Prediction of Hydraulic Characteristics of Aquifer and Availability of Water Supply for Irrigation Farming in Basement Complex Terrain, in Part of Ilorin Sheet North-Central Nigeria.

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ABSTRACT
An investigation to predict ground water supply for irrigation farming around Amodu-Irapa was carried out based on data from pre-drilling, aquifer testing for six (6) exploratory wells. Cooper_Jacob non-equilibrium graphical methods were used to interprete the constant rate and recovery data to determine the hydraulic properties. The discharge values range from 1.9 l/sec to 2.5 l/s, while hydraulic conductivities and transmissivities range from 0.2m/day to 2 m/day and 12 m2/day to 36 12 m2/day respectively, with average specific capacity of 2 m3/sec/m. the average yield per hour is 100l/hr and drawdown of 15 m. The six (6) wells will provide a total daily abstraction of 1,600.8m3 based on 16 hour daily pumping schedule. The hydraulic characterization indicated an average of 16 hrs of pumping per day with mean drawdown of 31.8 m, indicating 63.6% of the mean aquifer thickness But, the quarzo-pegmatite exhibited highest transmissivity and aquifer thickness values with 316.8 m3 daily pumping at maximium drawdown of 31.6% of the aquifer thickness and can supply water for 5 ha paddy field, should be targeted during geophysical survey. Pumping in excess of 16 hours a day should be avoided without monitoring of pumping water levels to assess the groundwater resources more fully.
Keywords: Water supply, groundwater supply, aquifer testing and Amodu-Asungbolu.

1. INTRODUCTION
Many factors have to be considered if water wells are going to be used to supply a city, town, industry, hamlet or farm. It is of importance to know, for instance, whether more than one well will be required; at what rate the well can be safely pumped; whether the well will be taking more water out of the ground than is being replaced; how long the well will last and what is the quality of the groundwater. In order to answer these questions, well contractors, and other people concerned with the development of groundwater supplies will know what type of basic information is required in order to evaluate groundwater resources and plan soundly for their use. To supply commercial farmland water all year round, most mechanized agricultural practice are resulting to groundwater exploration and exploitation, the Lafiaji Sugar company Lafiaji had embarked on drilling of

numbers of bore holes to replace dried water supply from river Agwan, few meter from river Niger (Owolabi and Kolawole, 2016). A 50, 000 ha farmland for rice farm at North of Aderan, Kiama Local government of Kwara State will depend mostly on groundwater (Owolabi and Okunlola, 2015). The concerns of the promoter of the project is the role of groundwater to support rice farming, during dry season and late rainy season. Rice-crop water requirement is estimated to be 6 mm/day in North-West Cambodia (Jean et al., 2016. Thus, 60 m3/day of water will be required to supply paddy field of 1 ha (Jean et al., 2016).

Pumping test results is often used to predict aquifer conditions, such as the presence of barrier boundaries, recharge and leakage effects and aquifer dewatering. Pumping test is controlled pumping of well so that the response of the production well and the growth of the drawdown and recovery can be measured. Clark (1988) suggested that the analysis of the pumping test can then be used to evaluate the aquifer characteristics. The study area comprises mainly of Crystalline basement rock and development of aquifers from crystalline rocks as a reliable source of water supply is notoriously complex, and groundwater occurrence is spatially highly variable in crystalline rock area (Wright, 1992; Chilton and Foster, 1995; Banks and Robins, 2002). Some of the greatest groundwater needs occur in the region and groundwater is the only dependable source of water for many users. Groundwater is available and widely used throughout the study area, but in varying quantities depending upon the hydrogeological characteristics of the underlying aquifer. Due to the low intrinsic primary permeability and porosity of the bedrock, crystalline aquifers differ in important ways from other aquifer types, and demand specific knowledge and techniques if groundwater is to be extracted and managed efficiently. A preliminary compilation and review of groundwater in the area had been documented by government, donor development agency and researchers; these include bi-water, Kwara State Water Cooperation, Olasehinde, Adelana and Olasehinde. Elsewhere JICA (2004) and NHISA reported that Ilorin and environ are water stressed and will face serious groundwater shortage.

Omada, et al., (2012) did a work on the assessment of groundwater resources in basement complex terrain of Gwarinpa-Kafe area of Abuja Metropolis, Central Nigeria for 28 boreholes. Among the 28boreholes developed, 14 (or 50%) had yield ranging from 3.33 m3/hr to 5.0 m3/hr. Wells located on weathered overburden had intermediate yield of 5.0 m3/hr to 5.2 m3/hr while the high yield are from wells located on northerly trending fractures. The groundwater resource is large enough for domestic consumption and supplements the limited surface water supply to the area.

Amah and Anam (2016) determines aquifer hydraulic parameters from Pumping Test Data Analysis: A Case Study of Akpabuyo Coastal Plain Sand Aquifers, Cross River State, South-East Nigeria. Five boreholes were subjected to a number of pumping tests: step drawdown, constant discharge and recovery tests to provide some preliminary estimation of hydraulic parameters for the study area. The results indicate that transmissivity T, hydraulic conductivity k, and specific capacity SC, ranged from 485.0m2/d to 1346.0m2/d, 9.7m/d to 27.9m/d, 0.02m3/d/m to 346.m3/d/m respectively. The litho-logs of the boreholes confirm that the estimated hydraulic parameters were obtained from unconfined gravelly sandy aquifers underlain by mostly sandy clay (aquitard)

Akaha and Pronmise (2008) investigate on Hydraulic properties from pumping tests data of aquifers in Azare area, North Eastern. Nigeria. Pumping test data from twelve boreholes were analysed to determine the hydraulic properties of the aquifers, and the availability of water to meet the conjugate demands of the increasing population. The values of the aquifer constants obtained from the Cooper-Jacob's non-equilibrium graphical method were generally low. Yield, Q, values range from 2.24 to 17.46m3/hr (6.22 x 10-4 to 4.85 x 10-3 m/sec), while Transmissivity, (T), fell between 7.39 x 10-6 and 3.55 x 10-4m2/sec and hydraulic conductivity, K, from 5.62 x 10-7 to 42.54 x 10-5 m/sec. The average specific capacity, Cs, value is 2.10 x 10-4m3/sec/m. The total yield is 98.67m3/hr or 2368.08m3/day, and drawdowns in excess of 20m were recorded. These values indicate that the hydraulic characteristics of the aquifers are poor. The implication is that the available boreholes cannot provide sufficient water for domestic and agricultural needs of the area. Hamidu et al., 2014 evaluated causes of low groundwater yield of boreholes in crystalline basement around Gwandu Town and its environ. Hydraulic properties of thirty-seven boreholes were asses.

This report aims at evaluating hydraulic charactesristics and the basement aquifer and availability of groundwater supply for irrigation in part of Ilorin sheet through the determination of aquifer characteristics of the borehole through monitored constant pumping and drawdown recovery measurements, for irrigation farmland.

2.0 MATERIALS AND METHODOLOGY

2.1 The Study Area

The study area is located north and south of link road between Irapa and Amodu-Asungbolu villages in Ifelodun Local Government Area of Kwara State, Nigeria (Fig. 1). The southern boundary runs along west – east slightly above latitude 8016' while a substantial part of the source of River Odunrun flows on northeast – northwest direction at the northern border a little above latitude 8018'. The area covers about 1,000ha (Table 1). The natural vegetation of the area belongs to the subtropical type represented by a mixture of grass, shrubs and woodland.

Boundary co-ordinates provided by the Kwara State Ministry of Lands are as follows: (In DD MM SS.S Minna).

Table 1: Study area boundary

Position	Latitude	Longitude
A	080 16.060'	040 42.835'
B	080 17.490'	040 42.800'
G	080 18.400'	040 43.410'
H	080 18.00'	040 44.560'
J	080 17.350'	040 44.500'
K	080 17.280'	040 44.020'
L	080 17.200'	040 44.010'
M	080 16.100'	040 44.210'

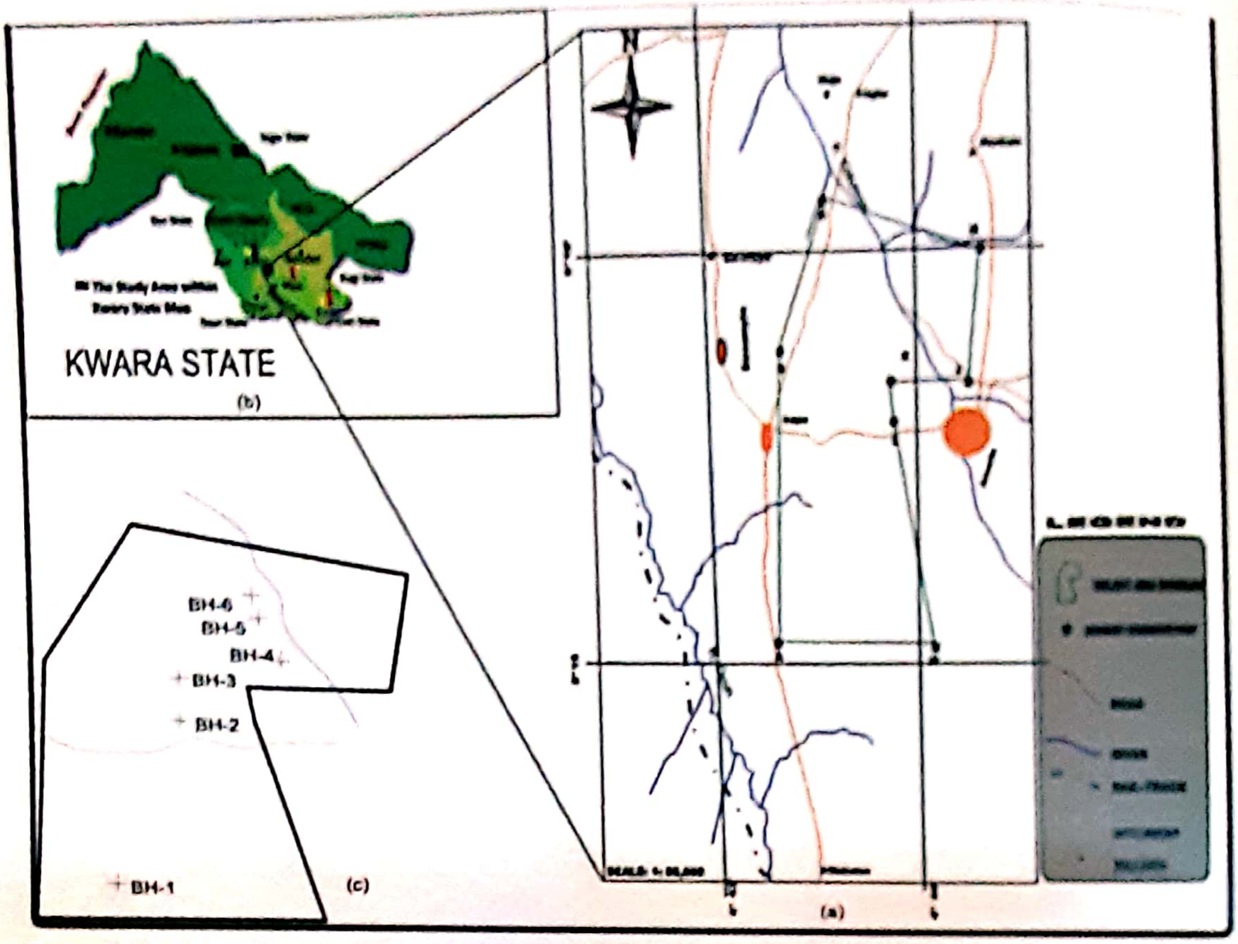

Figure 1: (a) Location map of Study; (b). Map of Kwara State (c). Borehole points (Adapted from Owolabi and Okunlola, 2015)

2.2 Regional Geology

The study area is part of basement complex, affected by the 600Ma Pan-Africa orogeny and made-up of granite, gneiss and migmatite group. (Mc Curry, 1976; OyawoyeBurke &Dewy 1972; Dada 2006). The migmatite group known as Migmatite-Gneiss Complex is the widespread of the Basement complex petro-lithological units (Rahman, 1988; Dada 2006). Asa River lies within the Migmatite-Gneiss-Quartzite Complex (Rahaman,1988). The general rock type includes; Granites, Porphyroblastic Gneiss, Biotite and Biotite Hornblende Gneiss, Older granite, Amphibolite Schist, Quartzites, quartz schists, and other minor occurrences such as pegmatites and quartz veins. However, the rocks are extremely weathered and highly fractured in most locations. The highly permeable weathered fractured zone varies locally and is sometimes composed of quartzo-feldspathic and amphibolitic materials. The class of basement rocks identified as migmatites underline about one/third of the study area (Fig. 2).

2.2.1 Geology of the Ilorin

The area is underlain by rocks of the Nigerian Basement Complex (Rahman, 1989; Mc Curry (1976).). In the area, three major rock units have been recognized namely gneisses, porphyritic granite gneiss and augen gneiss. The gneissic rocks occupy about 80% of the area. Migmatitic-gneiss is the dominant of these rock types (Oluyide, 1988). The gneiss is generally dark-grey in colour. It is medium grained and shows a dominantly north-south foliation trend. It outcrops as low-lying rock bodies. The outcrop in the area is a sequence of variably migmatitic- gneisses with concordant quartzo-feldspathic segregations and bands (Fig. 2a & d). Most of the outcrops are restricted to the northwestern edge of the study area.

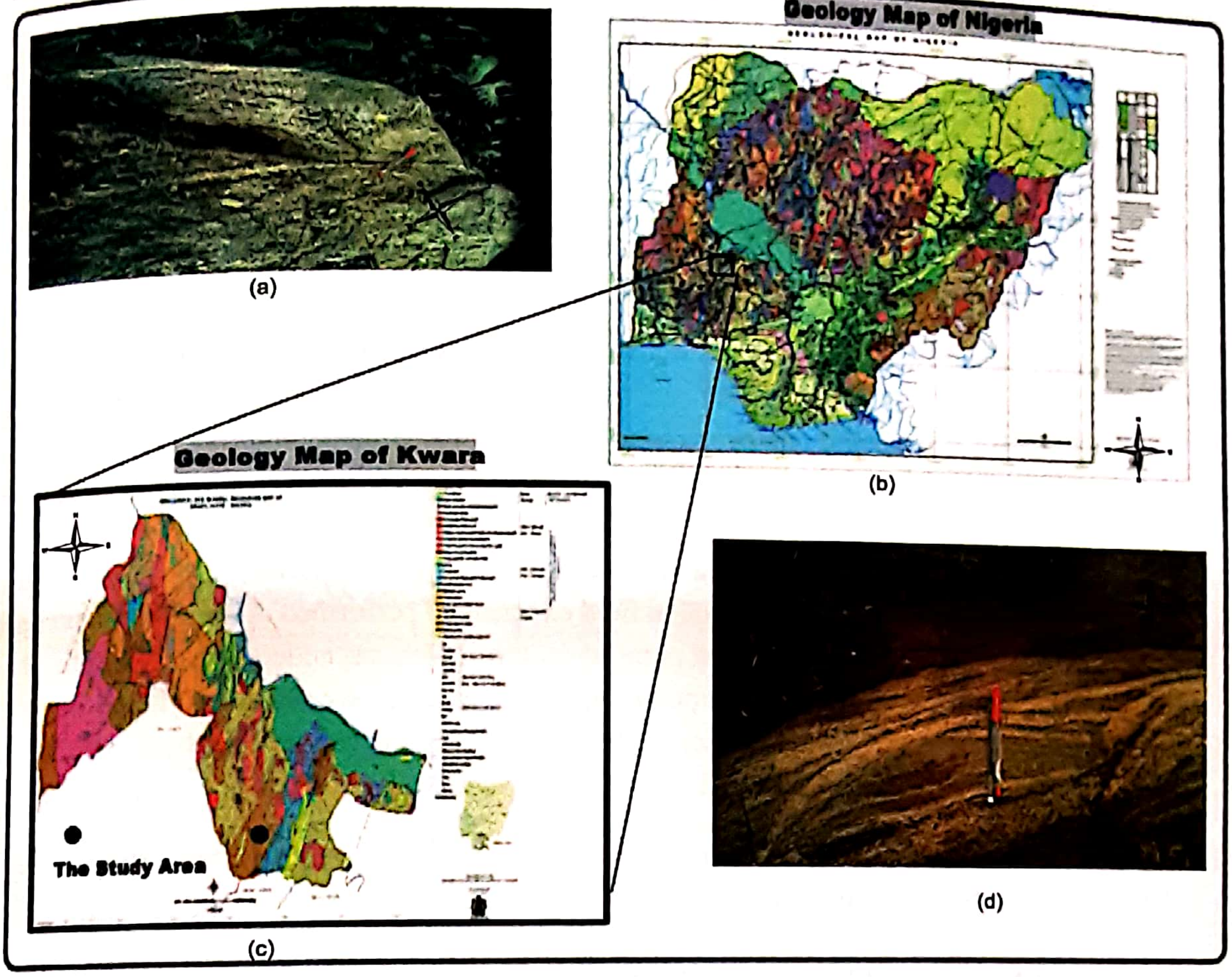

Figure 2: Geological map of the Study area (Modified from Owolabi and Okunlola, 2015). (a)Porphyritic granite gneiss with quartz veins {Red pen points to the North}. (b) Geology map of Nigeria (c) Geology map of Kwara (d): Migmatitic gneiss (N 08° 18.148'; E 004° 43.354', Elevation 381m) {Red pen points to the North}.

2.2.2 Hydrogeology

Ilorin is situated on the undifferentiated Precambrian Basement Complex rocks of granitic and metamorphic origin. These rocks represent the deeper, fractured aquifer which is partly overlain by a shallow, porous aquifer within the lateritic soil cover (Annor and Olasehinde, 1996). The rock units form part of the regional South Western highlands of Nigeria running NW-SE parallel to the River Niger (Offodile, 1987; Olasehinde *et al.*, 1998). The subsurface comprises the weathered, slightly weathered and fresh (fractured or unfractured) crystalline basement 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 city. Other rock types are the older granite mainly porphiritic granite, gneiss and granite-gneiss and quartz schist. The two main types of aquifer in this area are the weathered basement and jointed/fractured basement aquifers with the latter usually occurring below the former. The aquifers are localized and disconnected but occur essentially as unconfined to semi-confined under water table conditions. Although the crystalline nature of the basement rocks preclude development of the porosity and permeability necessary for good groundwater occurrence, Davis and De Wiest (1966) asserted that appreciable porosity and permeability may have been developed within these rocks through fracturing and weathering processes. Further information from available borehole lithological logs in the region revealed that weathering is fairly deep and that the rocks have been jointed and fractured severely occurring between 30 – 68m below the surface (Annor and Olasehinde, 1990).

2.3 Field Techniques

The pumping test methods used for the study are the constant rate test and recovery rate test for six (6) exploratory boreholes. Constant-rate test maintain pumping at the test well at a constant rate. i.e pumping at a specific rate over a long period of time while monitoring the drawdown, while water-level response (drawdown) is measured at specified intervals of time. The goal of this constant-rate pumping test is to estimate hydraulic properties of an aquifer system such as transmissivity, hydraulic conductivity and storativity (storage coefficient). A recovery test is also another efficient method used in controlled field experiment performed at the end of a pumping test (constant-rate) after pumping in the pumped (control) well has ended. Water-level response (residual drawdown) is measured after pumping has stopped in the control well itself. The above methods were used in the field to collect all the pumping test data around the study area. Lithological logs of the holes collected during drilling and VES data enable us to establish subsurface geological succession, as well as construct accurate well design.

2.4 Hydraulic Test analysis

2.4.1 Constant-Rate Test

Constant-rate pumping-test data can be utilized to determine aquifer transmissivity and storage coefficient. Observation wells were not available for the majority of the wells tested and hence, only values of aquifer transmissivity were determined. Time-drawdown data were analyzed using the Cooper-Jacob (1946) modification of the Theis formula equation. This modification is generally referred to as Jacob's method.

$$T=\frac{264Q}{\Delta S} \quad (1)$$

Where:

T= aquifer transmissivity in m2/day.

Q= pumping rate in l/sec.

ΔS= the slope of the time-drawdown graph expressed as the change in drawdown between any two values of time on the log scale whose ratio is 10.

One advantage of Jacob's method is that time-drawdown data can be plotted on semi-logarithmic paper, with time on the log scale and drawdown on the arithmetic scale. If aquifer characteristics are in accordance with the basic assumptions, then the data will fall on a straight line. Deviations from a straight-line plot can often be used to delineate boundary conditions or aquifer dewatering.

2.4.2 Recovery Test

Water level recovery data are often more accurate than time-drawdown data, since the recovery period is not affected by pump vibrations and fluctuations in the pumping rate. There are two common methods that are used to analyze water level recovery data. In the first method, calculated recovery versus time after pumping stopped is plotted on semi-logarithmic paper. In the second method, residual drawdown versus t/t' is plotted on semi-logarithmic paper, where t is the time since pumping started and t' is the time since when pumping stopped. The second method for analyzing water recovery data is preferred, as it provides a more independent check of the results that were calculated from the time-drawdown data. This is because the first method requires an extension of the time-drawdown plot for pumping and if there have been any deviations from a straight-line plot due to boundary effects or irregularities in the pumping rate, then the first method would provide erroneous results. Water-level measurements made during the recovery period provide a distinct set of information for aquifer or pumping test, thus providing a means of checking results that were determined from the time-drawdown period.

$$T' = 0.183 \times Q \text{ over } \Delta S' \text{ (m2/d)} \quad (2)$$

Q is discharge in l/s and is recorded in the field

Where,

0.183 is a constant

$\Delta s'$ value is obtained from semi-log diagram

The Cooper-Jacob excel spread sheet is used to carry-out the constant rate interpretation for Hydraulic conductivity and transmissivity for both constant rate and recovery.

2.4.3 Estimating Aquifer Productivity and Storage

2.4.3.1 Specific capacitance

The specific capacity *Sc* is the ratio of discharging (*Q*) to steady drawdown (S_w).

$$Sc = Q/S_w \quad (3)$$

Where,

Q = Discharge

Sw = Maximum drawdown

2.4.3.2 Groundwater Storativity

A relationship between transmissivity and specific capacity was carried out, while the groundwater storage GW was calculated as:

$$GW = Sy * \Delta z \quad (4)$$

Where,

Sy = the specific yield

Δz = Thickness of saturated aquifer

4. RESULTS AND DISCUSSION

4.1 Hydraulic and Aquifer Charaterisation

Table 4.1 contains a summary of the results of the constant-rate pumping tests. Values of aquifer transmissivity range from 9.4 m2/day to 41 m2/day and 12 hour specific capacities range from 0.04 to 41.47. Data indicated that transmissivity (recovery) was less than transmissivity (pumping) for most tests. This might not be attributed to less turbulence and non-Darcian flow during the recovery period than during pumping.

Table 2: Constant Rate and recovery Test Results

Well no	Pumping Duration	Average Discharge	SWL	Pumping Water Level	Specific capacity (Q/s)	T(m2/day)	T'(m2/day)	K (m/day	K' (m/day)
BH1	170	2.2	0.66	5.12	0.43	19	4.5	0.22	0.06
BH 2	150	2.2	1.55	18.85	0.12	36	8.3	0.51	0.17
BH 3	72	2.2	3.1	33.25	0.07	36	8.3	0.59	0.21
BH 4	300	2.14	4.85	15.1	0.14	35	26	0.39	0.38
BH 5	50	2.5	2.5	46.30	0.05	41	9.4	0.53	0.17
BH 6	40	2.5	3.7	63.80	0.04	41	9.4	0.49	0.15

4.1.1 Borehole (BH-1).

Borehole one (BH-1) was drilled to a total depth 0f 140m and depth to basement is 3 m. During drilling, water bearing fractures were noted at 51-60 m, and 72-102m, with total fracture zone of 30 m. Constant rate method of pumping test was conducted at pump in-take level of 128m for 110 minutes. Total drawdown was 5.12m i.e. from initial static water level of 0.66m. Dynamic water level was not attained, while discharging at constant rate of 2.2 litres per second. The first change in slope occurred at about 8 mins, this is as a result of barrier boundary or limit aquifer (Vincent and Sharma 1978). The second change in slope occurred at 100 mins when dewatering of the first fractured zone began. Based on the total drawdown of 5.12m over a period of 2 hours pumping time, a pumping period of 16 hours per day at 5litres per second is initially recommended at pumping period of 8 hours interval. The pumping period can be modified to suit demand once other wellfield has been established and monitored over a full season. The transmissivity was calculated as 36m2/day.

4.1.2 Borehole (BH-2).

This borehole was drilled to a depth of150m and fractures were encountered at 39-42 m, 60-63 m, and 68- 81 m. Total fracture zones is 18 m Constant rate method of pumping test was conducted at pump in-take level of 128.4m for 120 minutes. Total drawdown was 18.85m i.e from initial static water level of 1.55m. Dynamic water level was not attained, while discharging at constant rate of 2.2 litres per second. The first change in slope occurred at 15 mins without any dewatering.

4.1.3 Borehole (BH-3).

Total borehole depth is 140m and fractures were encountered at 15 m and throughout the drilled depth. Constant rate method of pumping test was conducted at pump in-take level of 111.30m for 180 minutes. Total drawdown was 33.25m i.e from initial static water level of 3.10m. Dynamic water level was not attained, while discharging at constant rate of 2.2 litres per second. Recovery of over 73.5% was attained within 60minutes. The first change occurred at about 15 mins as a result of boundary barriers or limited aquifer, the second slope change occurred at 100 mins when dewatering of the first fracture zone began.

4.1.4 Borehole No.4 (BH-4).

Borehole one (BH-4) was drilled to a total depth 0f 170m and depth to basement is 3 m. Fractures was encountered throughout the drilled hole. Constant rate method of pumping test was conducted at pump in-take level of 120m for 300 minutes. Fractures were encountered at 3-30 m and 60-72 m Total drawdown was 15.10m i.e from initial static water level of 4.85m. Dynamic water level was not attained, while discharging at constant rate of 2.14 litres per second. Recovery of over 77.4% was attained within 60minutes. The first change in slope occurred at about 10 mins, this is as a result of barrier boundary or limit aquifer (Vincent and Sharma 1978). The second change in slope occurred at 80 mins when dewatering of the first fractured zone began.

4.1.5 Borehole (BH-5).

Borehole BH-5 was drilled to a total depth is 156m and fractures were encountered at 60-71 m and 95-110 m, with a depth to basement of 5 m. Constant rate method of pumping test was conducted at pump in-take level of 114m for 60 minutes. Total drawdown was 46.3m i.e from initial static water level of 2.50m. Dynamic water level was not attained, while discharging at constant rate of 2.5 litres per second. Recovery of over 25.7% was attained within 60minutes. The first change in slope occurred at about 8 mins, this is as a result of barrier boundary or limit aquifer (Vincent and Sharma 1978). The second change in slope occurred at 40 mins when dewatering of the first fractured zone began.

4.1.6 Borehole (BH-6).

This borehole was drilled to a total borehole depth is 163.5m and rfactures were encountered at 40 -50 m and 75-90 m, with a total fracture zone of 25 m. Constant rate method of pumping test was conducted at pump in-take level of 125.3m for 180 minutes. Total drawdown was 71.92m i.e from initial static water level of 3.70m. Dynamic water level was not attained, while discharging at constant rate of 2.5 litres per second. Recovery of over 25.7% was attained within 60minutes. The first change in slope occurred at about 8 mins, this is as aresult of barrier boundary or limit aquifer (Vincent and Sharma 1978). The second change in slope occurred at about 25 mins when dewatering of the first fractured zone began.

Table 3: Operational Policy for all the boreholes

	BH-1	BH-2	BH-3	BH-4	BH-5	BH-6
Daily Pumping Period (Hr)	16	16	16	16	16	16
Pumping Rate (l/s)	5	4.8	4.5	5.5	4	4
Pumping Interval (Hr)	8	8	4	8	4	4
Total Abstraction (m3/day)	288	276.5	259.2	316.8	230.4	230.4
Pump Intake Level	160	140	130	160	145	150

4.2 Aquifer Characterisation and Water availability

The groundwater storage calculated with equation (4) is higher at BH-3 and BH-4 because of high transmissivity and aquifer thickness (Table 4). The mean groundwater storage calculated is 111.2 m and 83% values range between 60 and 220. The variation of the properties of the aquifer is perhaps due to variation of aquifer thickness. The estimated groundwater storage is closed to the storage estimated in other weathered hard rock aquifers (E.g Vouillamoz *et al.*, 2015).

To estimate, if the aquifer can provide 60 m3 daily for 1000 ha, The daily safe discharge of the boreholes varied considerably because of the local hydrogeology but a total discharge of 1,600,800 litres/day = 1,600.8m3/day has been calculated for the six wells tested. So for about 1000 ha of farmland, about 225 bore holes will be needed to meet the 60 m3/day of water required to supply paddy field of 1000 ha. The hydraulic characterization indicated an average of 16 hrs of pumping per day with mean drawdown of 31.8 m, this indicated 63.6% of the mean aquifer thickness (Table 4). But, the quarzo-pegmatite exhibited highest transmissivity and aquifer thickness values (Table 4), with 316.8 m3 daily pumping at maximium drawdown of 31.6% of the aquifer thickness and can supply water for 5 ha paddy field.

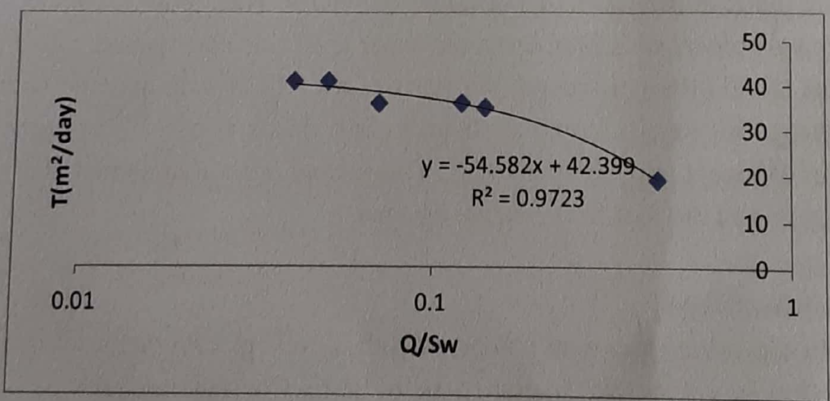

Figure 3: Plot of T (m2/day) Versus Q/Sw Versus

Table 4: Aquifer Test and Bore completion data

S/N	Total Depth	Pump-Intake	SWL	Discharge	Total Fracture Zone	Storagivity	Final Draw Down	Final Residual Draw down
1	140	111.3	3.1	2.2	30	66	33.25	24.45
2	150	128.4	1.55	2.2	18	39.6	18.85	9.5
3	102	128	0.66	2.2	100	220	5.12	3.11
4	102	120	4.85	2.14	100	214	15.1	11.69
5	156	114	2.5	2.5	26	65	46.3	11.9
6	163.5	125.3	3.7	2.5	25	62.5	71.9	00
Mean					50	111.2	31.8	

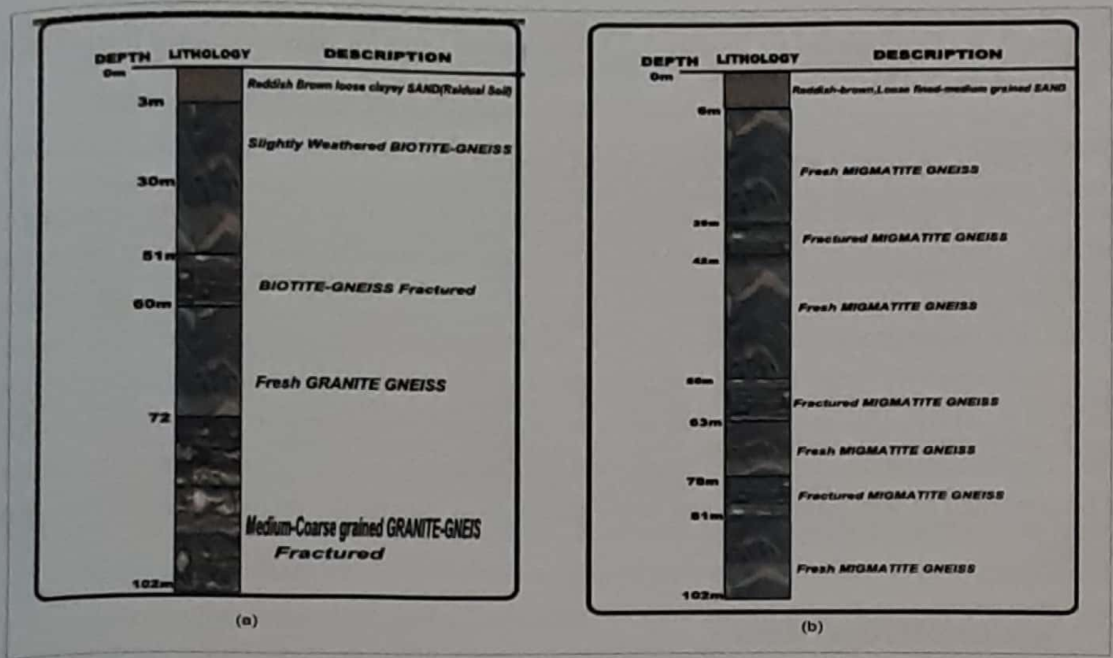

Figure 4: (a) Geological Logs for BH-1, (b) Geological Logs for BH-2 (Adapted from Owolabi & Okunlola, 2015).

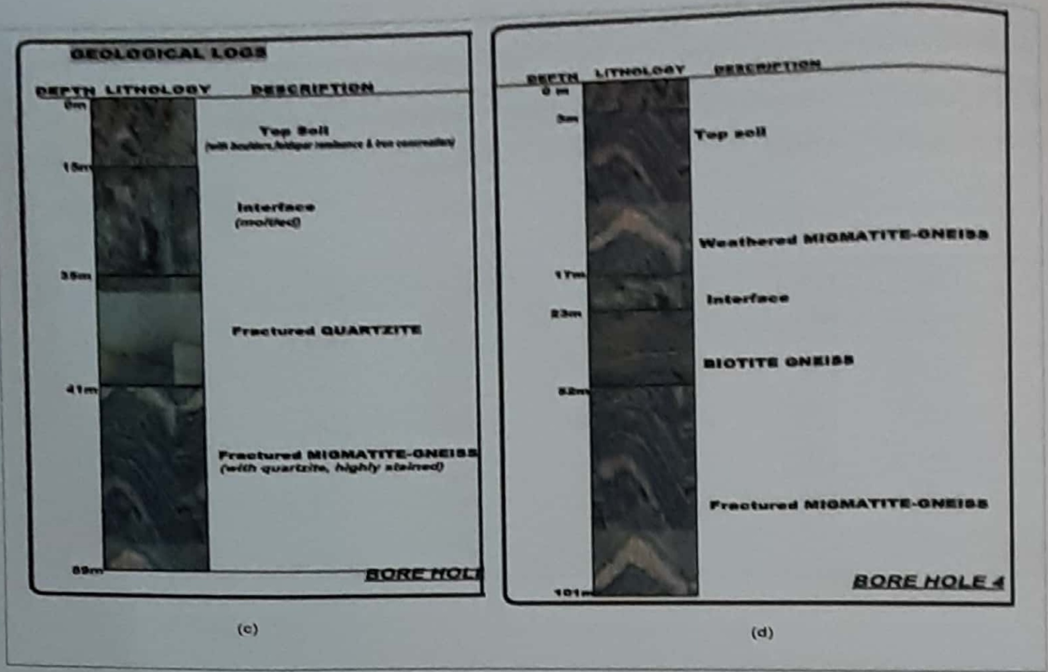

Figure 3: (c) Geological Log for BH-3, (d) Geological Logs for BH-4 (Adapted from Owolabi & Okunlola, 2015)

5.0 CONCLUSION AND RECOMMENDATION

Data on Table 4 indicates that transmissivity (recovery) is less than transmissivity (pumping) for most tests. This may not be attributed to less turbulence and non-Darcian flow during the recovery period than during pumping. The boreholes revealed variable hydraulic characteristics and hence all other designated production wells should be pump tested to ascertain their safe yield. Values of aquifer transmissivity range from 9.4 m2/day to 41 m2/day and 12 hour specific capacities range from 0.04 to 41.47. This is mainly due to more pronounced fracturing in groundwater discharge areas. The transmissivity (recovery) is less than transmissivity (pumping) for most tests. This may not be attributed to less turbulence and non-Darcian flow during the recovery period than during pumping.

5.2 RECOMMENDATIONS

I. Monitoring chart for a full operational season (wet and dry) should be established and maintained especially at the initial stage.

II. Increase in discharge from the boreholes should be backed up with scientific data.

III. To meet global requirement for water supply, a total of about 225 boreholes will be needed, perhaps River Odunrun could be dammed for conjunctive use with the groundwater.

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