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# The Yield Characteristics of the Shallow Aquifer of River Kastina Ala Floodplane in Nigeria

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**Abstract:** The yield of shallow aquifer of River Kastina Ala within Kastina Ala local Government of Benue State Nigeria was carried out at constant rate of pumping and recovery test on five existing tube wells located within the floodplain of the river stretching from Abaave to Government Secondary School Katsina-ala. An average duration of pumping for the flood plane was established at 149 minutes. The average recovery period for wells in the study area was 202 minutes while the stabilization period of 42 minutes was recorded. The study conducted revealed that an average discharge of 2268.89 $m^3$/day is achievable from each well while on an the average specific yield is 320.18 $m^3$/day. The aquifer has an average coefficient of permeability (K) of 189.5 m/day and coefficient of Transmissivity (T) of 808.32$m^2$/day. The aquifer is confirmed to be a semi-confined to confined, having a specific yield, transmissivity, permeability and average discharge per well obtained in the study area when compared with already established standards This also attested that the aquifers in the study area are moderate to good since the time taken for an aquifer to recover to its static water level is not more than 4 hours 15 minutes with a maximum cone of depression of 8.75 against the 6.22 achieved.

**Keywords:** Kastina ala floodplain, aquifer, permeability, transmisivity, yield

## 1.0 INTRODUCTION

Groundwater is an important source of water supply and plays an important role in industry, agriculture and domestic use [1] [2],[3], [4]. Water supply for irrigation and domestic use in fadama lands in Nigeria has been an subject of interest due to the existing rainfall pattern. To unravel the mystery of groundwater, a detailed geophysical and hydro-geological understanding of the aquifer types and their spatial location are paramount in order to characterize the hydraulic zones in an area[5] . Identification of the individual aquifer yields needs investigation of certain geologic and aquifer environments due to their complexity and the required analytical solution for the flow patterns are almost unobtainable. Some aspect of well hydraulic can be complicated and in some cases, mathematical model have developed complex solution for specific well and aquifer conditions such that the practical application of the theory is nearly impossible in the light of all the geologic and hydraulics uncertainties. Given the complexity of the groundwater environment only the most fundamental hydraulic theories can be used successfully in every day well design and construction. These basic methods regularly yield accurate result in most cases without laborious calculation. Practical determination of the well hydraulics or the yield of aquifers is necessary to enable practicing engineers and drilling contractors make sound decision on well design and construction for most situation. Most probable decision are well diameter, yield, safe rate of withdrawal, screen size, screen length, interferences, drawdown which are taken from analysis of pumping tests conducted to determine the aquifer yield. Continuous monitoring of the water level should be conducted for a complete hydrologic cycle to minimize payment for abortive wells (as it cannot be eliminated completely because of geologic uncertainties of groundwater and aquifer).

Certain problems have beset the use of groundwater around the world. Just as river waters have been over-used and polluted in many parts of the world, so too have aquifers. The big difference is that aquifers are out of sight. The other major problem is that water management agencies, when calculating the 'sustainable yield' of aquifer and river water, have often counted the same water twice, once in the aquifer, and once in its connected river. This problem, although understood for centuries, has persisted, partly through inertia within government agencies. Due to the problem of water scarcity in this part of the world during the dry period (November-march), and that with which is associated with some aquifer in some part of the world. Many water

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engineers and contractors have drilled and constructed tube wells with inadequate yield and have been aborted. In most cases, drilled tube wells get depleted beyond the suction lift of the centrifugal pumps being used by most farmers for irrigation.

The enormous potentials for irrigated agriculture in the fadama and flood plain is unquestioned. According to [6], the fadama lands have high potentials and agricultural values several times more than the adjacent upland. Fadama development is typical forms of small scale irrigation practice characterized by flexibility of farming operations, low inputs requirement, high economic values, and minimal social and environmental impact and hence conforms to the general criteria for sustainable development [7]. [7] Also submitted that pumping water from wells in fadama helps in controlling the water table and is thus, anti-water logging device. Similarly, pumping water from the wells increase infiltration and leaches harmful salts from the root zone thereby providing additional basis for sustainable fadama development. The national fadama development programme (NFDP) was established consequent to the failure of large scale irrigated schemes, which the country has pursued for the last 2 decades to yield the anticipated increase in food production despite the huge sums of money (>2.0 billion US$) spent on it [6].

In order not to mobilize into an extensive fadama land to drill tube well or wash bores that would not deliver a minimum required yield of about 2.00 l/s for successful irrigation and to avoid the drilling of abortive wells, pre-drilling investigations representative of the site should be conducted to ascertain the hydraulic conductivity or permeability, transmissivity, storage coefficient and safe yield. Determination of tube well performance is required in order to be able to predict aquifer yield and performance of proposed tube wells, minimize incidence of abortive tube wells due to lack of information's and to maximized incidence of water scarcity during draught period. This has prompt researcher to find ways of alleviating the problem of water shortage by determining the hydraulic yield of hand dug wells that will meet the total demand by the populace.

In the fadama lands and other agricultural regions of Nigeria, irrigation inefficiency is a major source of aquifer recharge. In many areas, drought-year groundwater supplies depend substantially on irrigation inefficiency in wetter year, when surface water is available and used by farmers [8]. Ironically, local inefficiency often improves regional water use efficiency and sustainability. However, excessive groundwater pumping causes long-term continual decline in groundwater levels ("overdraft") and irrigation inefficiency increases salt and nitrate loads to groundwater. There are few perfect solutions in water. Therefore, investigations and determination of aquifer yield are highly important and should be conducted into any fadama envisaged for medium to large scaled-irrigation development to ascertain the minimum safe yield that would sustain irrigation and the groundwater capacity.

**2. Generalized**

Well yields represent the range of potential yields from individual wells properly screened and developed in the aquifer. Yields may not represent sustained withdrawals from the aquifer but, rather, the potential short-term withdrawal yields in many areas are based on aquifer and well-capacity-test data and on reported yields from drillers and homeowners. Yields in some areas are estimates based on geologic logs, saturated thickness, and relation between grain size and hydraulic conductivity. Actual yields may differ from those indicated. Aquifers to which no range of yield is assigned are in areas from which data on wells or hydrogeologic properties were insufficient to estimate the yield. These areas are underlain by coarse granular material, however, should be considered aquifers of unknown potential [9]. The mode of occurrence and distribution of groundwater is controlled by the geology of the area concerned; however, groundwater abounds in both consolidated igneous and metamorphic rock materials and in unconsolidated sands [10]. The largest available source of fresh water lies underground. The total ground water potential is estimated to be one third the capacity of ocean [11]. Other sources of ground water include water from deep in the earth which is carried upward in intrusive rocks and water which is trapped in sedimentary rocks during their formation [11]. Water bearing formation of the earth's crust act as condition for transmission and as reservoir for storage of ground water. By comparison, rocks such as fractured sandstones and cavernous lime stones have large connected opening that permit water to move freely, such rocks transmits large quantities of water and are good aquifer. The amount of water that an aquifer will yield to a well may range from a few hundred gallons a day to as much as several million gallons a day.

Pump age from wash bore and tube wells constitute the major artificial discharge of ground water. Wash bore is a term used for a shallow tube well, the construction of which is achieved by the use of clear water jetting technology to bore the hole, the depth of which can go up to 15m [12]. Water well is a hole usually vertical, excavated in the earth to bring ground water to the surface [13]. Wells have been an integral part of man's life and activity, supplying clean and potable water where surface supplies are inadequate. These supplies are either used for domestic, irrigation or industrial purposes.

[14] Defined an aquifer as a water-bearing layer in which the vertical flow component is so small with respect to the horizontal flow component that it can be neglected. The groundwater flow in an aquifer is assumed to be predominantly horizontal. Common aquifers are geological formations of unconsolidated sand and gravel, sandstone, limestone, and severely fractured volcanic and crystalline rocks. [15] in their view defined define an aquifer as a saturated permeable geological unit that is permeable enough to yield economic quantities of water to wells. The most common aquifers are unconsolidated sand and gravels, but permeable sedimentary rocks such as sandstone and limestone, and heavily fractured or weathered volcanic and crystalline rocks can also be classified as aquifers. The four types of aquifer distinguished are: confined, unconfined, leaky and multi-layered.

Academic scholars of the world view aquifer from various angle of perspectives and may occur at various depths. Those closer to the surface are not only more likely to be used for water supply and irrigation, but are also likely to be tapped up by the local rainfall. Many deserts area have lime stone or mountains within them or close to them that can be exploited as ground water resource. Aquifer are typically saturated region of the subsurface that produce an economically feasible quantity of water to a well or spring (e.g. sand and gravels or fractured bedrock often make good aquifer materials). An aquifer is an underground layer of water-bearing permeable rock or unconsolidated materials (gravel, sand, silt, or clay) from which ground water can be usefully extracted using water well, where by the porosity and permeability of an aquifer determine its ability to hold and transmit water. It is capable of storing significant quantities of water that is underlain by impermeable material, and through which groundwater moves or transmitted trough springs.

**2.1 Assessment of Ground Water**

Aquifer over exploitation mainly deals negative aspect of ground water development [16],[17],[18],[19],[20]. Scholars have argued that the concept of ground water over development or aquifer over exploitation is not simple, merely linked to recharge and extraction balance but is rather complex linked to various undesirable consequences which are physical, social, economical, ecological, environmental and ethical in nature. Again these undesirable consequence also change with perceptions [17]. Hence, defining and assessing ground water over development is both difficult and complex and not amiable to simple formulations. The difficulties may include; Large and continues drops in ground water levels over time, Large seasonal drops in water level in wells and the drying up of wells in summer season, Increase in salinity of ground water, Reduction of ground water dependent vegetation and spring and seepage and Enormous increase in cost of ground water extraction.

One of the most effective ways of determining the hydraulic properties of water-bearing layers is to perform an aquifer test. The procedure is simple: water is pumped from a well in the aquifer for a certain time and at a certain rate, and the effect of this pumping on the water table is measured at regular intervals in the well itself and in a number of piezometers nearby. Aquifer tests are so costly that in most studies of regional groundwater resources, the number of aquifer tests that can be performed must be restricted [14]. It is possible, however, to perform an aquifer test without using piezometers, thereby cutting costs. Of course, one must then accept a certain, sometimes appreciable, error. To distinguish such tests from the normal aquifer test, they are often called single-well tests.

[21] proposed a simple criterion for assessing ground water development, which is based on net ground water draft against the gross ground water recharge, it proposed two methodologies for assessing ground water resource, for administrative units such as blocks and districts. The first is water level fluctuation approach which suggested that sufficient numbers of wells should be used for monitoring water level within the given administrative units in question. In this approach, the average annual recharge (Re) from precipitation is calculated by the following equation:

$$Re = ( A_s \times W_f \times S_y ) + D_w \ldots.(1)$$

Where; As = avarage annual storage, $S_y$ = specific yield of aquifer, $W_f$ = average water level fluctuation and $D_w$ = pumping rate.

GEC-1997**,** criterion for assessing groundwater development is far more realistic, and has a better scientific basis than that of GEC-1984. First of all, it proposes assessment of recharge for a separate period of time. Also, the methodology purpose analytical approach for estimating specific yield using ground water balance, such as storage change, the return flows from irrigation to ground water, base flows from ground water into streams and recharge from stream into ground water, net lateral ground water inflow into the area and ground water draft. According to [22], the difference between the dynamic reserve (Vm) at the end of a chosen water year (tm) and the dynamic reserve at the beginning of the water year (to) is the dynamic reserve change (±V). The volume of groundwater recharge during the water year is determined from

R = Q ± V -------------------(2)

where: R= groundwater recharge volume during the water year (m3)

Q= groundwater discharge volume during the water year (m3);

±V= dynamic reserve change during the water year (m3)

### 2.2 Hydraulic Trends of Aquifer

Ground water level trends are net effect of several changes taking place in the resource conditions owing to recharge from precipitation, return flows from irrigation field, seepage from water carriers (canal, channel etc), abstraction or groundwater drafts, lateral flows (either inflow or outflow) or outflows into the natural streams [13]. In a region, where long term levels of ground water pumping are less than the average annual recharge, the groundwater level can experience short term declining trends as a result of drastic increase in groundwater pumping owing to a period of heavy rainfall failure. But, such a phenomenon does not represent the long term trends. In contract, where groundwater outflows into the surface streams are quite large due to the peculiar geo-hydrological environment, even if the net annual groundwater draft is far less than the net recharge, water levels can decline on annual basis. In such situation, increasing draft over time can actually reduce the rate of decline in water levels on a long time horizon [23]

### 2.3 Hydraulic Yield of Aquifer

The hydraulic yield of unconfined as well as confined aquifer via, permeability coefficient (K) and coefficient of transmissivity (T) for steady flow rate may be evaluated by pumping test of wells. Pumping test is carried out to obtain data with which to assess the performance characteristics of the tube well and the transmission and storage property of the aquifer [24]. The porosity of aquifer is excellent due to the usually fine grained, well rounded and generally well-sorted deposits. But the hydraulic conductivity varies considerably depending on the average grain size. The commonly investigated parameter for the yield of aquifer used in planning, designing and construction of tube wells and wash bores for efficient ground water abstraction include; permeability coefficient, Transmissibility coefficient, Storage coefficient and Yield relationship.

Permeability is a function of porosity, structure and geological history of the aquifer material [25]. It measure the relative ease of fluid flow under unequal pressure, is the property of the capacity of a porous rock, sediment or soil for transmitting a fluid [26]. It is simply defined as the ease with which water will move through a porous medium ( soil ). The coefficient of permeability has been defined [27] as the rate of flow of water per unite cross-sectional area of the aquifer under a unit hydraulic gradient. Thus the coefficient of permeability has the dimensions of velocity and it is usually expressed in meter per second (m/s). Many attempts have been made to derive the formula of K, in terms of measurable values of the properties of materials. A formula use in connection with sand filter for water supply and applying, only to homogeneous rounded grain media of not too fine a size is:

$$k = cd^2_{10} \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where $d_{10}$ = Grain size in mm, where 10% of materials is fine and 90% is coarser.

c = a constant of value 400-1200 (an average value is 1000).

This formulae has little value in materials of a heterogeneous character or outside that precisely defined limits, k, is not necessary a constant for a particular soil, as chemical erosion or deposition may sometimes occurs with per collating ground water.

In 1956, a French hydraulic engineer 'Darcy' investigated the flow of water through the horizontal beds of sand to used foe water filtration and he observed that under laminar flow conditions, the flow of water through saturated porous media , the velocity of water (V) is proportional to the hydraulic gradient(Q). It is universally known as Darcy's law expressed as;

$$Q = kiA \ldots\ldots\ldots\ldots\ldots (4)$$

$$V = \frac{Q}{A} = ki \ldots\ldots\ldots\ldots (5)$$

Where i = hydraulic gradient and A = total cross-sectional area of soil mass perpendicular to the direction of flow.

$$Q = \frac{1.366k(H^2 - h^2)}{\log R/r} \ldots\ldots\ldots\ldots (6)$$

The knowledge of the aquifer transmissivity distribution provides a fundamental source of information on the quality of the aquifer and hence area where sustainable wells, boreholes could be installed or dug. Equation (6) is called "Thies well equation", while for a well operating under a confined aquifer he derived the expression as

$$Q = 2.73kb(H - h) = \log R/r \text{ ----(7)}$$

R, commonly kwon as radius of zero drawdown, measured from the centre of the well to a point, where the drawdown curve meets the original water table tangentially. In practice, the selection of the radius of influence R is approximate and arbitrary, but the variation in Q is small for a wide range of R. suggested values of R fall in the range of 100 to 300 meters. Alternatively, R may be computed from the following approximation expression give by sichardt:

$$R = 3000s\sqrt{k} \ldots\ldots\ldots\ldots\ldots\ldots(8)$$

Where; s = drawdown r = radius of the well in m, H = static head from the bottom of aquifer. in, m and h = depth of water in the well while pumping in, m. This law is valid only for laminar flow, because of very small pore dimension in fine grained soils, a laminar flow should exist, but in coarse grained soil, turbulent flow may be expected under certain conditions.

Transmissivity is the rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient. Transmissivity is given in cubic meters per day through a vertical section of an aquifer one meter wide and extending the full saturated height of an aquifer under a hydraulic gradient of 1 [26] . The T value of an aquifer is however, the rate at which water flows through the full saturated thickness, under a hydraulic gradient of 1( 100% ). If an aquifer has a transmissivity of less than 1.24 $m^2$/day, it can supply only enough water for domestic wells or other low-field uses where as yield of 1.24 $m^2$/day or more can be adequate for individual, municipal or irrigation purposes. [26] expressed T as;

$$T = kb\ldots\ldots\ldots\ldots\ldots..(6)$$

OR, $$T = pm\ldots\ldots\ldots\ldots(7)$$

where; b = aquifer thickness p= coefficient of permeability and m = depth of static water level before pumping in m.

## 2.4 Non-equilibrium Well Equation

Theis developed the none-equilibrium well equation in 1935. First, he took account of the effect of pumping time on well yield. Using this, the draw down can be predicted at any time after pumping begins. Average hydraulic conductivity and transmissivity can be determined during the early stages of a pumping, rather than after water level in wells have virtually stabilized. Aquifer coefficient can be determined from the time draw down in a single observation well rather than from two observation wells as required of equation 8 and 9 [26] and [28].

$$K = \frac{Q\log r_2/r_1}{1.366\,(h_2-h_1)} \ldots\ldots\ldots\ldots..(8)$$

$$K = \frac{Q\log r_2/r_1}{2.73b\,(h_2-h_1)} \ldots\ldots\ldots\ldots(9)$$

Where; $h_2$ = saturated thickness in, m, at the farthest observation well for unconfined aquifer, $h_1$ is saturated thickness in m, at the nearest observation well for unconfined aquifer, $r_2$ is distance to the farthest observation well in m, $r_1$ = distance to the nearest observation well in m. For a confined aquifer, $h_2$ is the head in meters at the farthest observation well measured from the bottom of the aquifer, $h_1$ is head in meters at the nearest observation well measured from the bottom of the aquifer and b is the thickness of the aquifer in meters.

## 2.5 Assumption of this Equation

This proposed a curve-fitting method for finding constant, S and T, from a pump out test. Derivation of this equation was based on the following assumption; The water-bearing formation is uniform in character and the hydraulic conductivity is the same in all directions, the formation is uniform in thickness and infinite in real extent, the formation receives no recharge from any source, the pumped well penetrates, and receives water from the full thickness of the water bearing formation, the water removed from storage is discharge instantaneously when the head is lowered, the pumped well is 100% efficient, all water pumped from the well comes from aquifer storage, laminar flow exists through the well and aquifer and the water table has no slope. In its simplest form, the Theis equation can be expressed as :

$$S = \left[\frac{Q}{4\pi T}\right] W(u) \ldots\ldots.(10)$$

Where; S = drawdown, in m at any point in the vicinity of a well discharge at a constant rate, W(u) = well function of u and represents an exponential integral and

$$\frac{r^2}{t} = \left[\frac{4T}{S}\right] u \ldots\ldots\ldots\ldots\ldots\ldots..(11)$$

with r = distance, from the centre of a pumped well to a point where drawdown is measured, s = coefficient of storage, t = Time since pumping stated in days

Theis recognized that the same concept could be applied to the regular distribution of the ground water head around a pumping well even though water flows towards the point source rather than away from it. [28]Cooper and Jacob (1946) modified theis equation, pointing out that when U significant small, than it modifies the non-equilibrium equation without significant error as $S = \frac{0.183QT}{\log 2.25Tt/r^2s}$ ………….(12)

## 2.6 Yield Relationship

The properties of aquifers that influence well performance are depth and areal extent of the aquifer, number of aquifer that are exposed to well and the hydraulics properties of the aquifer. An aquifer performs two functions, namely, storage function and conduit function. The properties of the aquifer may be expressed in terms of its hydraulic conductivity, transmissibility, storage coefficient and specific yield. In case of semi-confined aquifers, two additional properties, namely, leakage factor and hydraulic resistance are also important. Reliable data is best obtained when a saturated package of pumping and recovery tests are in carried out in a strictly controlled manner.

Although, the volume of water contained in a particular segment of aquifer is of interest, of more concern is how much water can be actually released from storage per unit area of the aquifer per change in head. Whereas porosity represents the volume of water an aquifer can hold, it does not indicates how much water the aquifer will yield. As earlier said, the total water yield of any aquifer has several component that should be considered separately. When water is drained from a saturated material under the force of gravity, the material released only part of the total volume stored in its pores. The quantity of water that a unit volume of an unconfined aquifer gives up by gravity is the specific yield, while the amount of water retained by a unit volume aquifer after gravity drainage is called Specific Retention. This water is retained by molecular attraction and capillarity in the pore.

$$\text{Specific yield} = \frac{\text{Discharge (m3/day)}}{\text{Drawdown (m)}} \quad \text{........(13)}$$

In order worlds, Specific yield plus Specific retention equals porosity of an aquifer. Both are expressed in decimal fraction or percentages.

## 3. MATERIAILS AND METHODS

### 3.1 The Study Area

River Katsina Ala is a river in central Nigeria.It serves as a major tributary of the River Benue in Nigeria. The source of the river is found on the Bamenda highlands in northwestern Cameroon. It flows 200 miles (320 km) northwest in Cameroon, crossing the Nigerian Cameroon border into Nigeria, with an area of 2,402 km$^2$. It lies between the coordinates of 7$^0$ 15` 0``N and 9$^0$ 30` 0``E. The study area experiences a typical tropical climate with two distinct seasons, the wet or rainy season and the dry season. The rainy season least from April to October with annual rainfall in the range of 150-180mm. the dry season begins in November and end in March with a fluctuation in temperature between 23$^{0c}$ and 31$^{0c}$ in the year.


Fig 1.Map of Benue state showing the catchment area.

The geological formations of the river katsina-ala is composed of alluvial deposits consisting of silts, clay and sand [27]. Comprising of weathered basement, sand stone basement complex or sedimentary rocks. (Fig 2.)

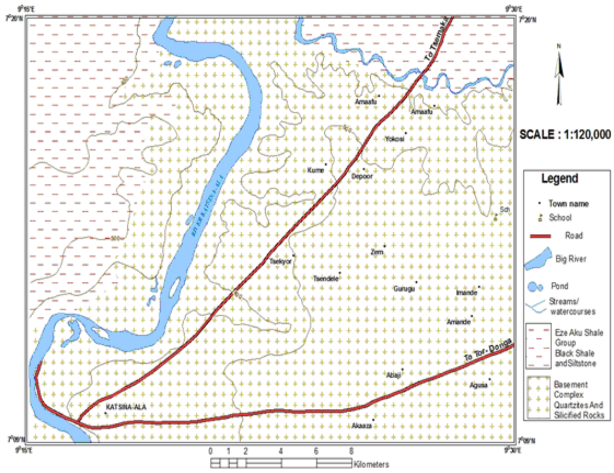


**Figure 2:** Geological Map of the Study Area (after Geological Survey of Nigeria (GSA) Sheet, 1994).

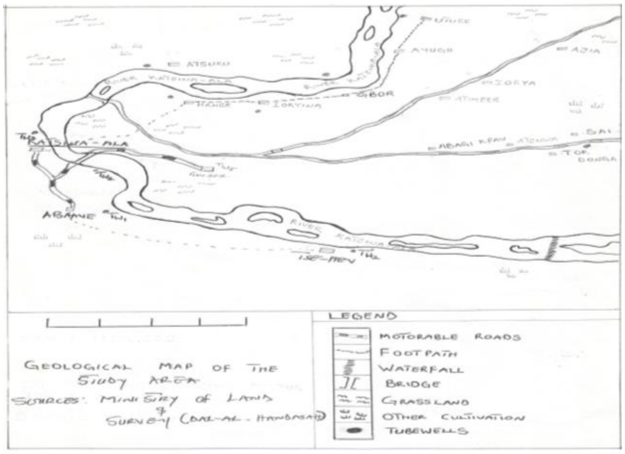


Fig. 3. Reduced Topographical Map of Katsina-Ala L.G.A, Showing the tube well Locations.

### 3.2 Pumping Test

Basically, two methods of pumping test are commonly used in the drilling industries. These are Constant-discharge teste and Step-test. In the constant discharge test, the well is pumped continuously for at least 24 hours [24] and drawdown is obtained in the tube well itself and in any nearby existing wells in the vicinity. The purpose of this test is to obtain data on the hydraulic characteristics of an aquifer within the radius of influence of the pumped wells. The **Step-test,** involves pumping a tube well or boreholes to established yield for drawdown relationship and there by isolate those elements of drawdown attributable to the well. The ideal procedure is to pump the tube well or boreholes at 25, 50, 75 and 100% of its maximum capacity. Hence, this is not always possible for places where the maximum yield is generally low.

Five tube well that have been already developed for clogging water formation, increase porosity and permeability with stabilized sand formation were identified in the study area( Fig3). Physical measurement of the static head and radius of these wells were also carried out. The radius of the cone of depression established, during pumping. The depth of water in the well during pumping was also noted and recorded. A tape meter was used to measure the water level in the tube well before commencement of pumping. The protective clothing and flash light, were used whenever and wherever the site condition become dark during the conduction or process of pumping or recovery test as the process must not be stopped under any condition unless, concluded. The umbrellas, serve the purpose of shed during sunny or rainy period of the test.

Pump testing at constant discharge rate were conducted on all identified wells in the study area, where by the tube wells were pumped at a constant pumping rate of discharge. The discharged were measured by computing theoretical discharge using the empirical formula (eqn6). This was repeated for several numbers of times. The time of commencement of discharge to the time of completion, and that of recharge were noted with a stop watch and recorded while gave the yield for a particular tube well was computed using eqn 13.

3.3 **Recovery Test**

Recovery test was conducted on all the pumped wells, taken the recovery of water level in the observed well at the shut-off of the pump until the rate of recovery shall become zero. At any instant of time during any recovery period, the depth of the water level in the well below the original static water level prior to pumping and is regarded as Residual drawdown. Theis showed that the residual drawdown can be given can be computed from eqn12 as

$$S^1 = \frac{2.30Q}{4\pi T} log_{e(\frac{t}{t^1})} \quad \text{...............(14)}$$

**4. Results / Discussion**

The result of the pumping and recovery test data for the various wells in the study area where as computed from starting time, stoppage time, stabilization time and depth of drawdown is presented in the table 1 below:

Table 1. Pumping and Recovery test for selected tube wells.

| Well | Duration of pumping(min) | Recovery Period(min) | Stabilization Period(min) | Depth of DD(m) |
|---|---|---|---|---|
| A | 105 | 175 | 55 | 1.83 |
| B | 165 | 165 | 45 | 1.22 |
| C | 135 | 285 | 30 | 0.92 |
| D | 160 | 250 | 30 | 0.99 |
| E | 180 | 135 | 50 | 1.56 |

**4.1 Determination of Water Discharge**

The quantity of water discharge of an aquifer can be determined by knowing the values of its Transmissivity and Permeability if that same aquifer. For a hand dug well, it is determined by knowing the Transmissivity and permeability of the aquifer surrounding the well. The discharge for each well under the study area is computed using of well equation ( Eqn 7 ) "Thies well equation". The values for tube well is presented in table 2, with tube well A having a value of 3075.84 $m^3$/day as the highest discharge, follow by tube well B, the lowest discharge value is that of tube well D with a quantity discharge of 1719.36 $m^3$/day.

**4.2 Computation of the Specific Yield and Quantity of Water Demand.**

**Table 2.**Computed Values of Discharge for Each Well

| Well | Q($m^3$/day) | SY($m^3$/d) | W demand |
|---|---|---|---|
| A | 3075.94 | 558.1 | 1470.25 |
| B | 2202.90 | 466.7 | 1037.1 |
| C | 2172.42 | 542.46 | 904.1 |
| D | 1719.36 | 464.69 | 844.89 |
| E | 2173.83 | 478.83 | 870.57 |

The specific yield of each well in the study area where computed from the data collected and analyzed using eqn13. The data for specific yield and the quantity of water demand by the populace for each well is plotted on bar chart graph shown in Fig4, with more than 70% of the discharge used up for tube well 1,3,4 and 5, while that for tube well 2 has only 30% of the water been used.

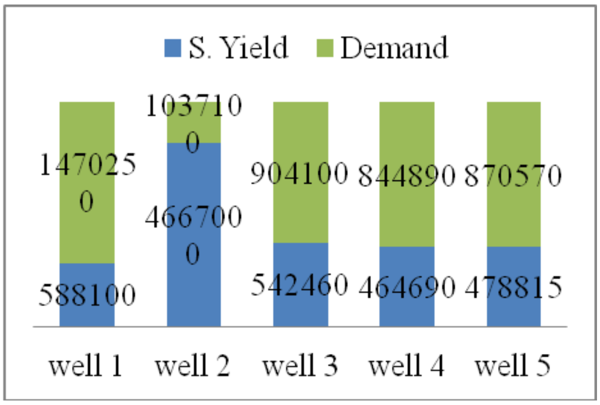


Fig4. Specific yield and water demand of the study area per well per day

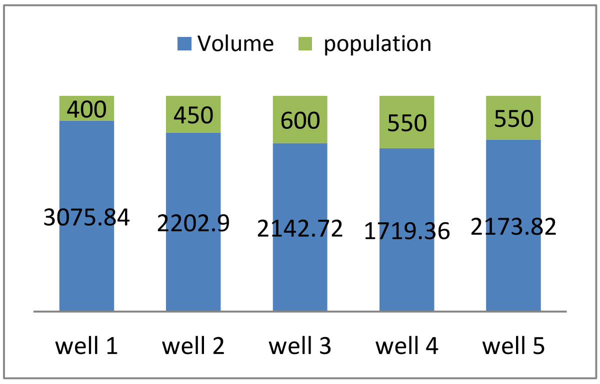


Fig4. Volume of water demanded by the population of the study are per well per day

Determining the population is on the most important factions in the planning of water usage, if the project has to serve the community for a certain design period. Normally a design period of 20-40 years is selected. What will be the population at the end of the design period, is the basic question, which can be achieved by using various method for population forecasts; Arithmetical increase method, Geometrical increase method, Incremental increase method, Decreased rate of growth method, Growth composition analysis method. etc. The water consumption in this study area may be conveniently divided into; Domestic, Trade, Agriculture, Public, Losses. Where by the total consumption of water depends upon several factors, such as a climatic condition, cost of water, living standard of the inhabitants, pressure in the pipelines, type of supply etc. The total quantity of water required divided by the total population gives per capital water demand. Fig5 gives the comparism between the water demand from each well and the corresponding population.

**4.3 Determination of Soil Diameter $d_{10}$, coefficient of permeability and transmissivity**

Soil samples, from the various locations of the wells in the field where collected and sieved, using a graduated set of sieves in order to determined each sample diameter, after it has been oven dried for 24 hours. By tracing the soil diameter, $d_{10}$, on the particle grain size graph tells the type sand particle of that location. The value is then used for the computation of the coefficient of permeability, K, in m/s in the study area by egn2 and the results presented in table 3.

**4.4 Computation of the R(Cone of Depression)**

The variation of the static water level for the various wells of the study area where taken on a weekly base for a period of fifteen (15) weeks and the mean computed. An alternative method was used in the determination of R (the cone of depression), using the expression in eqn 8. Table 3, presents the computed values for the cone of depression for each tube well in the study area, with a small variation in the variation during drawdown. From the data obtain in table 3, all the tube wells in the study area are classified as medium aquifer since their permeability value all are above 103 m/day. [28] classified good aquifer that have K values ranging from 105 – 103, medium aquifer to have K value between 103 – 1, poor aquifer to have K value ranging from 1- 153.

Table 3. Information data for tube well in the study area

| Well | Depth(m) | Dia(m) | SWL(m) | Users | $d_{10}$(m) | K(m/d) | T($m^2$/d) | R |
|---|---|---|---|---|---|---|---|---|
| A | 6.80 | 0.50 | 5.25 | 400 | 0.16 | 221.18 | 1157.76 | 8.75 |
| B | 6.99 | 0.68 | 4.72 | 450 | 0.15 | 194.40 | 915.94 | 5.49 |
| C | 8.83 | 0.56 | 3.95 | 600 | 0.19 | 311.90 | 205.92 | 5.24 |
| D | 7.43 | 0.55 | 3.70 | 550 | 0.17 | 249.70 | 924.48 | 5.05 |
| E | 9.20 | 0.74 | 4.54 | 550 | 0.14 | 169.30 | 768.96 | 6.55 |

The transmissivity of the aquifer at the study area were computed using the product of the static water level in the well before pumping to its permeability coefficient of that same well and presented in table 3, using eqn 4. The coefficient of transmissivity T, values computed in table 3 shows that the tube well with the highest transmissivity value of 1157.76 $m^2$/day is obtain from tube well A. And that with the lowest transmissivity is from tube well C, with a value of 205.92.

## 5.CONCLUSION/RECOMMENDATION

### 5,1 Conclusions

From the result and analysis of pumping and recovery tests and computation of the average discharge from each well within the study area, it can be concluded that the transmissivity, permeability and the cone of depression when compared with [28]and other standards, shows that the aquifers in the study area are moderate to good as well as confined - semi confined. The maximum drawdown in any pumped well to stabilization of the water level is 1.83m and the time taken for an aquifer to recover to its static water level is not more than 4 hours 15 minutes as against the three hours twenty two minutes obtained. The rate of recovery reduces as the atmospheric pressure turn to be greater than the pore water pressure, and to certain point, stops when it balances. Building of a well with burnt brick do not have any advance effect on its yield, instead, it stabilizes the soil. The yield of a well does not depend on the depth of the well, but on the type of aquifer that is found within the well site.

### 5,2 Recommendation

It is recommended that, in the study area:

1. In predicting the discharge of aquifers in these area, the permeability and transmissivity obtain could be used.
2. Further pumping of the tube wells in this area should be carried out to for at least 8 hours, to exceed the maximum hours used on this one.
3. Government should put place boreholes, by founding it, in other to support hand dug well, since not much yields are recorded during drought period.
4. For a perfect knowledge, of this study and beyond, it should be done also during the dry season (drought period).

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