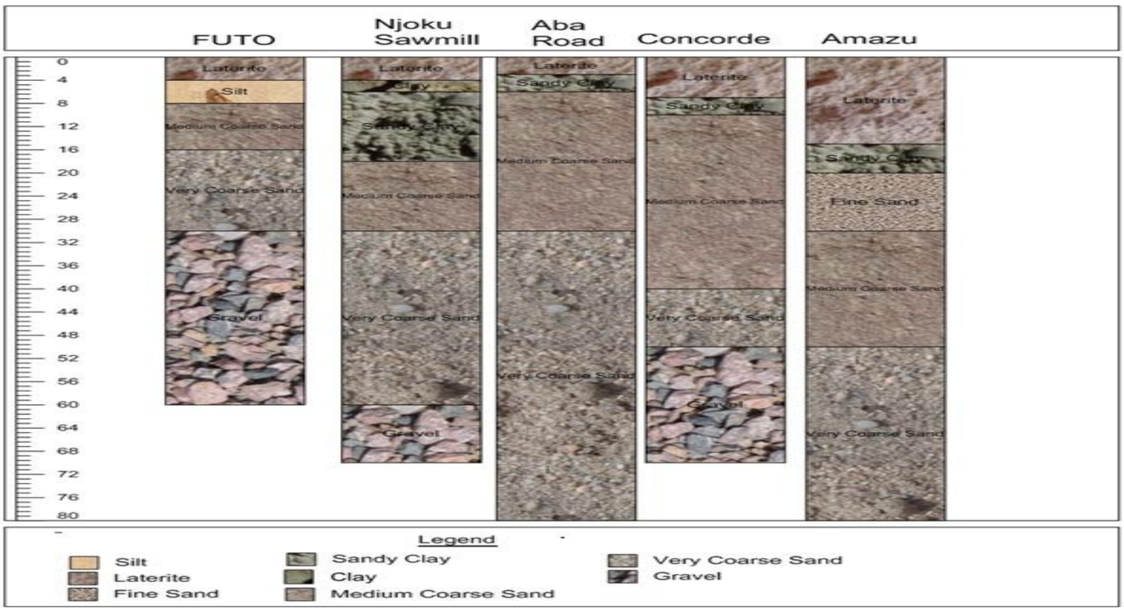


Figure 2 contd. Strata logs of the wells in the study area

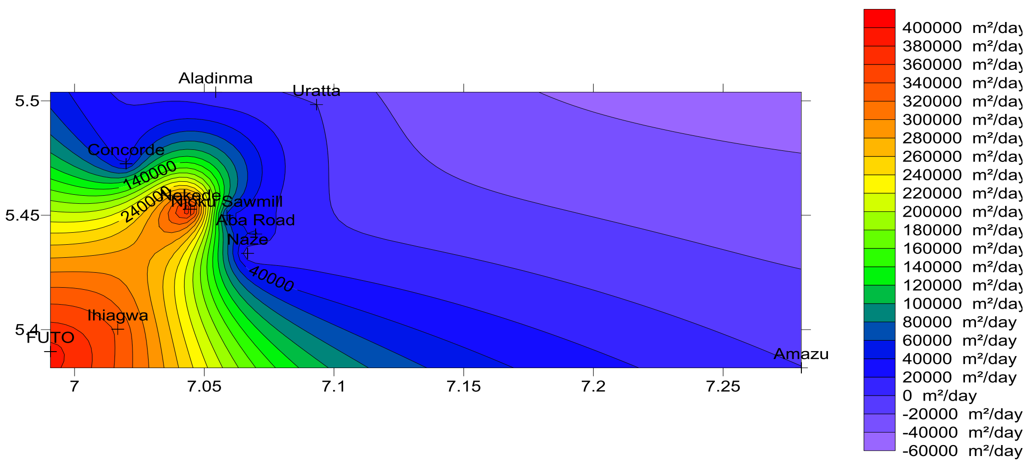


Figure 3. Groundwater flow potential model of the study area

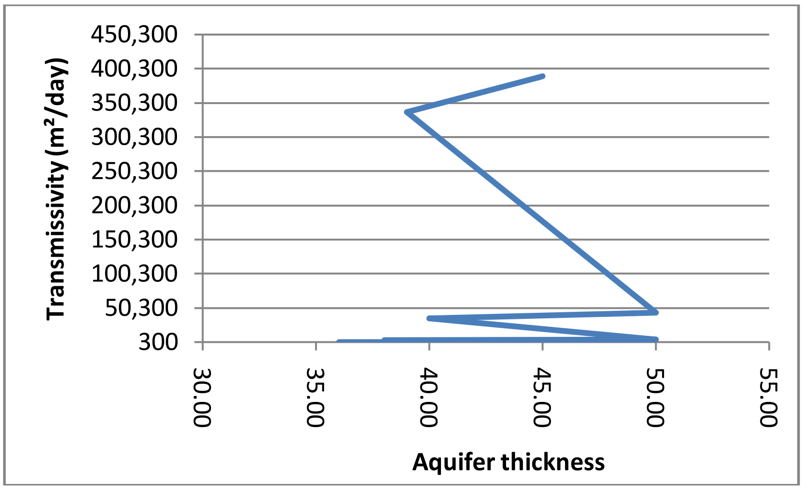


Figure 4. Variation of aquifer with aquifer thickness

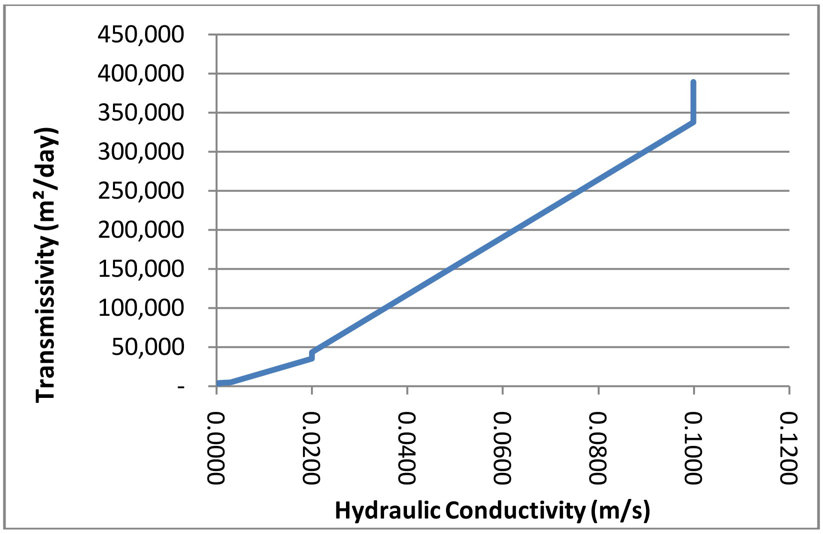


Figure 5. Variation of transmissivity with hydraulic conductivity

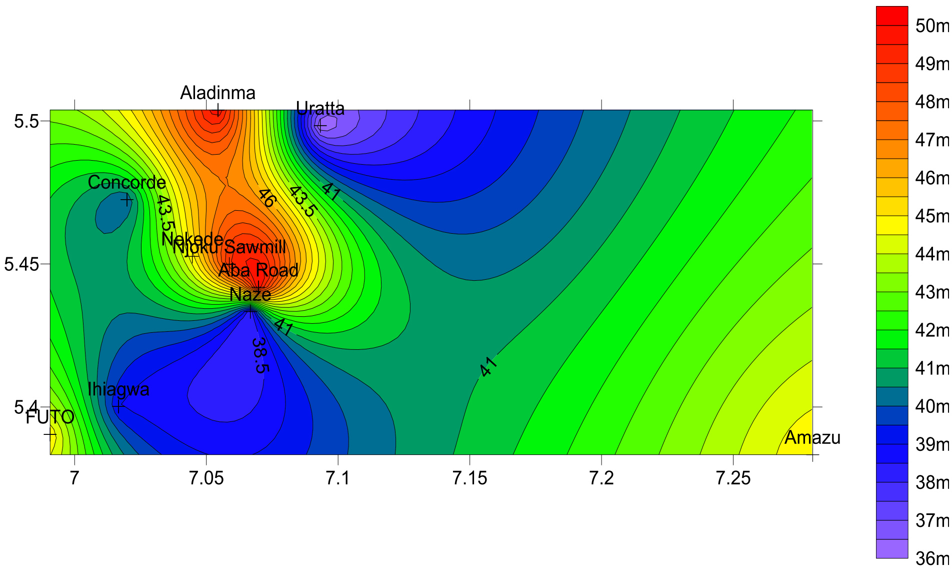
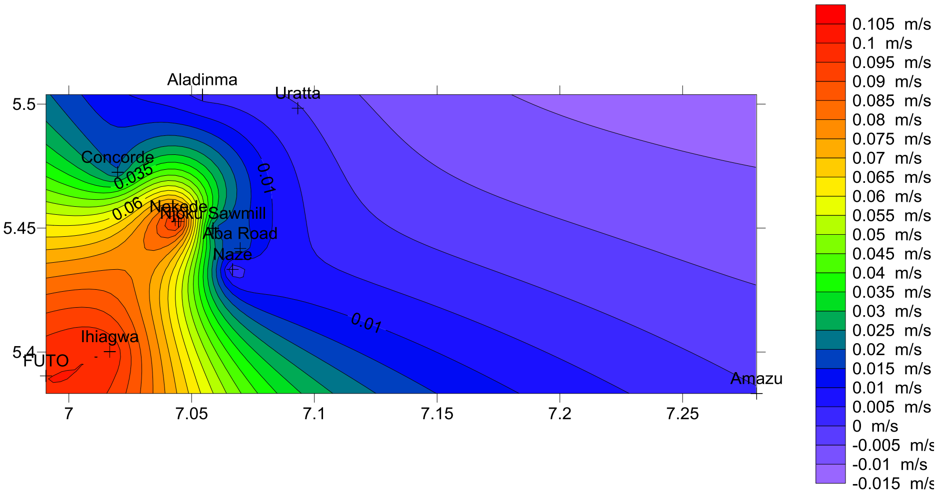


Figure 6. Contour map of aquifer thickness of the wells



Fifure 7. Contour map of the hydraulic conductivity

Table 1. Lithology and hydrological characteristics of groundwater in the studyarea

LOCATION	DEPTH (m)	LITHOLOGY	AQUIFER THICKNESS (m)	STATIC WATER TABLE (m)	HYDRAULIC CONDUCTIVITY (m/s)	Trasmissivity (m^2/day}	GEOLOGIC5L FORMATION
Nekede 1	**0 - 4 4 - 10 10 -16 16 - 30 30 - 40 40 -60**	**Laterite Fine sand Sandy clay Medium coarse sand Very coarse sand gravel**	**44.8**	**18.2**	**1o^{-1}**	**387,072**	**Benin Formation**
Aladinma	**0 - 6 6– 10 10 - 20 20 - 40 40 - 60 60 -80**	**Laterite Fine sand Medium Coarse sand Very coarse sand Medium coarse sand Very coarse sand**	**50**	**30**	**10^{-3}**	**4, 320**	**Benin Formation**

Uratta 3	**0 – 7** **7- 12** **12 - 24** **24 – 36** **36 – 50** **50- 90**	**Laterite** **Fine sand** **Very coarse sand** **Gravel** **Very coarse sand** **Medium coarse sand**	**36**	**54**	**10^{-4}**	**311. 04**	
Ihiagwa 4	**0 – 6.5** **6.5-10** **10- 15** **15 – 35** **35 – 65**	**Laterite** **Silt** **Sandy clay**	**39**	**26**	**10^{-1}**	**336,960**	**Benin Formation**
Naze	0 -5 5- 15 15 -17 17 – 24 24 -30 30 -60	Laterite Fine sand Sandy clay Gravel Coarse sand Medium coarse sand	38	22	10^{-3}	3, 283.2	Benin Formation
Futo 5	0 -4.0 4 – 8 8 – 16 18 -30 40 – 60	Laterite Silt Medium coarse sand Very coarse sand gravel	45	15	10^{-1}	388,800	Benin Formation
Njoku sawmill	0 -4 4- 6 6– 18 18-30	Laterite Clay Sandy clay Medium	49	21	10^{-2}	42, 336	Benin Formation

	30 -60 60- 70	coarse sand Very coarse sand gravel					
Aba Rd. 8	0- 3 3- 6 4- 6 6 -30 30 - 80	Laterite Sandy clay Silt Medium coarse sand Very coarse sand	50	30	10^{-2}	43, 200	Benin Formation
Concorde 9	0 – 7 7-10 10 -40 40 -50 50 -70	Laterite Sandy clay Medium coarse sand Very coarse sand gravel	40	30	10^{-2}	34,560	Benin Formation
Amazu	0 – 15 15 – 20 20 -30 30 – 50 50 – 80	Laterite Sandy clay Fine sand Medium coarse sand Very coarse sand	45	35	10^{-4}	388.8	Benin Formation

Table 2. Well classification based on transmissivity values

TRANSMISSIVITY (m^2/day)	CLASSIFICATION OF WELL
>500	High Potential
50 – 500	Moderate Potential
5 – 50	Low Potential
0.5 – 5	Very Low Potential
<0.5Neglible Potential	

SOURCE: Offodile (1983}

Table 3. Groundwater flow potential trend of the study area

LOCATION	AQUIFER THICKNESS (m)	HYDRAULIC CONDUCTIVITY (m/s)	Transmissivity (m^2/day)	Groundwater flow potential
Futo 5	45	10^{-1}	388,800	High
Nekede 1	44.8	10^{-1}	387,072	High
Ihiagwa 4	39	10^{-1}	336,960	High
Aba Rd. 6	50	10^{-2}	43,200	High
Njoku Sawmill	49	10^{-2}	42,336	High
Concorde	40	10^{-2}	34,560	High
Aladinma	50	10^{-3}	4,320	High
Naze	38	10^{-4}	3, 283.2	High
Amazu	45	10^{-4}	388.8	Moderate
Uratta 3	36	10^{-4}	311.04	Moderate