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Research Article

HYDRAULIC PARAMETERS FROM HAND DUG WELLS ON GROUNDWATER OF IGBO-ORA, IBARAPA CENTRAL LOCAL GOVERNMENT AREA OF OYO STATE, SOUTHWESTERN NIGERIA

[1]Ajibade Oludare S, [2]Idowu Olufemi A and [3]Adewuyi Gbola K*
[1, 2] Department of Water Resources Management and Agromeorology, Federal University of Agriculture, Abeokuta
[3]Department of Surveying and Geoinformatics, The Polytechnic Ibadan, Oyo State, Nigeria
**Author for Correspondence: adewuyismart@yahoo.com*

ABSTRACT
Groundwater potential of Igbo-Ora, South-western Nigeria was investigated in this study. The study employed the use of Theis recovery method for the estimation of hydraulic parameters of fifty (50) selected hand-dug wells. Estimated parameters included transmissivity, specific yield, static water level, direction of groundwater flow and well yield. The study covered both dry (December, 2009–January, 2010) and wet (June–July, 2010) seasons respectively. The hydraulic parameters of an aquifer studied include; porosity, specific yield/ storage coefficient, specific retention, transmissivity and hydraulic conductivity. In the dry season, the maximum and minimum well yield was 0.26 ℓ/s for Isale-Ajegunle and 0.0002 ℓ/s for Asdebisi-Idofin. Classification of wells in accordance with United States Public Health Department standard for well yield showed that 34% were poor, 44% were useable while 11% were acceptable for residential/domestic water supply. For the wet season, the maximum and minimum well yield was 0.62 ℓ/s for College of Agriculture and 0.04 ℓ/s for Adebisi-Idofin. Classification showed that 4% were poor, 58% were useable, 16% were acceptable while 18% were excellent for residential purposes. Specific yield ranged from 0.01 to 0.74 and 0.01 to 0.61 for dry and wet seasons respectively. Transmissivity values ranged from 10^{-3} to 10^{-4} m^2/s for both seasons. Static water level ranged from 0.83 to 8.00 m, with mean 3.98 m for dry season and from 0.42 to 5.93 m, with mean 2.69 m for wet season. Using t-test statistics, seasonal variations were used to analyze individual variations. At 90% and 95% confidence level, the t-test correlation was determined and the results showed the correlations that exist between parameters studied.

Keywords: *Hydraulic parameters, Theis recovery method, Classification of well*

INTRODUCTION
The hydraulic parameters of an aquifer include; porosity, specific yield/ storage coefficient, specific retention, transmissivity and hydraulic conductivity. The determination of hydraulic parameters of aquifers can be done in the field or in the laboratory. The laboratory method is the use of falling head and constant head permeameters to determine hydraulic conductivity only. Field method includes the radioisotope or tracer test, slug test and pumping test (Gordon et al., 1966). Several methods have been devised by scientists, researchers and engineers for estimating groundwater hydraulic parameters. Most of these methods are sometimes applicable only for estimating one among several hydraulic parameters. However some of these methods can be used for estimating all parameters. Oyeshomo (1987) in his hydrological assessment of the crystalline rocks of Oyo state reported yields of boreholes range from 0.24 m^3hr^{-1} to 36.3m^3 hr^{-1}, with an average of 6.74m^3 hr^{-1}. (Johnson, 1974) stated that geologically, the earth's crust is made up of rocks and soils. The rocks are igneous, sedimentary, and metamorphic in origin; the soils are derived from the rocks by weathering of rock exposures (Gordon et al., 1966). The change in water level relative to the original static water level during recovery period is known as the residual drawdown. Under ideal conditions, recovery of water levels after the end of pumping is a mirror image of the drawdown. Changes in water levels during the period of recovery are the same as if withdrawal

continued at the same rate from the pumping, but at the moment pumping is stopped, recharge into the well begins and water recharge at the same point at the same rate**.**

Jacob (1947) divided the drawdown in a pumping well into two components. The first component, termed "aquifer or formation loss" arises from the resistance of the formation to fluid flow. Groundwater accounts for about two-thirds of the fresh water resources of the world (Freeze and Cherry, 1979). Most of the pumping tests performed on boreholes in the study area were of short duration. Pumping tests of short duration do not allow unique curve match to be established (Idowu, 1992). The recovery method provides the closest estimate of transmissivity values of aquifers because the method rules out the drawdown variations that are caused by slight differences in discharge rates during pumping and the effect of pump variations (Todd, 1980). From the study, 18% of the wells excellently yielded water for residential/domestic purpose, thus indicating the possibility of water scouting, even in the wet season. Alternative water sources for public use are thus recommended. Disinfection is recommended for water drawn from wells due to sewage contamination tendencies, especially during the wet season.

Groundwater flow Direction

Figure 1 below shows the direction of groundwater flow of the study area. Groundwater predominantly flows out of the study area through the Northwestern side as evidenced by the flow towards INEC office. The flow towards the L.G.A Guest House is a flow in the Southwestern direction, while in the Northeast direction, groundwater flow towards Obasanjo farms. Groundwater flow towards College of Agriculture was also noticed, as well as groundwater flow away from Resort centre towards NDLEA office. The places from where groundwater flow includes: Resort Center, Ogongo, Express-Igbole, Odeyale-pako, Gbotikale, General Hospital and Bambeke-Igbole, and they represent the recharge areas in the study (figure 1).

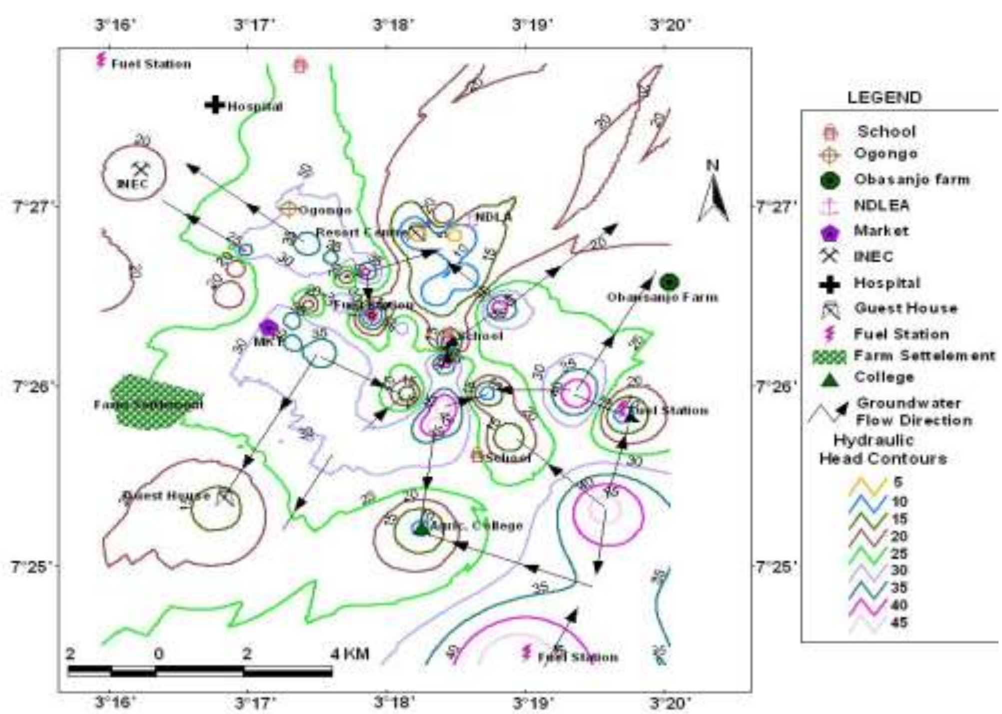

Figure 1: Groundwater flow direction of the study area
Source: Authors

Study Location

The study area, Igbo-Ora, is the headquarters of Ibarapa Central Local Government Area of Oyo State, Southwest Nigeria. The town is located between longitudes 3°13`mE and 3°19`mE and latitudes 7°22`mN and 7°28`mN. Igbo-Ora is approximately 66km North-West of Ibadan, the Oyo State capital and about 32km north of Abeokuta, the capital of Ogun State. Igbo-Ora share boundary with Ogun state to the South and West, Ibarapa North Local Government Area to the North-West, Iseyin Local Government Area to the North-East and Ibarapa East Local Government to the East (figure 2).

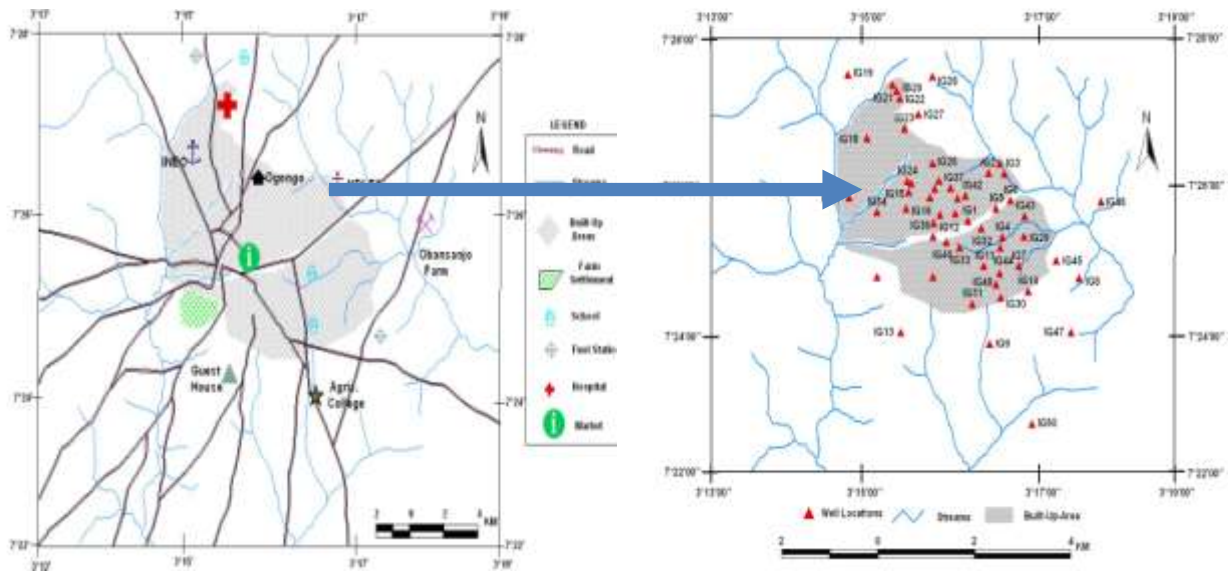

Figure 2: Map of the study area (Digitized map and map showing spatial location of wells)
Source: Author

MATERIALS AND METHODS

Materials used

Materials used for data acquisition are as listed below:

- ❖ Electric pump (1HP surface electric pump)
- ❖ Measuring tape
- ❖ Stop watch
- ❖ PVC riser pressure pipes
- ❖ Electronic handheld Global Positioning System (GPS)
- ❖ Plumbing appliances and materials
- ❖ Electricity generating set, electric cables and fittings.
- ❖ 50 units of 1 Litre plastic bottles.
- ❖ Graduated bucket
- ❖ White paper tape/markers
- ❖ Thermometer
- ❖ The pH/EC/TDS meter
- ❖ A sinker (a metal bulb) tied to a twine
- ❖ A floater (a plastic plate) tied to a twine
- ❖ 50 units of Sterilised (glass)10ml samplers
- ❖ Safety rope for pump suspension

Climate and Vegetation

The average weather conditions of the study area, like that of all part of Nigeria, are tropical. The weather is controlled by the moist southwest monsoons and the dry Northeast trade winds. The regular movements of these winds create distinct climatic seasons and vegetation pattern in the study area. There are two distinct climatic seasons that can be recognized in the study area. Iloeje (1976)

i. *The wet season:* The first episode of wet season starts in mid-March and lasts till July and the second episode of wet season follows the August break and usually lasts from September to November with mean annual rainfall calculated for the season is about 365mm, while the average monthly relative humidity is about 85 percent. The mean annual rainfall calculated for this period is about 800mm, while the average monthly humidity is about 85 percent. The mean monthly minimum and maximum temperatures for the long wet season are 25^oC and 30^oC respectively. The amount of rainfall increases from September to October, and decreases from October to November. The mean monthly minimum and maximum temperature of the episode are about 22^oC and 30^oC respectively.

ii. *The dry or harmattan season:* This season follows the wet season and continues from November to March. The water levels throughout the study area are lowered and many shallow open wells dry up during this season. The average annual relative humidity calculated for the long dry season is about 80 percent and the average monthly minimum and maximum temperature are about 25^oC and 35^oC respectively. Information available at Ogun-Osun River Basin Development Authority shows that the mean annual rainfall of the study area over a period of 30 years (1960-1990) is 1314mm ± 155mm.

Methods/Procedures

The spatial location of the study area for each sampled point was determined with the use of Handheld GPS. Longitude and latitude as well as the height of all sampled location were determined. The data obtained for different spatial location was processed using ArcGIS 10.2 software (figure 2). The study employed also employ the use of a sinker for total well depth determination, while a floater was used to determine static water level and residual water levels. 1HP surface model ATP1.25 by ATLAS electric pump was used for pumping. The study also employed the use of a sinker for total well depth determination, and a floater was used to determine static water level and residual water levels. Correlation analysis was conducted using (EVIEWS 11) statistical software. Pearson correlation coefficient ‘r’ was used to determine the relationship between parameters and their interrelationship. The value of ‘r’ at 95% and 90% confidence level was (0.279) and (0.235).

Pumping Process

After the pump set-up, the electric generating set was switched into operation. Electric cables were used to connect the generating set and the pump. The time at which pumping stated was noted and recorded. Pumping of water out of wells was done long enough to establish an appreciable change in water level and a visible cone of depression. However, caution was taken not to allow total dewatering of the wells

Discharge Measurement

During the data acquisition, pumping discharge was taken into consideration. At every point of data acquisition for each well, at least, three discharge measurements were taken using a 20litres calibrated bucket and a stop watch, discharge of water from individual well were taken, the average determined as stated below;

$Q_1 = V_1/t_1$

$Q_2 = V_2/t_2$

$Q_3 = V_3/t_3$

$Q_{av} = (Q_1 + Q_2 + Q_3)/3$

Q_1, Q_2, and Q_3 are discharge in liters per seconds

V_1, V_2 and V_3 are volumes measured in liters

t_1, t_2 and t3 are time recorded in seconds

Q_{av} is the average discharge calculated for each well in cubic meter per second (m^3/s). Q_{av} represents the discharge for each well. It was recorded and used in computation of other hydraulic parameters.

Shutting-down of pump

After an appreciable cone of depression has been established, though not allowing total dewatering of well, the pump was shut down and the Electric Generator switched off. The time at which pumping stopped was noted and recorded. Period for which the well was pumped was calculated. It is the difference between 'time at which pumping started' and 'time at which pumping stopped'. It was recorded as "period of pumping". Water level at this point was determined using the floater and twine. It served as the first recording for residual draw down; which is expected to be zero.

Observation and Measurements of Residual Draw Down

The first water level measurement was obtained as the pump was switched off. The first recorded value represented residual drawdown at time t, when residual drawdown is expected to be zero. Subsequent recordings were made at regular intervals of 5 minutes each. Periods of observation ranged from 10 minutes to 2 hours. This was dependent on a number of factors, among which were:

- Quantity of water in storage prior to pumping
- Rate at which water was pumped out of well
- Rate of well recharge
- Use for which well is put
- Disturbance from individuals wanting to fetch from tested well
- Approval of well owners

Theis recovery method to observed data

Well recovery values (m) obtained immediately after pump was switched off and were plotted against time (s) on arithmetic log papers. The relationship between the well recovery and time was expected to be positive; as well recovery values increased with time. Straight line graphs were derived from the relationships after plotting. Using Theis recovery test method of analysis involves plotting residual drawdown s^1 against time ratio t/t^1 as shown in (figure 3) below.

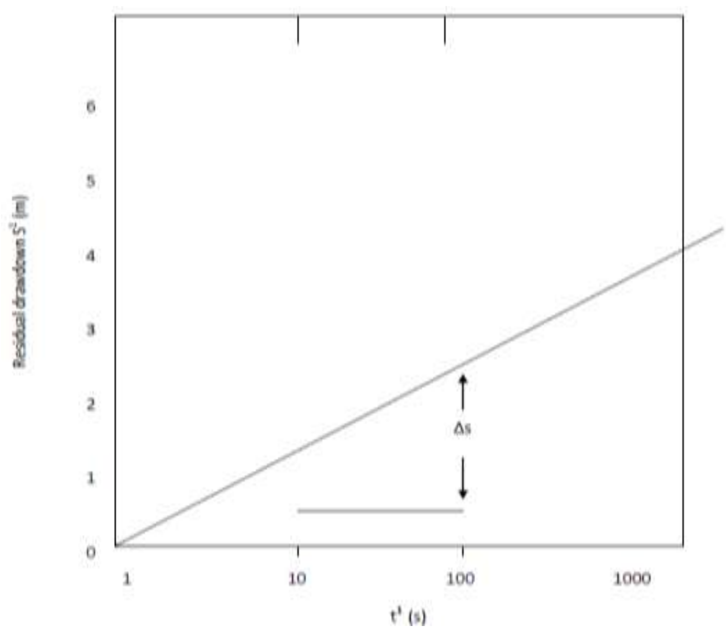

Figure 3: Theoretical plot of residual drawdown against time of recovery (after Theis).

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The equations used for recovery test method are:

$$s = \frac{2.3Q}{4\prod T} \log t/t^1$$

$$T = \frac{2.3Q}{4\prod T \Delta s^1}$$

Where, t^1 = time since recovery started (sec)

t = $t_0 + t^1$

t_0 = time at which pump was stopped (sec)

Q = discharge m^3s^{-1}

The storage coefficient for recovery test was estimated from the formula,

$$s = \frac{2.30Q \log}{4\pi T} \frac{2.25Tt_1}{r^2S}$$

Where, s = observed drawdown (m)

Q = discharge (m^3/day)

T = transmissivity (m^2/day)

t^1 = time since pumping was stopped (day)

r = radius of the well (m)

S = storage coefficient

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RESULTS AND DISCUSSION

Results of Hydraulic Parameters

The results of the study and their classification are given in Table (1-8). Seasonal variation of yield, static water level, transmissivity, hydraulic head and coefficient of storage are presented in chart (1-5). Tables (1&2) showed results field data and hydraulic parameters for dry and wet seasons, covering: depth, diameter, hydraulic head, static water level, transmissivity, coefficient of storage, yield. In the wet season, the total well depth ranged from 2.75m to 11.15m with a mean of 6.9m, well diameter ranged from 0.70m to 1.22m with a mean of 0.93m and topographic heights of well points ranged from 139m to 193m with a mean of 165.70m. In the dry season, yield ranged from $0.08m^3/h$ to $0.94m^3/h$ with a mean of $0.38m^3/h$, while wet season yield ranged from $0.14m^3/h$ to $2.23m^3/h$ with a mean of $0.72m^3/h$. Transmisivity ranged from $9.42m^2/day$ to $115.34m^2/day$ in the dry season while wet season values ranged from $19.89m^2/day$ to $120.00m^2/day$ with a mean of $51.93m^2/day$. Coefficient of storage ranged from 0.01 to 0.74 with a mean of 0.19 in the dry season, while it ranged from 0.01 to 0.61 with a mean of 0.16. In the dry season, static water level ranged from 0.83m to 8.00m with a mean of 3.98m and 0.42m to 5.93m in the wet season with a mean of 2.69m. A weak positive relationship was found between transmisivity and coefficient of storage with 0.10 in dry season and 0.14 in wet season, while correlation between yield and total well depth were -0.35 and -0.22 for dry and wet seasons respectively, showing a weak negative relationship. At 90% and 95% confidence level, the t-test correlations were determined. Table (3,4,&5) showed the level of correlation of parameters/chemical element studied. For the wet season, hydraulic head showed a strong positive relationship with the depth, height with (r = .587, .992), static water level a strong positive relationship with depth, height, weak relationship with hydraulic head only and pumping period with (r = .750, .505, .394, .539). Transmissivity correlates with the diameter, residual draw-dawn with (r = .273, .315). Also, yield correlates with the diameter, residual draw-dawn and transmissivity with (r = .722, .795, .277). In dry season, the hydraulic head correlate with the depth and height with (r = .567, .989), static water showed a strong positive relationship with the depth, height and hydraulic head with (r = .843, .513, .392), transmissivity showed a weak positive relationship with the diameter, pumping period and residual draw-dawn with (r = .268, .295, .393), yield correlates with the diameter, pumping period, residual draw-dawn and transmissivity with (r = .603, .311, 0.635, .334). For both seasons, coefficient of storage of wet season showed a strong positive relationship with coefficient of storage of dry season with (r = .989). Hydraulic head of dry season correlates depth (dry & wet), height (dry & wet) with (r = .567, .566, .989, .989) and hydraulic head wet season showed a strong positive relationship with depth (dry & wet), height (dry & wet), hydraulic head (dry) with (r = .588, .587, .992, .992, .990). Static water level of dry season correlates with depth (dry & wet), height (dry & wet), hydraulic head (dry & wet), pumping period (wet) with (r = .843, .844, .513, .513, .392, .430, .610) and that of wet season correlates with depth (dry & wet), height (dry & wet), hydraulic head (dry & wet), pumping period (wet), static water level (dry) with (r = .749, .750, .505, .505, .426, .394, .539, .807). Transmissivity of dry season correlates with the diameter (dry & wet), pumping period (dry), residual draw-dawn (dry & wet) with (r = .268, .268, .295, .393, .291) and wet season transmissivity correlates with diameter (dry & wet), pumping period (dry), recovery period (dry), residual draw-dawn (dry & wet), transmissivity (dry) with (r = .273, .273, .338, .272, .465, .315, .946). Yield of both dry and wet season correlates with diameter (dry & wet), pumping period (dry), residual draw-dawn (dry & wet), transmissivity (dry & wet) with (r = .603, .603, .311, .635, .530, .334, .400) and (r = .722, .722, .271, .511, .795, .246, .277, .665). Other parameters showed low and negative correlations.

Table 1: Field Data and Results of Hydraulic Parameters for Wet Season (June - July 2010)

S/NO	Well Location	Dep- th (m)	Dia- meter (m)	Hei-ght AMSL (m)	Static Wat-er Level (m)	Well Head (m)	Hydra-ulic Head (m)	Draw- down (m)	Pump-ing Period (min)	Resid- ual Draw-Down (m)	Recove-ry Period (min)	Transm- issivity (m^2/day)	Coe-ffi- cient of Storage	Yie-ld (m^3/h)
1	Owotutu Hq.	9.59	1.10	170	2.78	160.41	167.22	1.03	45	2.11	60	62.37	0.010	2
2	Resort Center	11.15	0.80	193	3.55	181.85	189.45	1.29	30	0.81	90	74.56	0.012	0.27
3	NDLEA	5.58	0.95	156	1.38	150.42	154.62	0.96	45	2.79	60	57.44	0.011	1.98
4	Adegoke N/PS	7.38	1.20	162	2.76	154.62	159.24	0.86	45	1.84	60	39.98	0.015	1.29
5	Akin Akintola	9.17	1.10	182	2.54	172.83	179.46	1.20	45	1.14	60	43.12	0.076	1.1
6	Ogboja	7.16	1.22	163	2.48	155.84	160.52	1.36	30	1.06	60	45.39	0.063	1.24
7	KSTD-Igbole	8.19	0.76	167	2.86	158.81	164.14	1.82	30	0.69	90	20.74	0.281	0.21
8	Owotutu-Igbole	9.17	0.82	172	5.47	162.90	166.53	1.63	30	0.74	60	24.16	0.131	0.39
9	College of Agric.	3.13	1.20	141	0.42	137.87	140.58	1.32	20	1.97	60	58.64	0.052	2.23
10	Moore	4.42	0.94	158	1.37	153.58	156.63	1.02	30	0.85	90	37.91	0.140	0.39
11	Okunrin-Rodo	7.21	0.78	168	2.92	160.79	165.08	1.63	45	1.26	90	61.25	0.012	0.4
12	Adebisi-Idofin	9.45	0.80	166	5.75	156.55	160.25	0.89	45	0.43	90	32.69	0.073	0.14
13	L.G.A.-Guest House	9.06	0.90	160	5.93	150.94	152.98	0.82	60	0.51	90	19.87	0.217	0.21
14	Agba-Akin Idofin	7.10	1.00	169	2.67	161.90	166.33	1.29	30	1.18	60	57.68	0.092	0.92
15	Afonja	6.28	0.95	174	1.89	167.72	172.11	1.47	25	1.56	60	72.19	0.053	1.1
16	Isale Oba (R.A)	4.81	0.80	156	1.47	151.19	153.69	0.92	20	1.36	60	43.26	0.215	0.68
17	Oke-Ayin Gramm. Sch.	5.43	1.20	154	1.86	148.57	152.14	1.47	30	1.43	60	58.35	0.058	1.62
18	INEC	6.00	1.00	155	2.13	149.00	152.87	1.61	30	1.52	60	53.17	0.042	1.19
19	Owotutu Idere Rd.	8.54	1.00	154	2.35	145.46	151.65	2.04	45	1.45	60	62.75	0.089	1.14
20	Olugbon M.C.	5.23	0.94	158	1.05	152.77	156.95	1.67	30	2.37	90	57.13	0.012	1.09
21	General Hospital	4.86	0.97	175	2.55	170.14	172.45	1.08	20	1.26	90	80.36	0.485	0.62
22	Owotutu Farm	4.45	0.80	162	0.97	157.55	161.03	1.27	15	1.36	60	50.32	0.216	0.68
23	Mechanic W.S.	9.06	0.98	156	3.49	146.94	152.51	1.29	30	0.82	60	60.18	0.614	0.62
24	Isale-Ajegunle (The blod)	9.47	1.00	155	3.34	145.53	151.66	1.12	30	1.63	60	78.39	0.093	1.28
25	Ogonbo Oke-Iserin	9.10	0.94	177	4.02	167.90	172.98	0.95	40	1.21	60	51.87	0.057	0.84
26	Lajorun H.S. Oke-Iserin	9.95	1.10	182	4.62	172.05	177.38	1.09	60	0.95	90	63.74	0.511	0.6
27	Igbo-Tapa	7.44	0.98	170	3.47	162.56	166.53	1.28	60	0.87	60	21.86	0.154	0.65
28	VET-Clinic	5.85	0.74	160	1.05	154.15	158.95	1.10	30	1.25	90	36.19	0.095	0.36
29	Ajibade's House	7.26	1.00	175	2.19	167.74	172.81	1.17	45	1.27	150	65.13	0.021	0.39
30	Methodist Sch.11	6.83	0.76	164	2.75	157.17	161.25	1.13	30	0.85	60	47.35	0.081	0.38
31	RCCG Iberekodo	5.25	1.22	160	1.13	154.75	158.87	1.21	45	1.21	60	67.38	0.014	1.41
32	Oduremi Pako	7.49	0.78	178	2.19	170.51	175.81	1.07	30	1.32	90	39.63	0.102	0.42
33	Elejire Iberekodo	7.84	0.79	176	1.17	168.16	174.83	1.20	45	1.18	120	32.84	0.287	0.29
34	Olu-Asho Iberekodo	8.10	0.91	175	4.61	166.90	170.39	2.15	60	0.87	120	23.76	0.243	0.28
35	Towobowo Market	7.24	0.79	173	3.11	165.76	169.89	1.23	60	1.15	90	31.62	0.274	0.37
36	Ojenike Sagan-un	6.83	0.74	168	4.35	161.17	163.65	1.63	45	0.45	60	21.83	0.218	0.19
37	Onikeke	7.47	0.82	170	3.85	162.53	166.15	1.12	60	0.62	60	36.94	0.117	0.33
38	Baptist Pry-Sch	8.05	0.78	170	4.03	161.95	165.97	1.08	30	0.92	60	53.65	0.011	0.44
39	Ile-Elegun	6.64	0.97	163	2.45	156.36	160.55	1.05	20	1.05	120	115.64	0.531	0.39
40	Ile Arisanyan	5.45	0.76	155	1.31	149.55	153.69	1.15	30	0.94	90	80.31	0.495	0.28
41	Ile Agbagbatele	6.43	1.10	172	3.23	165.57	168.77	1.09	60	0.88	90	37.84	0.198	0.55
42	Agborikura Iberekodo	8.29	0.90	179	5.17	170.71	173.83	0.98	45	0.74	90	43.17	0.316	0.31
43	Odeyale Pako	6.67	1.00	170	2.14	163.13	167.86	1.32	20	0.95	90	98.47	0.321	0.49
44	Adedokun	6.65	0.90	170	2.38	163.35	167.62	1.08	30	0.91	60	63.43	0.012	0.58
45	Bambeke Igbole	7.28	0.70	173	3.16	165.72	169.84	0.97	30	1.14	90	51.96	0.018	0.29
46	Obasanjo Farms	2.75	1.00	139	0.83	136.25	138.17	1.26	30	1.24	60	121.18	0.106	0.97
47	Express Igbole	4.27	0.94	159	2.65	154.73	156.35	1.02	30	0.65	60	23.42	0.131	0.45

48	Sawmill	3.84	0.90	160	0.63	156.16	159.37	0.87	20	1.26	60	48.32	0.095	0.8
49	Gbotikale	6.82	0.88	174	2.97	167.18	171.03	1.05	45	0.56	60	33.17	0.089	0.39
50	Shammans	3.80	0.78	147	0.81	143.20	146.19	0.91	20	0.94	60	43.94	0.207	0.45
Maximum		11.15	1.22	193	5.93	181.85	189.45	2.15	60	2.79	150	120.0	0.61	2.23
Minimum		2.75	0.70	139	0.42	136.25	138.17	0.82	15	0.43	60	19.87	0.01	0.14
Mean		6.91	0.93	165.70	2.69	158.79	162.98	1.22	36.50	1.15	75.60	51.93	0.16	0.72

Source: Authors Field Survey

Table 2: Field Data and Results of Hydraulic Parameters for Dry Season (December2009 - January 2010)

S/NO	**Well Location**	**Depth (m)**	**Diam-eter (m)**	**Hei-ght AMS L (m)**	**Stat-ic Water Level (m)**	**Well Head (m)**	**Hydr-aulic Head (m)**	**Draw-down (m)**	**Pump-ing Period (min)**	**Resi-dual Draw-Down (m)**	**Recov-ery Period (min)**	**Trans-missiv-ity (m^2/day)**	**Coefi-cient of Storage**	**Yie-ld (m^3/h)**
1	Owotutu Hq.	9.59	1.10	170	5.64	160.41	164.36	0.97	30	1.25	120	57.54	0.015	0.59
2	Resort Center	11.15	0.80	193	5.45	181.85	187.55	0.49	30	0.21	150	52.01	0.118	0.04
3	NDLEA	5.58	0.95	156	2.43	150.42	153.57	1.05	30	1.27	120	47.43	0.014	0.49
4	Adegoke N/PS	7.38	1.20	162	4.93	154.62	157.07	0.59	30	1.39	120	35.77	0.017	0.78
5	Akin Akintola	9.17	1.10	182	3.77	172.83	178.23	0.65	30	0.10	40	34.81	0.099	0.09
6	Ogboja	7.16	1.22	163	5.30	155.84	157.70	0.69	15	0.19	20	42.16	0.078	0.66
7	KSTD-Igbole	8.19	0.76	167	5.03	158.81	161.97	0.60	10	0.28	72	10.45	0.375	0.1
8	Owotutu-Igbole	9.17	0.82	172	8.00	162.90	164.00	0.77	30	0.10	30	20.04	0.154	0.12
9	College of Agric.	3.13	1.20	141	0.83	137.87	140.17	0.95	30	1.62	120	45.19	0.073	0.91
10	Moore	4.42	0.94	158	3.42	153.58	154.58	0.75	15	0.11	30	18.66	0.175	0.19
11	Okunrin-Rodo	7.21	0.78	168	3.83	160.79	164.17	0.65	15	0.80	180	48.99	0.017	0.13
12	Adebisi-Idofin	9.45	0.80	166	6.66	156.55	159.34	0.68	15	0.10	70	21.08	0.095	0.01
13	L.G.A.-Guest House	9.06	0.90	160	7.02	150.94	157.98	0.91	15	0.14	90	15.21	0.329	0.18
14	Agba-Akin Idofin	7.10	1.00	169	3.58	161.90	165.42	0.20	30	1.70	120	35.16	0.104	0.66
15	Afonja	6.28	0.95	174	3.83	167.72	170.17	1.15	30	1.97	120	44.15	0.067	0.69
16	Isale Oba (R.A)	4.81	0.80	156	2.31	151.19	153.69	1.02	30	1.52	120	30.15	0.260	0.38
17	Oke-Ayin Gramm. Sch.	5.43	1.20	154	3.13	143.57	150.87	1.06	30	1.62	120	45.19	0.079	0.91
18	INEC	6.00	1.00	155	3.35	149.00	151.65	1.20	30	1.83	120	47.43	0.056	0.72
19	Owotutu Idere Rd.	8.54	1.00	154	5.84	145.46	148.16	0.40	30	1.70	120	35.16	0.104	1.14
20	Olugbon M.C.	5.23	0.94	158	1.58	152.77	156.42	1.13	30	2.10	120	47.82	0.015	1.09
21	General Hospital	4.86	0.97	175	1.09	170.14	173.91	0.87	30	1.32	180	78.11	0.532	0.62
22	Owotutu Farm	4.45	0.80	162	1.23	157.55	160.77	0.91	30	1.52	120	30.15	0.260	0.68
23	Mechanic W.S.	9.06	0.98	156	4.32	146.94	151.68	0.95	25	1.60	120	57.36	0.740	0.62
24	Isale-Ajegunle (The blod)	9.47	1.00	155	4.77	145.53	150.23	0.20	30	1.20	60	72.46	0.106	1.28
25	Ogongo Oke-Iserin	9.10	0.94	177	6.65	167.90	170.35	1.10	30	1.94	120	44.18	0.068	0.84
26	Lajorun H.S. Oke-Iserin	9.95	1.10	182	5.27	172.05	176.73	0.35	20	0.24	30	60.86	0.534	0.6
27	Igbo-Tapa	7.44	0.98	170	5.63	162.56	164.37	0.75	15	0.18	30	18.43	0.168	0.65
28	VET-Clinic	5.85	0.74	160	1.89	154.15	158.11	1.21	30	1.54	120	34.21	0.103	0.36
29	Ajibade's House	7.26	1.00	175	3.06	167.74	171.94	1.13	30	0.82	150	56.42	0.026	0.39
30	Methodist Sch.11	6.83	0.76	164	4.26	157.17	159.74	0.83	20	0.17	25	45.73	0.093	0.38
31	RCCG Iberekodo	5.25	1.22	160	2.80	154.75	157.75	0.92	30	1.49	120	35.77	0.019	1.41
32	Oduremi Pako	7.49	0.78	178	4.54	170.51	173.46	1.31	30	0.98	180	30.33	0.117	0.42
33	Elejire Iberekodo	7.84	0.79	176	5.41	168.16	170.59	1.08	30	0.84	180	13.99	0.306	0.29
34	Olu-Asho Iberekodo	8.10	0.91	175	5.85	166.90	169.15	0.84	20	0.48	150	13.66	0.260	0.28
35	Towobowo Market	7.24	0.79	173	4.81	165.76	168.19	1.10	30	0.83	180	13.97	0.306	0.37
36	Ojenike Sagan-un	6.83	0.74	168	4.29	161.17	163.71	0.80	15	0.13	160	10.97	0.274	0.19
37	Onikeke	7.47	0.82	170	6.30	162.53	163.70	0.77	15	0.09	20	20.04	0.154	0.33

38	Baptist Pry-Sch	8.05	0.78	170	4.67	161.95	165.33	1.03	15	0.80	180	48.98	0.017	0.44
39	Ile-Elegun	6.64	0.97	163	2.87	156.36	160.13	0.83	30	1.18	180	105.84	0.647	0.39
40	Ile Arisanyan	5.45	0.76	155	3.22	149.55	151.78	1.61	30	1.34	170	78.11	0.532	0.28
41	Ile Agbagbatele	6.43	1.10	172	4.63	165.57	167.37	1.12	60	0.65	120	29.20	0.253	0.55
42	Agborikura Iberekodo	8.29	0.90	179	6.18	170.71	172.82	0.91	15	0.14	90	15.21	0.329	0.31
43	Odeyale Pako	6.87	1.00	170	3.10	163.13	166.90	1.21	30	1.16	180	94.26	0.433	0.49
44	Adedokun	6.65	0.90	170	3.50	168.35	166.50	1.19	30	1.26	10	47.43	0.014	0.58
45	Bambeke Igbole	7.28	0.70	173	3.30	165.72	169.70	1.14	45	0.96	120	37.93	0.021	0.29
46	Obasanjo Farms	2.75	1.00	139	0.95	136.25	138.05	1.32	30	1.12	60	115.36	0.121	0.97
47	Express Igbole	4.27	0.94	159	1.34	154.73	157.66	0.75	15	0.11	30	18.66	0.175	0.45
48	Sawmill	3.84	0.90	160	1.14	156.16	158.86	0.20	30	0.85	60	35.16	0.124	0.80
49	Gbotikale	6.82	0.88	174	4.48	167.18	169.52	1.03	15	0.20	60	22.98	0.102	0.39
50	Shammans	3.80	0.78	147	1.30	143.20	145.70	0.94	30	1.52	120	30.15	0.258	0.45
Maximum		11.15	1.22	193	8.00	181.85	187.55	1.61	60	2.10	180	115.34	0.74	0.94
Minimum		2.75	0.70	139	0.83	136.25	138.05	0.20	10	0.09	10	9.42	0.01	0.008
Mean		6.91	0.93	165.70	3.98	158.79	161.84	0.89	26.20	0.93	106.54	39.14	0.19	0.38

Source: Authors Field Survey

Table 3: Correlation coefficient matrix for Wet season

Paramet-ers	CS	Depth	Diamet-er	DD	H AMBL	HH	PP	RP	RDD	SWL	Tran	W_H	Y
C S	1												
Depth	0.047	1											
Diameter	-0.107	-0.07	1										
D D	-0.020	0.100	0.024	1									
H AMBL	0.045	0.652**	-0.198	-0.015	1								
HH	0.026	0.587**	-0.186	-0.015	0.992**	1							
PP	-0.027	0.474*	0.109	0.062	0.360*	0.306*	1						
R P	0.320*	0.175	-0.208	0.068	0.360*	0.366*	0.204	1					
R D D	-0.344	-0.255	0.370*	0.036	-0.314	-0.256	-0.187	-0.147	1				
SWL	0.144	0.750**	-0.158	0.026	0.505**	0.394*	0.539*	0.110	-0.542	1			
Tran	0.162	-0.187	0.273*	-0.044	-0.205	-0.164	-0.423	0.067	0.315*	-0.3645	1		
W_H	0.040	0.529*	-0.207	-0.037	0.988*	0.993*	0.309*	0.368*	-0.300	0.415*	-0.194	1	
Yield	-0.384	-0.221	0.722**	0.047	-0.419	-0.383	-0.127	-0.483	0.795**	-0.421	0.277*	-0.424	1

**and **Represent 5% and 10% at two tail Significance level*

Table 4: Correlation coefficient matrix for Dry season

Parameters	CS	Depth	Diameter	DD	H AMBL	HH	PP	RP	RDD	SWL	Tran	W_H	Y
C S	1												
Depth	0.069	1											
Diameter	-0.118	-0.073	1										
D D	0.035	-0.325	-0.177	1									
H AMBL	0.043	0.653**	-0.198	-0.124	1								
HH	0.053	0.567**	-0.200	-0.094	0.989**	1							
PP	-0.070	-0.170	0.192	0.279*	-0.037	-0.000	1						
R P	0.216	-0.029	-0.180	0.354*	0.098	0.134	0.314*	1					
R D D	-0.091	-0.356	0.215	0.303*	-0.419	-0.383	0.524*	0.449*	1				
SWL	0.004	0.843*	-0.083	-0.220	0.513*	0.392*	-0.285	-0.169	-0.468	1			
Tran	0.224	-0.151	0.268*	0.192	-0.233	-0.195	0.295*	0.223	0.393*	-0.383	1		
W_H	0.029	0.525**	-0.225	-0.067	0.983**	0.988**	-0.007	0.090	-0.395	0.398**	-0.224	1	
Yield	-0.227	-0.312	0.603**	-0.071	-0.464	-0.455	0.311**	-0.039	0.635**	-0.320	0.334**	-0.458	1

Table 5: Correlation coefficient matrix for Wet and Dry seasons

	COS (D)	COS (W)	DEP (D)	DEP (W)	DI (D)	DI(W)	DD (D)	DD (W)	H_ (D)	H_ (W)	HH (D)	HH (W)	PP (D)	PP (W)	REC P (D)	REC P (W)	RDD (D)	RDD (W)	SWL (D)	SWL (W)	TRAN (D)	T (W)	WH (D)	WH (W)	Y (D)	Y(W)
COS (D)	1																									
COS (W)	0.989*	1																								
DEP (D)	0.069	0.049	1																							
DEP (W)	0.066	0.047	1.000*	1																						
DIA (D)	-0.118	-0.107	-0.073	-0.074	1																					
DIA (W)	-0.118	-0.107	-0.073	-0.074	1.000	1																				
DD (D)	0.035	0.053	-0.325	-0.327	-0.177	-0.177	1																			
DD (W)	-0.020	-0.020	0.101	0.100*	0.024	0.024	-0.092	1																		
H_ (D)	0.043	0.045	0.653**	0.652*	-0.198	-0.198	-0.124	-0.015	1																	
H_(W)	0.043	0.045	0.653	0.652	-0.198	-0.198	-0.124	-0.015	1.000*	1																
HH	0.05	0.05	0.56	0.56	-	-	-	-	0.98	0.98	1															

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D)	3	2	7*	6*	0.200	0.200	0.094	0.055	9*	9*																
HH (W)	0.021	0.026	0.588*	0.587*	-0.186	-0.186	-0.096	-0.015	0.992*	0.992*	0.990*	1														
PP (D)	-0.070	-0.066	-0.170	-0.171	0.192	0.192	0.279*	-0.117	-0.037	-0.037	-0.000	0.013	1													
PP (W)	-0.055	-0.027	0.472*	0.474*	0.109	0.109	-0.097	0.062	0.360*	0.360*	0.301*	0.306*	-0.168	1												
REC P (D)	0.216	0.208	-0.029	-0.032	-0.180	-0.180	0.354*	0.141	0.098	0.098	0.134	0.126	0.314*	-0.117	1											
REC P (W)	0.317*	0.320*	0.177	0.175	-0.208	-0.208	0.182	0.068	0.360*	0.360*	0.383*	0.366*	0.061	0.204	0.429*	1										
RDD (D)	-0.091	-0.070	-0.355	-0.356	0.215	0.215	0.303*	0.085	-0.419	-0.419	-0.383	-0.365	0.524*	-0.440	0.449*	-0.178	1									
RDD (W)	-0.378	-0.344	-0.256	-0.255	0.370*	0.370*	0.109	0.036	-0.314	-0.314	-0.286	-0.256	0.409*	-0.187	0.242*	-0.147	0.658*	1								
SWL (D)	0.004	-0.002	0.843*	0.844*	-0.083	-0.083	-0.220	0.134	0.513*	0.513*	0.392*	0.430*	-0.285	0.610*	-0.169	0.083	-0.468	-0.384	1							
SWL (W)	0.158	0.144	0.749*	0.750*	-0.158	-0.158	-0.266	0.026	0.505*	0.505*	0.426*	0.394*	-0.362	0.539*	-0.163	0.110	-0.568	-0.542	0.807*	1						
TRAN (D)	0.224	0.222	-0.151	-0.156	0.268*	0.268*	0.192	-0.090	-0.233	-0.233	-0.195	-0.203	0.295*	-0.406	0.223	0.069	0.393*	0.291*	-0.383	-0.295	1					
TRAN (W)	0.165	0.162	-0.182	-0.187	0.273*	0.273*	0.149	-0.044	-0.205	-0.205	-0.164	-0.164	0.338*	-0.423	0.272*	0.067	0.465*	0.315*	-0.402	-0.365	0.946*	1				
WH (D)	0.029	0.036	0.525*	0.524*	-0.225	-0.225	-0.067	-0.050	0.983*	0.983*	0.988*	0.987*	-0.007	0.302*	0.090	0.360*	-0.395	-0.305	0.398*	0.410*	-0.224	-0.187	1			
WH (W)	0.034	0.040	0.530*	0.529*	-0.207	-0.207	-0.073	-0.037	0.988*	0.988*	0.993*	0.993*	-0.007	0.309*	0.115	0.368*	-0.398	-0.300	0.405*	0.415*	-0.230	-0.194	0.995*	1		
Y (D)	-0.227	-0.193	-0.312	-0.311	0.603*	0.603*	-0.071	0.093	-0.464	-0.464	-0.455	-0.431	0.311*	-0.161	-0.039	-0.397	0.635*	0.530*	-0.320	-0.418	0.334*	0.400*	-0.458	-0.457	1	
Y (W)	-0.403	-0.384	-0.222	-0.221	0.722*	0.722*	-0.056	0.047	-0.419	-0.419	-0.416	-0.383	0.271*	-0.127	-0.055	-0.483	0.511*	0.795*	-0.265	-0.421	0.246*	0.277*	-0.437	-0.424	0.665*	1

W = Wet, D=Dry, DEP=Depth, Di=Diameter, DD = Drawn-Down, H_AMSL = Height above mean sea Level, SWL = Static Water Level, WH = Well Head, HH = Hydraulic Head, PP = Pumping period, RDD = Residual draw-dawn, RP = Recovery period, T = Transmissivity, CS = Coefficient of storage

Table 6: Classification of wells yield

S/No	Well Location	Dry season (Remark)				Wet season (Remark)			
		Poor	Useable	Acceptable	Excellent	Poor	Useable	Acceptable	Excellent
1	Owotutu Hq.		•						•
2	Resort Center	•					•		
3	NDLEA		•						•
4	Adegoke N/PS			•					•
5	Akin Akintola	•						•	
6	Ogboja		•						•
7	KSTD-Igbole	•				•			
8	Owotutu-Igbole	•					•		
9	College of Agric.			•					•
10	Moore	•					•		
11	Okunrin-Rodo	•					•		
12	Adebisi-Idofin	•				•			
13	L.G.A.-Guest House	•				•			
14	Agba-Akin Idofin		•					•	
15	Afonja		•					•	
16	Isale Oba (R.A)	•					•		
17	Oke-Ayin Gramm. Sch.		•					•	
18	INEC		•						•
19	Owotutu Idere Rd.	•						•	
20	Olugbon M.C.	•						•	
21	General Hospital	•					•		
22	Owotutu Farm	•					•		
23	Mechanic W.S.	•					•		
24	Isale-Ajegunle (The blod)		•						•
25	Ogongo Oke-Iserin	•						•	
26	Lajorun H.S. Oke-Iserin	•					•		
27	Igbo-Tapa		•				•		
28	VET-Clinic		•				•		
29	Ajibade's House		•				•		
30	Methodist Sch.11	•					•		

31	RCCG Iberekodo			•					•
32	Oduremi Pako	•					•		
33	Elejire Iberekodo	•					•		
34	Olu-Asho Iberekodo	•					•		
35	Towobowo Market	•					•		
36	Ojenike Sagan-un	•				•			
37	Onikeke	•				•			
38	Baptist Pry-Sch	•				•			
39	Ile-Elegun		•			•			
40	Ile Arisanyan	•				•			
41	Ile Agbagbatele		•			•			
42	Agborikura Iberekodo	•				•			
43	Odeyale Pako		•			•			
44	Adedokun		•			•			
45	Bambeke Igbole	•				•			
46	Obasanjo Farms			•			•		
47	Express Igbole	•				•			
48	Sawmill		•				•		
49	Gbotikale	•				•			
50	Shammans		•			•			

•Denote classification of wells accordance to their standard

Table 7: Summary; Classification of Yield

U.S CLASSIFICATION		EQUIVALENT YIELD	PERCENTAGE REPRESENTATION OF RESULTS	
Wells Yield (Gallons/Min)	**Remark**	**Wells Yield (m^3/day)**	**Dry season Classification**	**Wet Season classification**
Below 1	Poor	Below 5.5	34%	8%
3	Useable	5.5 – 16.35	44%	58%
5	Acceptable	16.35 – 27.25	22%	16%
10 & Above	Excellent	27.25 – 54.51	–	18%

** Source: United States Department of Public Health, (2008) http://inspectapedia.com 19/04/2010*

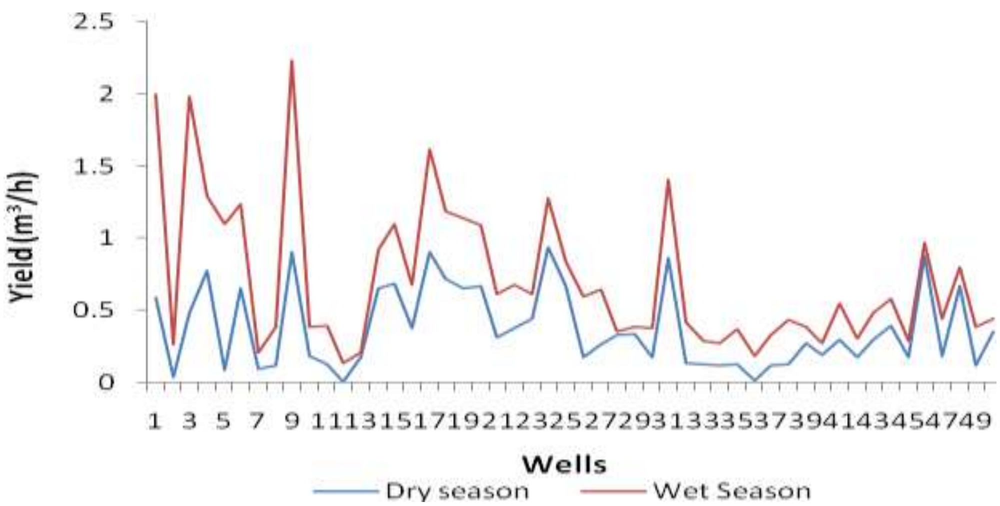

Chart 1: Variation of yield for dry and wet seasons

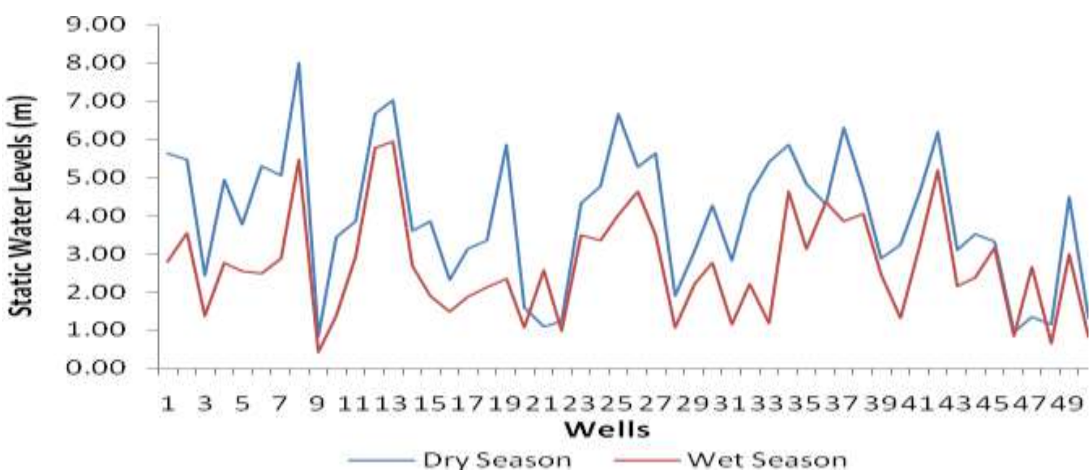

Chart 2: Variation of static water level for dry and wet seasons

Table 8: Classification of transmissivity for dry and wet season

		Dry season Transmissivity				Wet season Transmissivity			
S/No	**Well location**	**Large[1]**	**Moderate[2]**	**Small[3]**	**Very Small[4]**	**Large**	**Moderate[2]**	**Small[3]**	**Very Small[4]**
1	Owotutu Hq.			•				•	
2	Resort Center			•				•	
3	NDLEA			•				•	
4	Adegoke N/PS			•				•	
5	Akin Akintola			•				•	
6	Ogboja			•				•	
7	KSTD-Igbole				•				•
8	Owotutu-Igbole				•				•

9	College of Agric.			•				•	
10	Moore				•			•	
11	Okunrin-Rodo			•				•	
12	Adebisi-Idofin				•			•	
13	L.G.A.-Guest House				•				•
14	Agba-Akin Idofin			•				•	
15	Afonja			•				•	
16	Isale Oba (R.A)			•				•	
17	Oke-Ayin Gramm. Sch.			•				•	
18	INEC			•				•	
19	Owotutu Idere Rd.			•				•	
20	Olugbon M.C.			•				•	
21	General Hospital			•				•	
22	Owotutu Farm			•				•	
23	Mechanic W.S.			•				•	
24	Isale-Ajegunle (The blod)			•				•	
25	ogongo oke-iserin			•				•	
26	lajorun h.s. oke-iserin			•				•	
27	igbo-tapa				•				•
28	vet-clinic			•				•	
29	ajibade's house			•				•	
30	methodist sch.11			•				•	
31	rccg iberekodo			•				•	
32	oduremi pako			•				•	
33	elejire iberekodo				•			•	
34	olu-asho iberekodo				•				•
35	towobowo market				•			•	
36	ojenike sagan-un				•				•
37	onikeke				•			•	
38	baptist pry-sch			•				•	
39	ile-elegun			•				•	
40	ile arisanyan			•				•	
41	ile agbagbatele			•				•	
42	agborikura iberekodo				•			•	
43	odeyale pako				•			•	
44	adedokun			•				•	
45	bambeke igbole			•				•	
46	obasanjo farms			•				•	
47	express igbole				•				•
48	sawmill			•				•	
49	gbotikale			•				•	
50	shammans			•				•	

•Denote classification of wells accordance to their standard
[1] >2,500 m^2/day [2] 250–2,500 m^2/day [3] 25-250m^2/day [4] <25 m^2/day

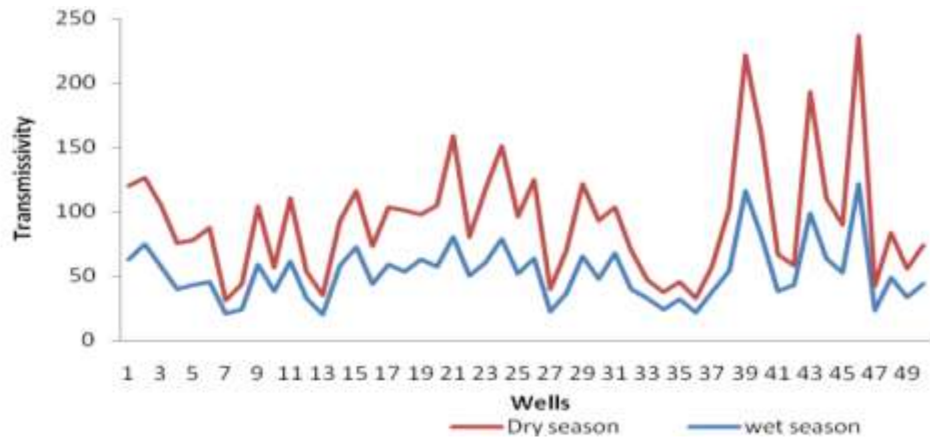

Chart 3: Variation of transmissivity for dry and wet seasons

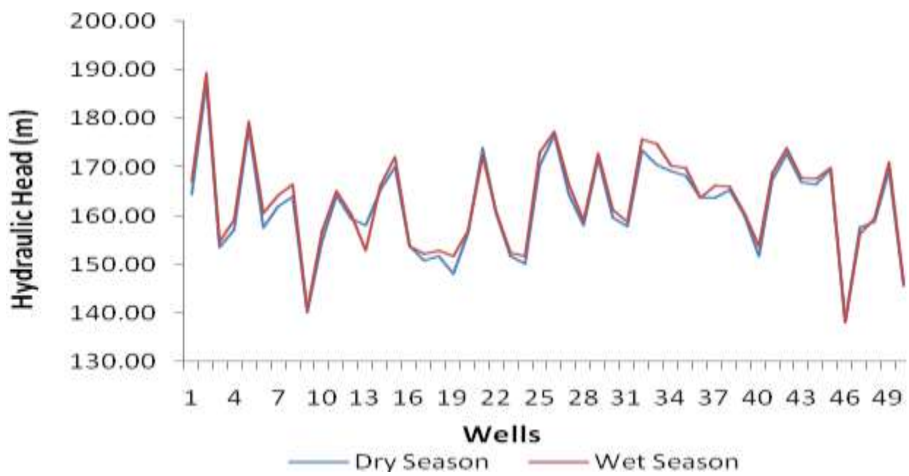

Chart 4: Variation of hydraulic head for dry and wet seasons

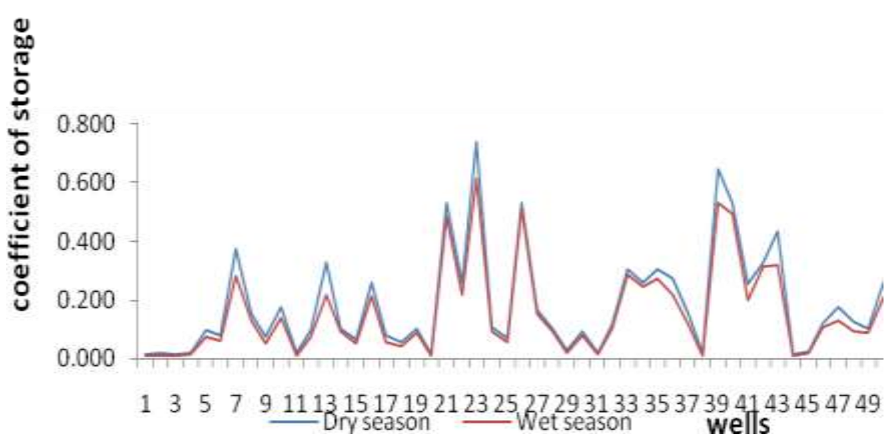

Chart 5: Variation of coefficient of storage for dry and wet seasons.

RESULTS

Well parameters investigated include location, total depth, diameter, static water level, yield, transmissivity and coefficient of storage. In this study, investigated wells were all hand dug and their depths ranged between 2.75m and 11.15m, with an average of 6.91m. This limitation is due to the use of crude implements and man power. From the results, it was found that well diametric size ranged from 0.7 m to 1.2m, with an average of 0.93m. The hand-dug wells have ranges of these sizes because of the space size required during digging and excavation and by pre-cast or cast in-situ concrete walls. Idowu et al., (2005) reported a depth range of 0.91to 7.10m with an average of 3.96m, diameter range of 0.74m to 1.85m with an average of 0.99m and static water level range of 0.01m to 3.80m. Also in Martins et al, 2000, reported overburden thickness of between 0 and 30m with an average of 7m was reported for Basement complex areas of Ogun State, which shares similar formation with the study area. However, on the other hand, drilling of borehole involves the use of hydraulic-engine powered machines. Thus, greater depths are reached and aquifers located far beneath the surface are accessed. It should be noted that borehole diametric sizes range usually between 4 inches 12 inches, depending on the drill-bit size. Boreholes tap water from greater depths while hand-dug wells are shallower. In the basement terrain of Ondo State, Awopetu (1986) reported a range of total borehole depths of 21m to 120m with an average of 73.1m. In the basement terrain of Oyo State, borehole depths range from 12.0m to 182.9m, with an average of 58m. In the basement complex of Ogun state, total borehole depths range from 6.71m to 152.4m with an average of 84.40m. Approximately 90 percent of the wells in the basement complex of Ogun state were drilled to depths bellow 150m. In the Northeastern boundary of the study area, tested wells have low depths as reflected in the values of Oke-Ayin Grammar School, INEC Office, Olugbon and Owotutu Farm. They ranged in values between 4.45 -6.00m and this is comparable to the values obtained in the Southeastern boundary at College of Agriculture, Obasanjo Farms, Express Igbole and Shammans Petroleum ranging from 2.75m to 4.27m. In these two portions of the study area, static water levels were also found to be low ranging from 0.83m to 3.35m in the dry season and 0.63m to 2.65m in the wet season.

Furthermore, the central part and the Northeastern part are dominated by wells with greater depth and higher static water levels when compared to the values obtained in the Northwestern and Southeastern boundaries. Wells in these portions have depths above 8m and their static water levels were between 3.77m and 8.00m in the dry season and 2.33m to 5.93m in the wet season. Generally, there appeared to be an increase of static water level values from dry to wet season. Rainfall seems to have had an immense contribution to a general rise in water level from dry to wet season. Dry season yield for the tested wells gave a range of $0.008m^3/h$ to $0.94m^3/h$ with a mean of $0.38m^3/h$ while in the wet season a range of $0.14m^3/h$ to $2.23m^3/h$ with mean $0.72m^3/h$ was found. On classification, dry season yield showed that 34% were POOR, 44% were USEABLE, 22% were ACCEPTABLE and non was found in the EXCELLENT yield range, however, wet season yield showed that 8% were POOR, 58% were USEABLE, 16% were ACCEPTABLE and 18% fell in the EXCELLENT yield range, all for domestic purposes. Yield of boreholes are comparatively higher in the same geographical environment. Oyeshomo (1987) in Hydrological assessment of the crystalline rocks of Oyo state reported yields of boreholes range from 0.24 m^3hr^{-1} to $36.3m^3$ hr^{-1}, with an average of $6.74m^3$ hr^{-1}. Idowu (1992) in his assessment of groundwater resources of Ogun state Nigeria investigated 73 boreholes. The boreholes are located in the basement complex section of the state. He reported 50 of the boreholes to have had yields ranging from 0 to 5.9 m^3 $hr\text{-}^1$, 16 of them had yield range $6m^3$ $hr\text{-}^1$ to $11.9m^3$ $hr\text{-}^1$, 4 boreholes had yield range $12m^3hr\text{-}^1$ to $17.9m^3$ $hr\text{-}^1$,while the last 3 had yields above $17.9m^3$ $hr\text{-}^1$.

Generally, it was observed that the directions towards which groundwater flow have higher yield as found in INEC office, NDLEA office, Obasanjo Farms, College of Agriculture, Isale-Ajegunle, RCCG Iberekodo, Owututu HQ, Ogboja, Adegoke NPS. They also have lower depths and static water levels, while within their immediate environment flow a stream or exists a swamp. Transmissivity ranged from

9.42m^2/day to 115.34m^2/day in the dry season while wet season values ranged from 19.89m^2/day to 120.00m^2/day with a mean of 51.93m^2/day. Transmissivity values are generally low; falling within the expected range of 10^{-4} – 10^{-5} m/s for weathered crystalline rocks (Bernard and Mouton, 1981). Coefficient of storage ranged from 0.01 to 0.74 with a mean of 0.19 in the dry season, while it ranged from 0.01 to 0.61 with a mean of 0.16. The typical coefficient of storage for an unconfined aquifer may be on the order of 0.01 to 0.3 (Watson and Burnett, 1995). The high values obtained for the study area reflects the potential for a high storage impact on the holding capacity of the aquifers. This is understandable in view of the constitution of the aquifers of clayey materials (which has high capacity for storing water but low capacity for transmitting it) derived from the weathering of the basement rocks (Idowu et al., 1998). The high variation of the transmissivities and specific yields may indicate varying degree of weathering or constitution of the aquifer materials varying amounts of clayey materials. The recovery method provides the closest estimate of transmissivity values of aquifers because the method rules out the drawdown variations that are caused by slight differences in discharge rates during pumping and the effect of pump variations (Todd, 1980). The trend that occurred between these parameters showed an indication that the pollutant present in the water and the parameter tested is strongly interrelated and interdependent on one another with common variable values that was observed. Thus, high correlations show that the parameters are derived from the same source (Edet *et al.,* 2011).

Conclusion

The study revealed from results of yield that the hand dug wells tested in this study could only serve domestic purposes and none was comparable in yield to an average borehole tapping from like formation and their depth could only tap from the regolith aquifers. Also, their transmissivity and coefficient of storage were found to be low and high respectively, militating against the geologic formation from yielding water into the well at a faster rate. The direction in which groundwater flow was found to enhance yield, produced water at shallow depths and lower static levels. High values of height above the mean sea level could have worked in a way against accessing water at a shallower depth, but it provides recharge points for wells at lower elevation. Access to test holes for periodic appraisal that will give knowledge of changes that might occur in the future be encouraged. Also, adequate solid waste disposal system be adopted, waste deposit or discharge on identified recharge points be avoided and water from hand dug wells be well treated before consumption.

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