In-Situ Assessment of Seasonal Variations of Aquifer Depth in a Part of Basement Rock of North Central Nigeria

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Abstract

Depth to water table was monitored for six consecutive months by direct and indirect measurements in nine hand-dug wells within Ilorin metropolis, lying within the basement complex of north central Nigeria. Weekly time series of rainfall and well water level were cross-correlated to investigate seasonal variations in groundwater level response times, based on periods of 6-month duration. The aims were to monitor the fluctuation of the aquifer recharge, determine the drying rate, detect possible seepage in the studied wells and to analyze geohydrological information using suitable self-developed mathematical models. The result shows that in three of the wells, some volumes of water are leaking fast at the rate of 0.46, 0.47 and 0.56 m/week to the host rock probably through connected pores. This could imply that the wells are seated on fractured and or porous basement. It could also indicate that underground water flow direction is toward those wells. With exception of well 2, all other remaining wells show appreciable response to the rainfall. This signifies that rainfall is a major recharge source to the aquifer in the study area.

Keywords: Well, Aquifer, Drying-rate, Recharge, Seepage.

Introduction

Hand-dug well is sometimes cost intensive for local people and poses danger to the passers-by. However, it appears the most reliable source especially to the local community in question as it could be sited anywhere and sometimes it can be resourceful round the year. Hand dug wells are dug until at least first aquifer is encountered. Hence, hand dug wells vary in diameter and depth. When using a ventilator for fresh air during digging, it becomes even possible to dig up to 30 meter or more. A hand dug well can be made in hard soils as well as in soft soils.

Ilorin town could not have been the permanent habitat of an ancient population but for the existence of good quality groundwater, which is available almost throughout the year for both intensive agriculture and domestic use. Common sources of useable water around the area are borehole, spring, river, rain and hand dug wells. High cost makes borehole out of reach for common man. Spring and river water are easily contaminated by activities such as fishing, sewage flow, drainages etc (Olugboye, 1978; Alley, Reilly and Franke 1999). Rain sourced water is seasonal, it occurs for less than four months per year in the area.

The present study aims to determine the seasonal variation of aquifer within a part of Ilorin, Kwara State Nigeria.

An aquifer is a geologic formation, group of formations, or part of a formation that contains sufficient saturated permeable materials to yield significant quantities of water to springs and wells (McGinley, 2007; Oyawoye, 1964). In other words, aquifers are underground strata of permeable rock or sand that allow the movement of water between layers of non-porous rock (sandstone, gravel, or fractured limestone or granite). Water infiltrates into the soil through pores, cracks, and other spaces until it reaches the zone of saturation where all of the spaces are filled with water.

Aquifer can be classified into confined/artesian, unconfined/pyretic/free, semi-confined and complex aquifer (Fig. 1). Confined aquifer is bounded up and below by aquiclude and filled with water which is under pressure. Unconfined aquifer is usually underlain by aquiclude but the top of the aquifer consists of soil layers that are permeable enough to provide easy passage of water, at least in a vertical sense. A semi-confined aquifer is an aquifer underlain by an impermeable stratum and bounded at the top by soil layers of relatively low permeability (hydraulic conductivity), especially in horizontal sense. Some characteristics that determine the quality of an aquifer include depth, thickness, porosity, pore connectivity, recharge sources etc. Aquifer recharge sources in the area studied are mainly rain and underground flow.

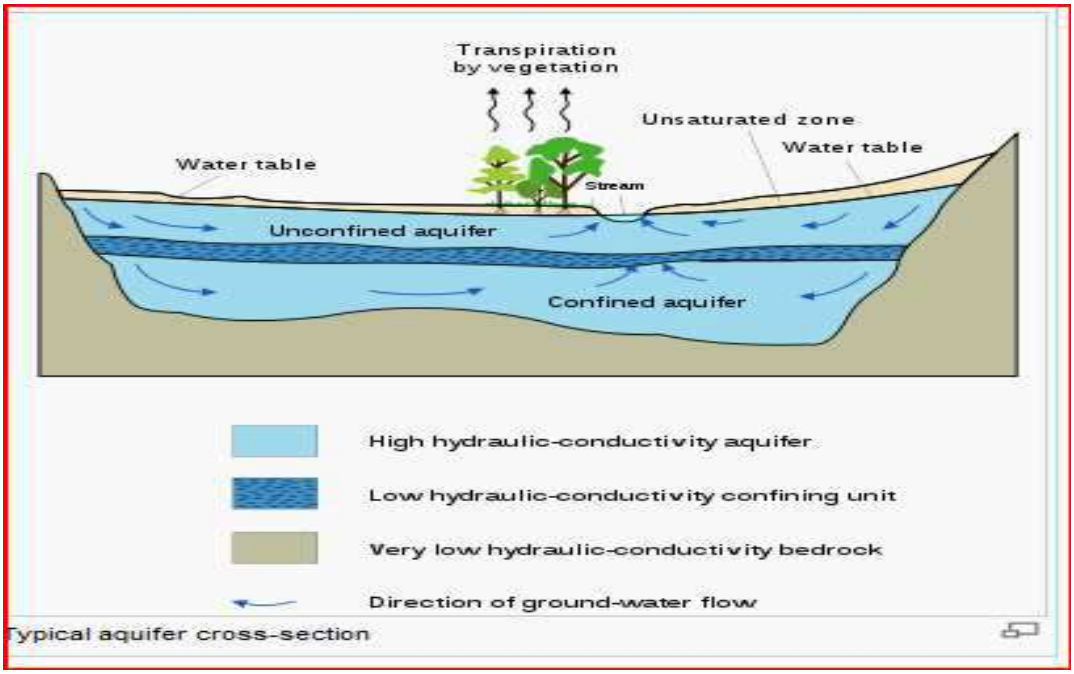


Fig. 1: Cross-section of aquifer

Two main forces drive the movement of groundwater as hydraulic head. First, water moves from higher elevations to lower elevations due to the effect of gravity. Second, water moves from areas of higher pressure to areas of lower pressure due to pressure gradient created around the area. Subsurface water has the potential to move through four different types of rocks: unconsolidated

rock like sand and gravel, porous sedimentary rocks, porous volcanic rocks like basalt, and fractured rocks. Movement in the consolidated rocks is through fractures. The amount of movement through fractured rock depends on the frequency and interconnectivity of the fractures (McGinley, 2007; Driscoll, 1986).

Brief Geomorphology and Geology of the Area

The study area lies in the Precambrian Basement complex of Northern Nigeria around coordinate 8.5131^0 N and 4.609^0 E (Fig.2) and is underlain by rock of metamorphic and igneous types. The hydrological setting of the area is typical of what is obtained in other Basement complex area where the availability of water is a function of the presence of thick-little clay overburden material and presence of water filled joints, fracture or faults within the fresh Basement rocks. The humid tropical climate of Ilorin has particularly encouraged relatively deep weathering of the near surface rocks to produce porous and permeable material that allows groundwater accumulation as shallow aquifer which is recharged principally through infiltration of rainwater.

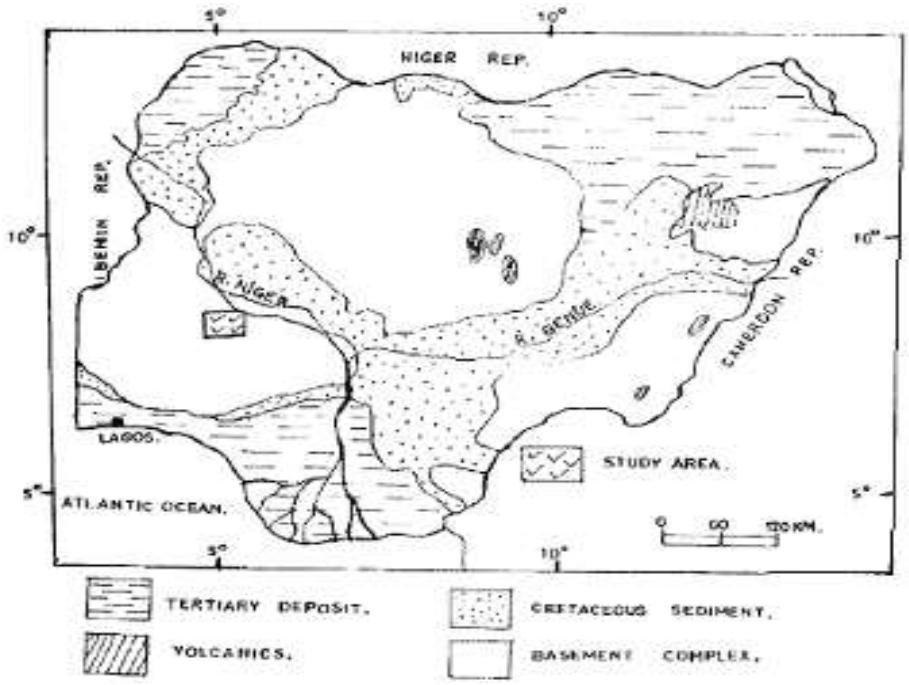


Fig. 2: Simplified Geology of Nigeria Showing the Location of the Study Area (GSN. 1984)

Basement rocks of North Nigeria has been classified into four by Jacobson, Snelling and Truswell, 1963. Rahman (1976) in his review of the Basement complex geology of southern Nigeria recognized five major groups of rock. Also, Odeyemi (1976) classified specified four classes. These are summarized viz:

i. The migmatite-gneiss complex
ii. The metasediment, complex of schist, calc gneiss, quartzite and metaconglomerate.
iii. The phophoritic older granite.

iv. Miscellaneous rock type, mostly post orogenic like Aplites, pegmatite, and dolerite dykes.

The geology of the study area (Ilorin) may be grouped as Surface/Superficial Geology. Apart from the obvious outcrops of solid rocks in some places, most part of the area is covered by dark sandy or clayey loam top soils. This is usually followed by laterite and red soil which form the bulk of the superficial deposited with thickness varying between 4 – 8 m. These obscure much of the underlying geology.

In some cases, the laterites may form capping and are exposed on a few ridges (Olugboye, 1978), which constitutes Subsurface/Solid Geology. This is composed of the weathered, slightly weathered and fresh (fractured or unfractured) crystalline Basements rocks. The oldest rocks in the area comprise Gneiss complex whose principal member is biotite-hornblende gneiss with intercalated amphibolites. This underlies over half of the study area other rocks types are the older granites mainly porphiritic granite, Gneiss and granite-gneiss and quartz-schist.

Materials and Methods

A set of nine wells in the area were strategically selected to cover notable areas for a good representation of the study location. The wells were identified by a GPS for their latitudes and longitudes and numbered from Well 1 to Well 9 (Fig. 3). The elevations of the wells above mean sea level (MSL) were determined using a GPS as presented in table 1.



Well 1: (Coordinate: 4.609^0E, 8.5131^0N)



Well 2: (Coordinate: 4.609^0E, 8.5131^0N)



Well 3: (Coordinate: 4.609^0E, 8.5133^0N)



Well 4: (Coordinate: 8.5135^0E, 4.6093^0N)

Fig. 3a: Physical View of Selected Wells



Well 5 (Coordinate: 8.5132^0E, 4.6092^0N)



Well 6 (Coordinate: 8.5148^0E, 4.6083^0N)



Well 7: (Coordinate: 8.5153^0E, 4.6080^0N)



Well 8 (Coordinate: 8.5153^0E, 4.6098^0N)

Fig. 3b: Physical View of Selected Wells

Having located the coordinates and elevations of the nine target wells, a loaded rope was immersed into the wells one after the other to measure the depth of the water table by an indirect method. These were then measured by direct method on a tape. This was accomplished weekly for six months.

Table 1: Location Properties of Selected Wells

Properties	Well 1	Well 2	Well 3	Well 4	Well 5	Well 6	Well 7	Well 8	Well 9
Latitude(^{0})N	8.5131	8.5131	8.5133	8.5135	8.5132	8.5148	8.5153	8.5153	8.5135
Longitude(^{0})E	4.609	4.609	4.609	4.6093	4.6092	4.6083	4.6080	4.6098	4.6086
Elevation(m)	313	303	306	306	305	310	308	303	306
Azimuth (^{0})	064	310	118	350	336	317	355	039	068

The depth to the top of the well waters was measured weekly for 6 months from April up to September. This is the time window for the driest and wettest periods in the area as studied over years. Measurements were done early in the morning before daily activities commenced on the well. That is considered to be when there is maximum recharge retention in the wells. Thus, depth measurement was done after making sure that the time lapse after any irrigation from the well was at water table level. The depth of water in the well was measured from a uniform reference point at a known height from the land surface. Suitable mathematical models were developed for data processing where necessary.

Results

Typical weekly variation of depth to water table plots is as shown in Fig. 4a-e. Daily and weekly variations of depth to water-top calculated are as shown in table below.

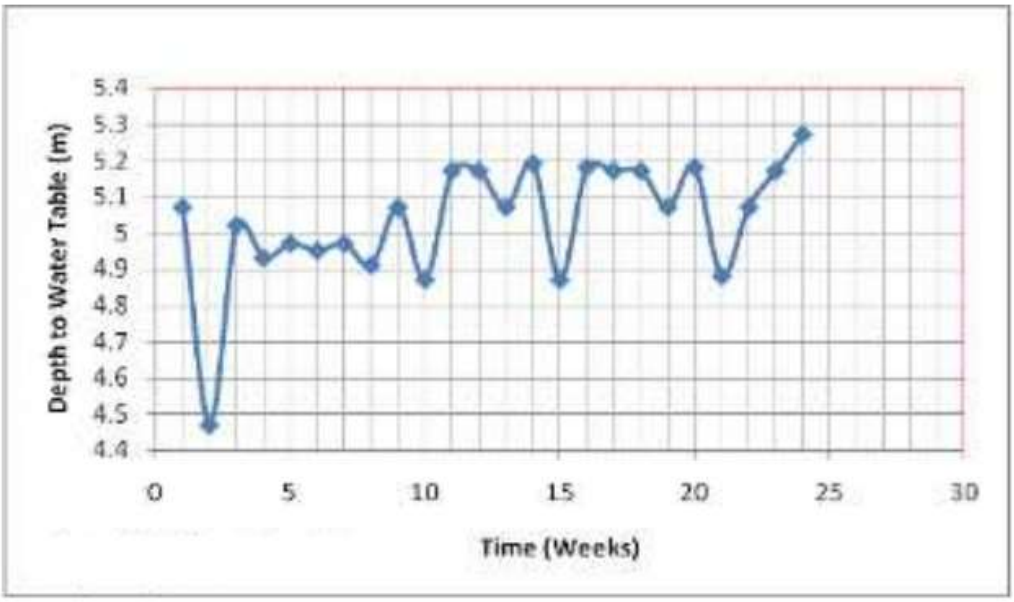


Fig. 4a: Depth/Time Plot for Well 1

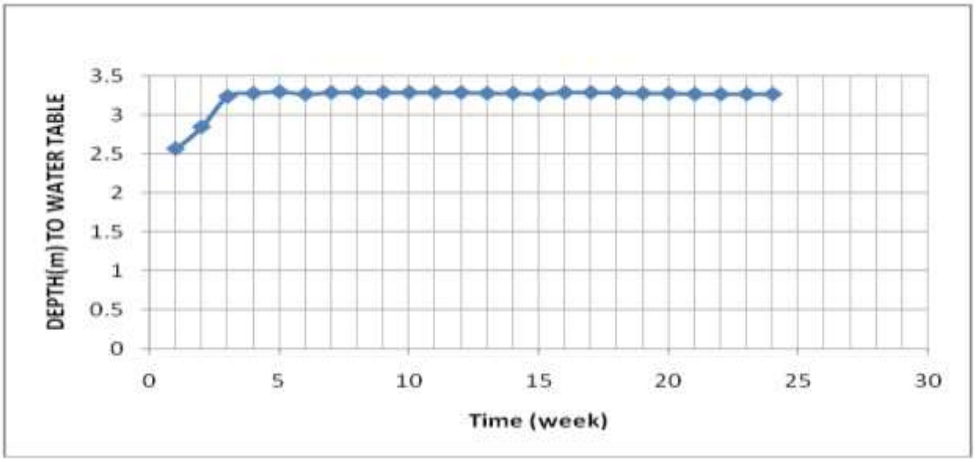


Fig. 4b: Depth/Time Plot for Well 2

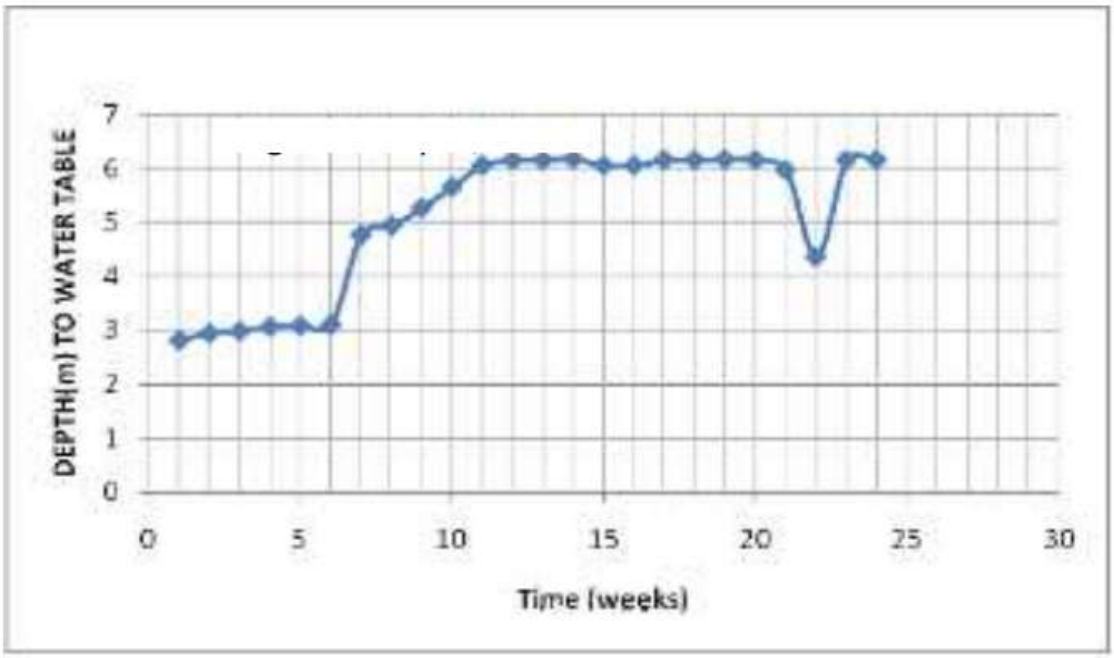


Fig. 4c: Depth/Time Plot for Well 3

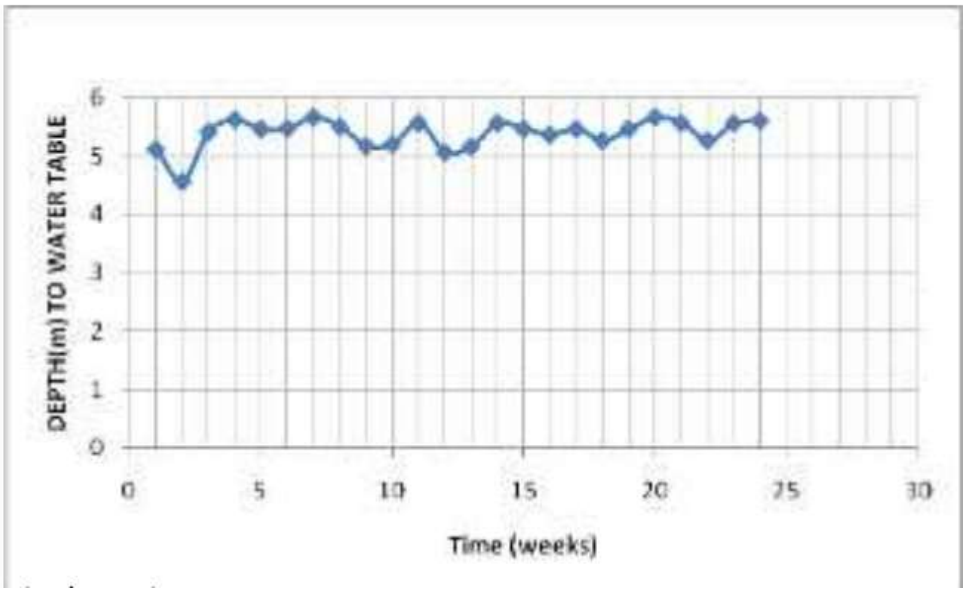


Fig. 4d: Depth/Time Plot for Well 4

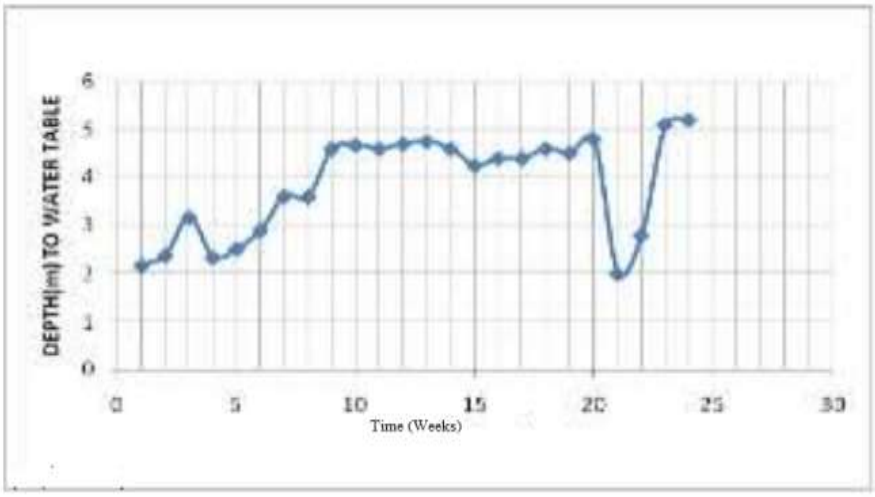


Fig. 4e: Depth/Time Plot for Well 5

Table 2: Drying Rate of Wells

Well	Maximum Depth (m)	Minimum Depth (m)	Drying Rate Per Week (m/week)	Drying Rate Per Day (m/day)
Well 1	5.27	4.47	0.1143	0.0333
Well 2	3.27	2.56	0.1014	0.0296
Well 3	6.17	2.81	0.4800	0.1400
Well 4	5.66	4.56	0.1571	0.0458
Well 5	5.20	2.00	0.4571	0.1333
Well 6	8.46	5.15	0.4729	0.1379
Well 7	8.44	6.62	0.2600	0.0758
Well 8	7.14	3.20	0.5629	0.1642
Well 9	5.10	2.65	0.3500	0.1021

Discussions

Well 1 has the maximum depth to water at 5.27 m and minimum depth at 4.47 m within the months considered. This gives a drying rate of 0.11 m/week and 0.03 m/day. Well 2 has a maximum depth to water-table at 3.26 m and minimum of 2.56 m. At week 3-24, a constant depth to water-table was maintained due to dryness of the water well. The drying rate of Well 2 is 0.10 m/week and 0.03 m/day. In Well 3 it is shown that at a particular period of time the depth to water-table varies and the drying rate is 0.48 m/week and 0.14 m/day. The depth to water table of Well 4 varies appreciably per week and the variation is between 4.56 m and 5.66 m depth. The drying rate is recorded to be 0.16 m/week and 0.05 m/day.

Remarkable variations were observed between week 9 and week 20 of the field work in Well 5. The drying rate is given by 0.46 m/week and 0.13 m/day. From the result obtained, Well 6 has the maximum depth to water-table of 8.46 m. At week 6 - 11 the depth to water-table has a small variation and at week 12, the depth to water-table increased while the drying rate is given by 0.47 m/week and 0.14 m/day. Well 7 has 8.44 m depth to water-table which occured at week 20 of the research. The drying rate for Well 7 is 0.26 m/week and 0.098 m/day.

Well 8 has a peak value of 7.14 m which marked the maximum depth to water-table of the well within the study time. The drying rate for W8 is 0.56 m/week and 0.16 m/day. Well 9 experiences small variation within 6th and 21st week. Later at the 22nd week the depth to water-table increases due to effect of the New Year rainfall. The drying rate for Well 9 is 0.35 m/week and 0.10 m/day.

It could therefore be suggested that some volumes of water are leaking fast to the earth probably through underground connected pores. A very high drying rate obtained for wells 5, 6 and 8 could imply that they are seated on fractured, porous basement, as proposed by Ogunlela (2018); Knapp (2016). Further, the flow direction of the underground water is toward these wells. Further, with exception of well 2, all other wells show appreciable response to the rainfall. This could imply that rainfall is a major recharge sources to the aquifer in the study area.

Conclusion

This research has provided information on the depth to the shallowest water table and that rainfall appears as the major source of aquifer recharge in the area. Low drying rate in most of the wells could signify that most of the wells are underlain by semi or impermeable formation such as fresh basement or slightly fractured basement rock body. This information is vital to the development of an effective water scheme for the area and possibly beyond other areas underlain by the formation. Although the present investigation has not investigated this issue in any great detail, it is concluded that, the major sources of Aquifer recharge is Rainfall. The drying rate is also moderate in most of the wells. This implies that most of the wells could be resourceful within the month studied. In addition, it shows that the wells are underlain by impermeable rocks that limit the aquifer leakages.

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