
Design and Construction of Clear Wash Bores and Tubewells for Irrigation Purposes in the Fadama Area of Gakpan, Kwara State, Nigeria

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Abstract:

Gakpan fadama is an extensive flood plain of over 18,000 hectares of land occasioned by alluvium deposits with a potential for both small and large scale irrigation development on the bank of River Niger in Patigi Local Government Area of Kwara State. Alternative well designs and construction methods for ground water abstraction from fadama aquifers were investigated. Test and analysis of results for Soil particle Size distribution, infiltration; yield (pumping and recovery) tests as well as recharge rates were conducted. Results showed that effect of well diameter of 750 mm (75cm) on recharge was very minimal (11.15cm/hr). Permeability measurements of 9.74cm/hr indicated that surface water contributes immensely in the recharge of the aquifer. Transmissivity of 1265.09m³ /day and storativity of 7.91x10⁻³ was calculated. The results of the aquifer and the textural class of the Soil (silty-clay-loam) shows yield potentials of the wash bore. However, high variability in Soil Size Fractions were, revealed in the Practical Size Distribution Analysis, this is an indication of likely variation in permeability and consequently, well recharge rate within the fadama. Therefore, a clear water wash bore is feasible in Gakpan fadama area.

Keywords: *Fadama, Irrigation, Wash bore, Jetting, Groundwater, Recharge*

1. Introduction

Population in Nigeria is greatly on the increase, hence the need for increase in food production is very enormous. The need to increase food production for highly growing population of Nigeria vis-à-vis the world has led to the substantial investment in the construction of dams and reservoirs for irrigation purposes. So many parastatals established under the States Ministry of Agriculture and Natural Resources in Nigeria, these are to help in complementing the small and medium scale irrigation schemes. All these efforts have not in anyway translated into increased food production largely due to lack of capacity building in respect of the use of these various sophisticated and complicated equipments which has led to the near collapse to some of these projects in Nigeria. As a result of these, the Federal Government of Nigeria shifted their focus from the medium and large irrigation projects to the development of the abundantly rich “Fadama” that are available for small scale irrigation purposes, hence the introduction of the National Fadama Development Projects I. The Agricultural Development projects (ADPs) through the Federal Government of Nigeria implemented the World Bank assisted project between the period of 1988 and 1999. The project focused on the development of small – scale irrigation through the extraction of ground and surface water. The use of groundwater for irrigation serve as a supplementary water supply and made agriculture to some extent less dependent on rainfall; this however, further improved dry season farming (NFDO, 2005).

Fadama land is generally low-lying flood plains and composed of alluvial deposits. The flood prone plain has finer textured soils which is less-acidic slow draining and has markedly different moisture regime from the surrounding upland soils. The vast expanse of fadama lands are commonly found in the Northern part of Kwara State that could be harnessed for irrigation development. A source of irrigation water in the fadama has principally been direct pumping from rivers or hand dug wells. However, most fadama areas that are viable for irrigation within Kwara State do not have flowing rivers around them. Thus, there is the need to explore alternative source of irrigation water which is the wash bore and tube wells for small scale irrigation development in the fadama areas (Mande, 2000).

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 (NFDO, 2005).

Water well is a hole usually vertical, excavated in the earth to bring ground water to the surface (Todd, 2006). Wells have been an integral part of mans life and activity, supplying clean pure water where surface supplies were in adequate (Hansen et al., 1980). These supplies are either used for domestic irrigation or industrial purposes. The initial exploitation of ground water has been generally from relatively easier and cheaper sources. The rate of development is not only dependent on the ease of the ground water availability but also on other factors such as technical know-how, Government Planning, financial and technical facilities available to the farmer and socio-economic factors (Michael, 19978).

The main source of groundwater utilization for irrigation development would continue to be open well, followed by shallow tube well such as wash bore /tube well. Efficient and economical utilization of groundwater through wells depends on the design of well to best suit the characteristics of the water bearing formation (Michael, 1978). Dogged wells usually shallow wells are generally less than 15m in depth and may be up to 1m in diameter. In the past they were usually excavated by hand and even today in many areas, this is still the principal method of constructing wells.

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 so also in unconsolidated sands.

This study is aimed at exploring the possibilities and or feasibilities of exploiting groundwater for irrigation purpose(s) in fadama lands that have no river running through or by them, using the clear water jetting method; this is to boast dry season farming particularly, fadama small- scale irrigation as a complement to the predominantly rain fed agriculture.

Gapkan is a small community that lies on latitude $8^{\circ}21'' - 8^{\circ}56''$ N, and longitude $5^{\circ}25'' - 6^{\circ}20''$ E in Patigi Local Government Area of Kwara State; it shares her major boundary with river Niger on the Northeast. (MANR, 2003).

2. Materials and Method:

Profile hole of 2m X 1m X 1m were dug on project area in specified locations with a shovel, two locations were chosen for the profiling. Samples were collected at different horizon depths, placed in polythene bags, labeled and taken to the laboratory for analysis. So also, sample were collected from the water bearing sands during the test-hole drilling and wash bore installation and analyzed in the laboratory. The soil samples were spread in the laboratory under shade for drying. After drying, mortar and pestle were used to break-down the aggregate material and sieved.

50g of a sieved soil was placed inside a conical flask, 100ml of $\text{Na}(\text{PO}_3)_6$ solution was added and left for 30 minutes for the reaction to be completed. This was thereafter poured into a cup and than stirred using a mechanical stirrer for 3 -5 minutes. After which, it was then poured into a mercury cylinder and water was added to it up to a 1 litre mark. The particles were brought into suspension using a stirring rod, at 40 seconds, after removing the stirring rod, the hydrometer and the temperature readings were taken. The cylinder was left on a stable surface undisturbed for 2 hours, after which the hydrometer and temperature reading were again taken. A blank solution was prepared with distilled water and calgon (minus the soil sample), and readings were further taken this time at 40 seconds; after the initial 2 hours with the hydrometer and thermometer. The determination of the texture was done by using the soil water characteristics model for the texture.

2.1 Soil Infiltration Test

The field measurement was conducted by driving the two rings into the ground using a wooden the mallet, in such a manner that only 15cm was left exposed. The rings were filled with water; on completion the time was noted. Also the time it took the water in the inner cylinder to drain was taken. Initially, the experiment was started by considering 5 minutes for taking of readings. After each reading, water is added into the infiltrometers to the 11.5cm mark. Later, the time for taking readings was changed to 10 minutes, 15 minutes, 20 minutes, 30 minutes, 45 minutes, 60 minutes, 80 minutes, 100 minutes, 120 minutes and 130 minutes were recorded. In all, ten different sites were used for the conduct of the test (Musa, 2004).

2.2 Yield (pumping and recovery) Test

The wash bore was pumped using a 2" centrifugal (Robin) pump at a constant rate for 5 hours. The discharge for the pumping test was determined as 3.8 liters per second during development of the wash bore as the maximum sustainable flow without causing wash bore to run dry. Water level draw-downs were measured in the pumping well and the observation well.

The duration of pump test was determined by the time required for stabilization to occur in the water level in the observation well or when draw down was linear with time and minimal compared to the saturated thickness of the aquifer immediately after the pumping test was stopped, water level recovery measurements were made in the observation well to determine recovery characteristics.

2.3 Recharge Rate Determination

One of the important methods of assessing the performance of a well is by determining its recharge rate. The recharge rate is easily discerned by means of a pumping test. On the commencement of the pumping test, the static water level in the monitoring (observation) well and the wash bore were measured. The measurement was done by dipping a stick into the hole and noting the depth between the soil surface and the static water level. The pump was started with the pump suction hose protected by strainer dipped into the well. The speed of the pump was reduced and allowed to run a steady state- a state at which the pumping water level was maintained. As pumping continued at steady state, water levels in the observation well became lowered due to differential pressure gradients. The lowering of the water table in the observation well was measured at 5,10,20,30,50,60,90,120, 180 and 300 minutes (totaling 5 hours). The difference between the pumping water level and static water level gives the draw. Equilibrium is said to have been reached when the cone of depression around the discharging well has reached. At equilibrium, the discharge from the pumping well (pumping rates) equaled the recharge rate at the draw-down. At equilibrium, the pump was put of, the time for the pumping water level to rise 10.cm inside the well was determined by a stop watch.

Recharge rate is calculated from theoretical equation.

$$\text{Rate of Recharge (Q)} = \frac{A(h_p - h_n)}{T} \quad 1$$

Where A is the Cross-sectional area of well (cm²), Hp is the pumping water level (cm), Hn is the new height of water (hp-10) (cm) and T is the time of rise from hp to hn. In min or hrs

2.4 Design of wash bore

Choice of well diameter is largely dependent on the outer diameter of drilling bit when using a rotary rig) or drill/jetting pipe when jetting with a centrifugal pump.

The diameter of wash bore is usually the same from top to bottom and is given by the relationship.

$$WD = OD + A \quad 2$$

Where WD is the well (wash bore) diameter in (cm²), OD is the outer diameter of drill pipe (cm²) and A is the allowance provided for gravel packing and ranges from 0.5 – 1.0 Depending on diameter of gravel packing material and drill bit (dimension-less).

2.5 Well Screen

A well screen is a strainer that separates the groundwater from the granular material in whose pores it is contained. Often referred to as the in-take section, well screen design is a critical element in well construction. The screen permits to flow into the well and keeps sand and gravel out. The quality of water that can be tapped from a well depends on length of the screen, diameter of screen, screen slots and total slotted area. Choice of a screen for a formation is determined by the sizes of grain material from aquifer bearing stratum.

Size of screen slot opening (perforating) is based on the grain-size distribution. For homogenous formation, screen slot opening should retain 40 – 50% of the aquifer material. However, 40% is a common design parameter. Size of slots commonly used is 1.5 to 5mm beyond which no substantial reduction in clogging is obtained. Width of slots varies from the range 0.2 to 0.5mm and 2 to 5mm depending on grain size distribution of aquifer and screen construction. Slot openings can be achieved by using hack-saw.

3. Results and Discussion

The percentage of sand from the sample collected from the profile was 30% while that of silt and clay were 40% and 30% respectively. Using the soil water characteristic model, the type of soil in the area is clay soil which is known to have wilting point of 16.7%, afield capacity of 31.2%, saturation of 49.5% the saturated hydraulic conductivity is 1.105x10⁻⁵m/sec was obtained while the organic matter was 0.7%, the moisture content was 47.9% matric potential of 52.5mmHg while the hydraulic conductivity of 8.024x10⁻⁴ m/sec.

The soil textures within a profile were variable probably as a result of the alluvium deposition in the fadama. The soil materials were coarse to intermediate in particle size distribution. The soils were sands ranging from coarse loamy sands to sandy clay loams. Low silt fraction, medium clay content and high sand fractions are characteristic of the soils in this area. Generally, the clay content decreased with depth. The mean clay content of 0 – 15, 15 -30, 30 -45, 45- 60, 60 -75, 75- 90, and 90 – 105cm with well depths of 16.9, 8.0 11.6, 12.7, 15.7, 17.4, and 19.9% respectively. A deviation from the trend occurred in the 0-30cm layer which may be due to the cumulative effect of the population size. The silt fraction ranged 18.4% on the surface (0 – 15cm) layer but decreased gradually to 5.9% in the 90-105cm depth.

The sand fraction exhibited no particular trends between depth intervals. All the horizons were predominantly sands. The percentage sand content varied between 64.0 to 84.4% with the highest value in the 15-30 cm layer. The co-efficient of variation ranged from 9.0 to 28% for sand, 24.4 to 41.7% for silt and 5.4 to 5.4% for clay. Generally, the analysis revealed high variability in size fractions. Recharge rates of wells constructed in this fadama area are likely to exhibit some variability in their recharge capabilities. This is elaborated in table 1.

Table 2 shows the sieve analysis of the soil samples collected from the area. It was discovered that sieve number 60 with an opening of 0.25mm retained 90.10% of the soil sample.

3.1 Analysis of Pumping test Data

Analysis of pumping test data provides the information required to determine the appropriate abstraction rate from the wash bore, and the sustainable yield from the aquifer. Analysis carried out using Cooper–Jacob semi-log methods shows that the aquifer transmissivity and storativity (storage coefficient) were calculated for to be 1265.09 m²/day and 7.91X 10⁻³ respectively, as elaborated in table 3.

3.2 Effect of Groundwater Abstraction on Table Levels.

Water-table is the natural level of free groundwater. Natural groundwater flows through an aquifer under a natural hydraulic gradient but an artificially induced flow can be initiated by imposing an increased hydraulic gradient around a well and the artificial induction is by means of a pump. When water is being retrieved from a well, the well is said to be discharging. The water level in the vicinity of a discharging well falls as the rate of pumping increases or as time increases at a fixed steady rate of abstraction and the degree of fall of water level decreases with increasing distance from discharging well. The moisture condition at time of measurement may affect soil conductivity and hence, draw-down. However, when no pumping is taking place, the water pressure within the well is less than that of the formation outside the well. During abstraction the pressure within the well is lowered and pressure gradient is created by the well and greater pressure outside the well. The greater pressure in the well surround would force water into the well and flow occurs. The lowering of pressure within the well could be accompanied by lowering of the water table in the well vicinity water then flows radially into the well from all directions by a converging flow. Perhaps, pumping groundwater in areas where suitable permeable aquifers exist would be a more effective way of lowering the water table and in drainage by controlling excess water in water logged soils. This could diversity crops and cropping systems.

Under natural conditions, the aquifers are replenished through infiltration of surface waters during the rainy season and by hydraulic connection with perennial treams running through/or across fadama. At the end of the dry season, the water level in an aquifer is at its lowest point, generally very near the elevation of the water level in the river which is also at its lowest point when the rains begin and stream channels, fill, the hydraulic head in the river becomes higher than in the aquifer which causes water to flow into the aquifer. The process continues until an equilibrium is reached between the water level in the river and in the aquifer.

Most often, there is not a direct lateral connection between the river and the aquifer. The alluvial aquifers underlying the fadama are typically former channels of the river and thus are relatively long and narrow. The points at which these old channels intercept the present channels are where recharge occurs most effectively. The surface materials over most of the fadama are clays and silts which have low inter-granular hydraulic conductivity. However, desiccation cracks are quite common in clays. These openings provide pathways for flood water to infiltrate downward to recharge the aquifers.

From the infiltration test and re-charge rate determination, recharge would naturally be fast. However the path ways along which the recharge water moves into the aquifer are long and the hydraulic gradients are relatively low and therefore this recharge water process is typically slow. As a result, full replenishment of the aquifer should be late in the rainy season when the rains would have fully established. Recharge rates for the 2hr period was determined to be 11.15cm.

During dry season, the water level in the river drops, the hydraulic head in the aquifer becomes higher than that of the river. As a result, water moves from the aquifer to the river channel, thereby sustaining flows in the river long after the rainy season has ended. Where there are extensive alluvial aquifers beneath the flood plain, the discharge to the river may sustain flow throughout the dry season when irrigation activities are at their peak.

Vertical withdrawal of water from aquifer by evapo-transpiration is also an important and significant factor. Where the water level is close to the surface, water is abstracted through plants, by phreatic consumption.

To determine the full extent of recharge for the aquifer at Gakpan fadama, long-term monitoring of the well is required. Monitoring of this washbore at Gakpan fadama that has become a test well in case of future development of the land for irrigation purpose, on regular basis becomes imperative to obtain a full season cycle of readings. In any case, the discharge data that was obtained for River Niger and the average infiltration rate (9.3cm/hr) of the soil provides an insight into the good recharge potentials of the alluvial in this fadama.

3.3 Irrigation Return Flows

A significant portion of the water applied on the ground to support crop growth infiltrates downward and returns to the aquifer. Michael (1978) considered a return flow of about 30% of irrigation water to the aquifer as a common phenomenon.

4. Conclusion

In exploring the feasibility of the clear water washbore jetting method for Gakpan fadama various construction methods were considered. The performance of the design however depends on the recharge rates and yield of the well. If an engineering design aims mainly at performance, relative cost and useful life of a design, then the washbore by clear water jetting method would be most economical and profitable to the fadama small-scale irrigation farmer than the other washbore construction methods because of their disadvantages in accessibility to site and drilling costs. The clear water jetting method in spite of its relative cheapness and the simplicity with which drilling is completed, has the disadvantage of difficulty in penetrating very thick clays and for formation underlain by granitic basements thus, it is best for old river course or alluvium deposited formations. It however, has an advantage in case of adoption of the technology by an un-skilled farmer which should be the ultimate goal of any irrigation planner.

The high permeability values obtained during the infiltration rate(s) test from fadama shows that construction of shallow wells should be adequate for the area rather than the highly expensive deeper tubewell that may be abortive. Hence, the feasibility of the washbore by clear water jetting method at Gakpan fadama.

It is thus recommended that possibilities of fitting jetting pipe with a drill bit even if it is improvised, to enable easy penetration into consolidated formations need to be explored.

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Table 1: Particle size distribution and texture of the soil at different soil depth*

Parameter	Depth (cm)	Gravel (g/100g)	Coarse Sand (%)	Fine Sand (%)	Silt (%)	Clay (%)	Texture
X	0-15	0.9	33.8	30.9	18.4	16.9	Loam
CV		89.8	31.5	34.5	41.7	54.0	
X	15-30	1.9	53.0	31.1	7.9	8.0	Coarse Loamy sand
CV		40.5	22.7	28.2	38.0	17.2	
X	30-45	3.5	53.9	25.9	8.9	11.6	Coarse Loamy sand
CV		65.0	22.4	11.7	24.4	36.4	
X	45-60	3.7	55.5	24.8	6.4	12.7	Coarse Loamy sand
CV		52.7	22.4	18.8	33.0	36.5	
X	60-75	3.1	41.6	25.2	6.9	15.7	Coarse Sandy loam
CV		41.1	12.5	18.0	33.0	24.0	
X	75-90	2.4	50.4	25.0	5.3	19.4	Coarse sandy clay loam
CV		117.4	5.8	15.3	39.6	8.0	
X	90-100	3.0	49.9	24.3	5.9	19.9	
CV		50.5	3.0	15.0	35.3	5.4	Sandy clay loam

* *International Society of Soil Science Classification.*

Where X is the Mean of Population and CV is the Coefficient of Variation (%)

Table 2: Sample Sieve Analysis Summary

Sieve Number	Sieve Opening (mm)	Cumulative Wt Retained (g)	Com. % Retained
10	2.00	47	11.63
14	1.41	59	14.60
20	0.84	125	30.94
25	0.71	160	39.60
40	0.42	302	74.75
60	0.25	364	90.10

Pan wt 404 100
Original wt 407

Table 3: Pumping test data for Gapkan Fadama

Elapsed Time T (min)	Draw down Δs	Log t (min)
0	0	∞
5	2.4	0.7
10	2.7	1.0
20	3.0	1.3
30	3.6	1.5
50	4.1	1.7
60	4.3	1.8
90	4.8	2.0
120	5.4	2.2
180	6.1	2.3
300	7.6	2.5