Assessment of the Groundwater Potential of a Typical "Fadama" in Kaduna State, Nigeria

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Abstract: River courses on the Basement Complex are often characterized by a narrow strip of alluvium called "fadama". Several fadamas abound all over Kaduna State, and they have become a source of livelihood for many farmers who depend on the swampy conditions for both wet season and dry season crop production. In order to assess the groundwater potential of a fadama in Kaduna State for irrigation, 20 Vertical Electrical Soundings (VES) were made and the existing borehole data were obtained. Geophysical investigation results were found to be consistent with the interpreted drilling data. With good recharge capability, shallow depth to water table (generally within 1-10m), tested yield of between 1.3 to 10m^3/h, permeability range of 0.13 to 0.48 m/day, and an estimated groundwater storage capacity of about 23.6 million m^3, there is indeed a great groundwater potential for irrigated farming, and possibly rural water supply in the fadama.

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1. Introduction

The study area is a catchment of the rivers Chidawaki and Chikaji which lies between latitudes 10°34'N and 10°46'N, and longitudes 7°14'E and 7°28'E in Kaduna State of Nigeria, covering an area of about 154 Km^2 (Figure 1). The area falls within the Guinea Savanna region, and is characterized by two distinct climatic seasons: the wet season, which occurs usually between mid-April and mid-October, and the dry season that lasts for the remaining months of the year. Annual rainfall, which ranges between l000 to 1500mm, occurs in the wet season reaching its peak values between July and August. Maximum temperatures often rise to about 38°C or more between March and April, and may drop significantly to about 24°C or less during peak rainy periods (July/August) and during the cold, dry, north-easterlies or harmattan winds (November/February).

Vegetation consists of broad-leaved savanna woodland which, when well-developed, may attain heights of about 10 to 15m, and may be dense enough to suppress the growth of grasses. Large flood plains support a distinctive vegetation of tall grass and palms, with relatively dense forest occurring along some of the streams. Elsewhere, the land is open to the cultivation of rice, vegetables and other food crops, as well as grazing by animals and bush burning. The topography of the study area is characterized by a gently undulating plain, sloping from an elevation of about 670 m along the eastern watershed to about 580 m at the drainage point into the R. Tubo. The dominant slope in the Tubo plains is 2% (Bennett et al, 1977). The most prominent topographic feature is the 660m high Nagijmbe Hill near the western end of the catchment. The catchment area is traversed mainly by River Chidawaki and River Chikaji which formed a confluence that flows westward into R. Tubo, and subsequently drains southward into River Kaduna, a major tributary of the River Niger (Figure 1).

The actual fadama land in the study area covers an area of about 23.6 Km^2. (FDWR/EDF, 1985). 'Fadama' is the local name used in northern Nigeria to describe land area along the river valley that is covered temporarily with water for about two to six months in a year. While the so-called fadamas (flood plains or valley swamps) are swamps during the rainy season, they completely dry up during the dry season; only very few swamps may extend the marshy conditions till after December, depending on geology and annual rainfall amount and distribution. Fadamas are formed by the water flowing in the streams and by the seepage water thereof which saturate the land and raise the water table (Savvides, 1981).

By taking the good advantage of the water availability of this fadama for farming, many people make their living out of it, and since such fadamas exist severally in Kaduna state, a study of this nature is inevitable. This paper assesses the availability of groundwater resources of a fadama for irrigation.

2. Geology

In tropical Africa, more than half of the total land area is underlain by ancient crystalline rocks such as granites, gneisses and schists, which are altogether known as Basement Complex rocks (David & Ofrey, 1989). The entire land area of Kaduna State is underlain by Precambrian migmatite-gneiss complex, metasediments/metavolcanics (mostly schists, quartzites, amphibolites and Banded Iron Formations), Pan-African granitoids and calc-alkaline granites, and volcanics of Jurassic age towards the south-eastern border of the state (Oluyide, 1995). However, the characteristic Basement Complex rocks of the study area are the migmatites and gneisses, the metasediments and the older granites (Figure 2).

The migmatites (mixed rocks, generally consisting of a metamorphic host invaded by granitic material), biotite and granitic gneisses are the largest group of rocks. They are characterized by a variety of structures, and textures, and they represent reactivated older metasediments. The metasedimentary rocks are metamorphosed sedimentary and metavolcanic rock group which consists of ferruginous quartzites (Banded Iron Formation), amphibolites and pelitic slightly migmatised schists (mixed flaggy quartzites, gneisses and pegmatoids), which altogether have been grouped variously in Birnin Gwari area as Kushaka and Birnin Gwari Formations (Trusswell & Cope, 1960; Ajibade & Wright, 1988). The Pan African (or Older) granites are characterized by lofty topography and inselbergs which formed along the western margin of the study area. The lithological varieties of the rock formation believed to have been emplaced during the Late Palaeozoic era (550+/-100 my) include coarse-grained porphyritic granite, biotite homblende granite and fine-grained granites, and fayalite-quartz monzonite (Oluyide, 1995). According to Jones (1985), quartz, potassium feldspars (such as orthoclase and microcline) and plagioclase (sodium and calcium feldspar series) each generally account for between 20 and 50% of the total minerals present in the Basement Complex rocks, while micas, amphiboles and pyroxenes can comprise up to 25%.

The main structural trend detected by aerial photograph interpretation is northwest-southeast (NW-SE), while the relative straightness of some rivers, especially R.Tubo, may also indicate the presence of north-south (N-S) trending structures, possibly faults (FDWR/EDF, 1985). A thin, discontinuous mantle of weathered rock lies over most of the area underlain by the Basement Complex rocks in northern Nigeria, and is more pronounced where the topography is subdued. The average thickness of the mantle is about 15m, although depths of about 60m may be encountered (du Preez & Barber, 1965).

3. Hydrogeology

In the Basement Complex regions, aquifers generally occur within the highly weathered overburden (regolith) and the fractured zones or fissure systems of the bedrock. Fissure systems in Nigeria rarely extend beyond 50m, as evidenced by the available drilling data (Clark, 1985). The local water table depth is controlled by textural and compositional changes within the regolith vertical profile and the bedrock topography (David & Ofrey, 1989). Groundwater occurrence takes place mainly in the weathered mantle, and in the overlying fadama alluvium. Although the saturated zone usually has typically thin thickness range of 8 to 20m with relatively low permeability due to high clay or mica content of the weathered rock, the storage potential of the already extensive aquifer is somewhat significant (Omorinbola, 1983).

In the study area, highly weathered migmatites and gneisses are degraded to a material containing a very large proportion of kaolinite which occurs on the uppermost part of the weathered zone, and is associated with low permeability. The best prospect for groundwater, therefore, occurs in that part of the weathered zone below the kaolinized layer towards the base of the weathering zone (the active weathering front) where the rock has been broken down into sand-size and larger fragments (MRT, 1978). The catchment area is drained mainly by rivers Chidawaki and Chikaji which together are fed by a good network of tributaries well distributed all over the area.

4. Field Data Acquisition

Geophysical investigation consists of 20 vertical electrical soundings (VES) taken within the study area. These include crossed soundings, in which two soundings were taken at the same centre point but with orientations at about right-angles to each other. Curves In such cases are similar and so are their interpretations. However, minor differences do occur, possibly due to ambiguities caused by suppression and equivalence, while major difference due to lateral variation was observed at only one instance. Typical VES curves are shown in Figure 3. VES A was taken at the site of well 3, VES B at 560m south-west of well 3, VES C at the site of well 5 and VES D at 625 m away from well 5 towards Nagijmbe Hill.

Available hydrogeological parameters of nine wells (numbered 1 to 9) in the study area are given in Table 1. It is interesting to note that while other wells in the catchment were drilled primarily for water supply, wells 3, 4 and 5 were particularly sunk by the National Water Resources Institute, Kaduna (NWRI) for research purposes. The western end of the catchment was chosen since it is the outlet where the aquifer is expected to be thickest. Well 5 was drilled to a depth of 102m in order to test the fresh Basement Complex. Well 4 was drilled just to the top of the fresh Basement Complex at 15 m, while well 3 was drilled on the opposite side of the fadama strip to determine the maximum thickness of the alluvium and the weathered zone near the course of River Chidawaki.

5. Discussion Of Results

The VES data have been used to delineate the geoelectric succession which generally consists of the top lateritic layer, followed by the micaceous silty clay layer that grades vertically down to sand and gravel, and then the weathered transition zone. This zone is poorly aquiferous at the upper kaolinized horizon, but is capable of yielding significant quantities of water through wells at the lower horizons.

The geoelectric sections interpreted for VES C and VES A were compared with the borehole lithologs of the corresponding wells 5 and 3 respectively, as shown in Figure 4. In well 5, the 800 ohm-m layer is interpreted as the dry, lateritic surface layer, followed by the 270 ohm-m layer which serves as the capillary fringe, since the static water level in the well is at 1.90m from the surface. The resistivity in the alluvium below this layer will then vary according to the grain size and clay content of subsequent horizons. Underlying this is the weathered basement with resistivity of about 200 ohm-m. The relatively low resistivity value of 300 ohm-m at the interface with the fresh Basement rock may be explained on the basis of possible extensive fracturing of the rock which, of course, is not apparent from the drilling results.

The interpretation for well 3 is similar to that of well 5. The 1100 ohm-m layer is the hard, surface clay horizon underlain by aquiferous sand with ferruginous concretions, followed by the weathered Basement (aquitard) and then the black, hard gneiss of the Basement Complex. The general inference that may be drawn from these and similar comparisons in this study is that the geoelectric sections are consistent with the drilled sections.

The aquiferous zone is mainly the sandy clay and sandy to gravelly alluvium below the uppermost lateritic layer, and its yield will depend on how argillaceous or arenaceous the detrital material is. The aquiferous zone in the weathered Basement rock is the lower part where the rock has not been weathered significantly into finer materials, as in its upper kaolinized part. The water table generally stands at shallow depths (between 1 & 10m from the surface), while annual fluctuation could be as high as 3 m or more (MRT, 1978). The water in the aquiferous zones is generally unconfined. As shown in Table 1, most boreholes in this area have a yield ranging from 1.3 to 3.2 m^3/h, except for well 4 which has a thick fadama alluvium and a yield of 7.4 m^3/h, and well 7 which probably encountered well developed fractures in the fresh Basement and so has a yield of 10 m^3/h. Available permeability data of the mean screened sections (estimated by using the Logan approximation of the Theim formula) show a range 0.13 to 0.48 m/day.

Drilling litholog revealed that the aquifer consists of alluvial sand and gravel containing some vegetation and wood remains, underlain by clayey silt of the weathered zone that grades down into sand-sized particles and fragments of decomposed Basement Complex rock. The Basement Complex itself consists mainly of dark-coloured banded gneiss with some quartzite veins. Figure 5 shows a lithological cross-section prepared from the drilling litholog along wells 5, 4 and 3 in a NW-SE direction.

The entire fadama areal extent of 23.6 Km^2 is expected to be thicker westward towards the drainage outlet as shown in Figure 5, and thinner eastward. If an average aquifer thickness of 10 m is assumed for the entire fadama land, then it follows that about 236 million m^3 of water is indicated in the aquifer. However, if a specific yield of 10% (common value applied to clayey sands and sandstone) is assumed for the fadama, then it can be estimated that about 23.6 million m^3 of water is available in ground storage for exploitation through wells. With good vegetation or forest cover, the infiltration and permeability properties of the catchment will be improved, and the aquifer storage can be replenished continually through natural recharge.

6. Conclusion

This study showed that fadamas have significant groundwater potential and are, therefore, capable of supplying water for rural needs. With good natural recharge, the fadama land investigated is capable of providing adequate water for small scale irrigation, and possibly for rural domestic needs. The agricultural potentials of fadama farmers are enormous, and the contribution of fadamas to total agricultural produce cannot be ignored because several fadamas abound all over Nigeria. Therefore, if water can be made readily available through boreholes for irrigated farming and rural life from the fadamas, the area currently under irrigation would be increased and, consequently, food production would be enhanced.

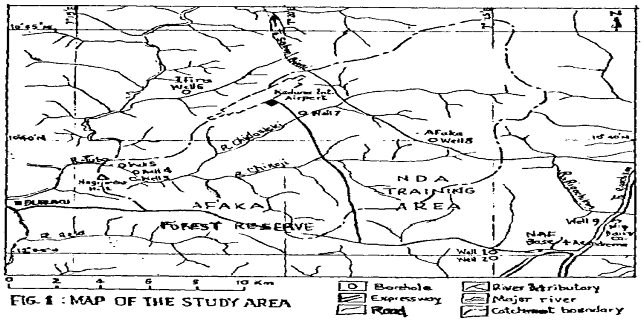


Figure 1: Map of the study are

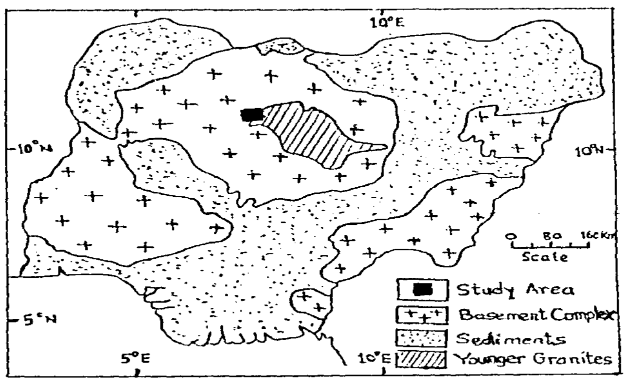
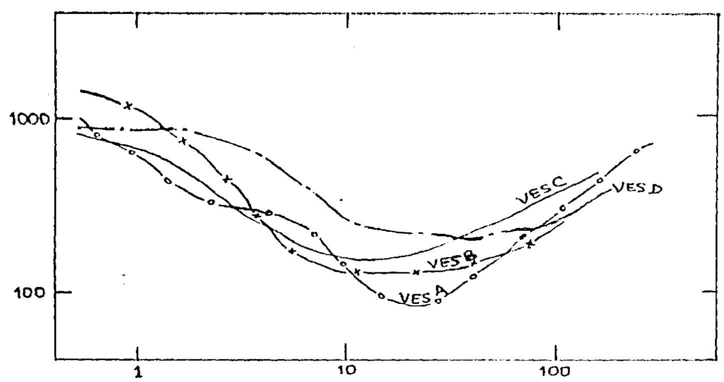


Figure 2: Simplified Geological Map of Nigeria Showing the Study Area



Electrode Spacing (m)

Figure 3: Geoelectric Sounding Curves for VES A, B, C and D

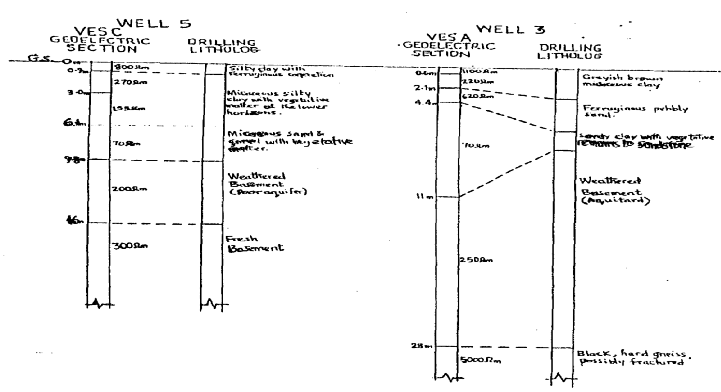


Figure 4: Comparison of Geoelectric Section with Drilling Litholog

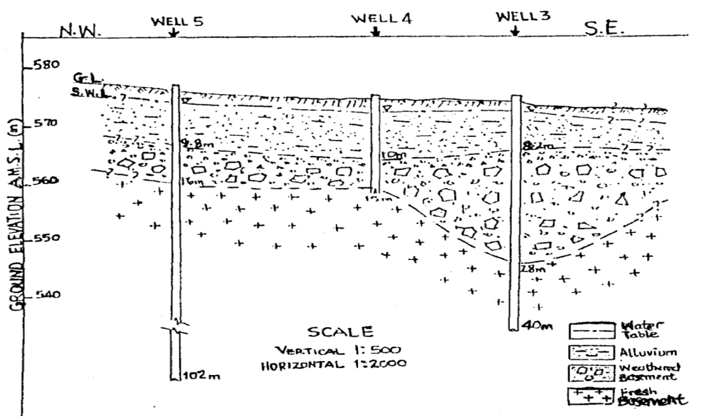


Figure 5: Lithological Cross-section from Well Data (NW-SE)

Table 1: Summary of Existing Borehole Data

Location	BH No.	Date Completed	Ground Elevation (m)	Total Depth (m)	Depth To Fresh BC (m)	Screen Setting (m)	Max. Tested yield (m^3/h)	Pumping duration (hr)	SWL from ground level (m)	Spec. Capac $m^3/h/m$	Draw Down (m)	T_L (m^2/day)	K_L (m^2/day)
NWRI	1	05/1982	-	102.0	42	24-27 36-42 69-72 82-85	3.2	72	5.3	0.08	39.6	2.4	0.16
NWRI	2	12/1984	625.0	92.0	38	Open 40.8-92	2.5	2.06	-	-	-	-	-
Nagijmbe Hill side	3	03/1985	574.1	40.1	28	5.3-11.3 26.3-32.3	-	-	1.06	-	-	-	-
-do-	4	03/1985	574.8	15.0	15	6.8-13.9	7.4	4	1.70	-	3.70	-	-
-do-	5	02/1985	575.1	102.0	16	Open 18-102	0.6	1	1.90	-	>80	-	-
Ifira	6	05/1982	-	30.2	27	16.9-24.4	2.0	24	8.6	0.12	16.2	3.6	0.48
Kad. Int. Airport	7	05/1980	-	-	-	-	10	-	-	-	-	-	-
Afaka	8	05/1982	-	34.2	32.2	17.3-29.3	1.3	24	6.4	0.05	24.3	1.6	0.13
Nig. Dairy Co.	9	1980?	-	100?	-	-	2.0?	-	2.2	-	-	-	-

Source: FDWR/EDF, 1985: T_L, K_L are transmissivity and permeability determined using Logan approximation of Theim formula.

Borehole number does not conform to any pre-existing numeration or serialization.

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