Assessment of Clear Wash Bores as an Alternative Source of Irrigation Water for Fadama Areas of Kwara State, Nigeria

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ABSTRACT

This study adopted the experimental research design to find the 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) textutre as well as recharge rates were conducted. Results showed that effect of well diameter of 750mm (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 (Calculated transmissirity and storativity of 1265.09m3/day and 7.91x10-3 respectively). The results of the aquifer and the textural class of the Soil (silty-clay-loam) shows yield potentials of the wash bore. Also, high variability in Soil Size fractions as revealed in the practical Size distribution analysis is an indication of likely variation in permeability and consequently, well recharge within the fadama. The clear water wash bore is feasible in Gapkan Fadama area.

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

INTRODUCTION

Population in Nigeria is greatly on the increase; going by the 2006 census figures hence food production has become imperative. The need to increase food production for every -growing population of the world has lead to the substantial investment in the construction of dams and reservoirs for irrigation purposes. So many government parastatals established under the States Ministry of Agriculture and Natural Resources in Nigeria, are to help in complementing the small and medium scale irrigation schemes. All these efforts have not in any way translated into increased food production largely due to lack of capacity building with respect to the use of these various sophisticated and complicated equipment which has led to the near collapse of some of these projects in Nigeria. As a result, the Federal Government of Nigeria shifted focus from the medium and large scale 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. 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 use of ground and surface water. The use of groundwater serves as a supplementary water supply to rainfall 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). Gakpan Fadama is an extensive flood plan of over 30,000 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. 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 man's life and activity, supplying clean and potable water where surface supplies are inadequate (Hansen *et al*., 1980). These supplies are either used for domestic irrigation or industrial purposes.

The initial exploitation of ground water has been generally and 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 known-how, Government Planning, financial and technical facilities available to the farmer and socio-economic factors (Michael, 1978). The main source of groundwater for irrigation development would continue to be open well, followed by shallow tube well such as wash bore. Efficient and economical utilization of groundwater through wells depends on the design of the well to best suit the characteristics of the water bearing formation (Michael, 1978). Dugged 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 manually 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 in unconsolidated sands.This study is aimed at exploring the feasibility 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.

MATERIALS AND METHOD

This experiment was carried out in Gapkan, a small community that lies on latitude 8021" - 8056" N, and longitude 5025" - 6020" E in Patigi Local Government Area of Kwara State, Nigeria. It shares her major boundary with river Niger on the Northeast (MANR, 2003). Profile holes of 2m x 1m x 1m were dug on project area in specified locations with a shovel. Two locations were chosen for the profiling. Soil samples were collected at different horizon depths and collected from the water bearing sands during the test-hole drilling and wash bore installation. All samples were placed in labeled polythene bags and taken to the laboratory for analysis. 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 Na (PO3)6 solution was added and left for 30 minutes for the reaction to be completed. This was thereafter poured into a cup and then stirred using a mechanical stirrer for 3-5 minutes.

After stirring, the mixture was 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 readings 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.

Soil Infiltration Test: The field measurement was conducted by driving the two rings into the ground using a wooden 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 respectively. In all, ten different sites were used for the conduct of the test (Musa, 2003).

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, respectively. 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 dawn 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.

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 on 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 over a period of 5 hours. The difference between the pumping water level and static water level gives the draw down. Equilibrium is said to have been reached when the cone of depression around the discharging well is 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 off, the time for the pumping water level to rise to 10cm inside the well was determined by a stop watch. Recharge rate was calculated from the equation. Rate of Recharge (Q)= A(h_p-h_n)/T. Where: A is the Cross-sectional area of well (cm^2), 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 minutes or hours.

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. Where: WD is the well (wash bore) diameter in (cm), ODis theouter 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).

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 the 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 (perforation) 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 achieved. 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.

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 which is known to have wilting point of 16.7%, a field capacity of 31.2% and saturation of 49.5%. A saturated hydraulic conductivity of 1.105x10-5m/sec was obtained while the organic matter content was 0.7%. The moisture content was 47.9%, with a matric potential of 52.5mmHg and 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 soils ranged from coarse loamy sands to sandy clay loams. Low slit fraction, medium clay content and high sand fractions are the characteristic of the soil in this area. Generally, the clay content decreased with depth. The mean clay content of the 0 - 15, 15 -30, 30 -45, 45- 60, 60 -75, 75- 90, and 90 - 105cm depths well were 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 decreased 18.4% in the surface (0 - 15cm) layer 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 15-30cm layer. The percentage 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 are likely to exhibit some variability in their recharge capabilities. Table 1 below shows the textural classification of the various types of soils collected while drilling the wash bore.

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

P	**D**	**G**	**CS**	**FS**	**SS**	**C**	**T**
X	0-12	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	CLS
CV		40.5	22.7	28.2	38.0	17.2	
X	30-45	3.5	53.9	25.9	8.9	116	CLS
CV		65.0	22.4	11.7	24.4	36.4	
X	45-60	3.7	55.5	24.8	6.4	12.7	CLS
CV		52.7	22.4	18.8	33.0	36.5	
X	60-75	3.1	41.6	25.2	6.9	15.7	CSL
CV		41.1	12.5	18.0	33.0	24.0	
X	75-90	2.4	50.4	25.0	5.3	19.4	CSC
CV		117.4	5.8	15.5	39.6	8.0	Loam
X	90-100	3.0	49.9	24.3	5.9	19.9	
		50.5	3.0	15.0	35.3	5.4	SCL

Source: International Society of Soil Science Classification.

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

Key: P = Parameter; D = Depth (cm); G = Gravel (g/100g); CS = Coarse Sand; FS = FineSand; SS = Silt Sand; C = Clay (%); T = Texture (%); CLS = Coarse Loamy Sand, CSL = Coarse Sand Loam, SCL = Sandy clay loam; CSC = Coarse Sandy Clay

Table 2: Sample Sieve Analysis Summary

Sieve Number	Sieve Opening (mm)	Cumulative Wt Retained (g)	Cumulative % 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

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.

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 transmisivity and storativity (storage coefficient) were calculated to be 1265.09 m2/day and 7.91X $10^{-3}m^3$, respectively.

Table 3: Pumping test data for Gapkan Fadama

Elapsed Time T (min)	Draw down changes	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

Effect of Groundwater Abstraction on Water 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. The 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 lead to great diversity of 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 streams 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 equilibrium is reached between the water level in the river and in the aquifer. Most often, there is no 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 Gakpanfadama, long-term monitoring of the well is required. Monitoring of this wash bore 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 inorder 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. 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.

CONCLUSION

In exploring the feasibility of the clear water wash bore jetting method for Gakpanfadama 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 wash bore by clear water jetting method would be most economical and profitable to the fadama small-scale irrigation farmer than the other wash bore 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 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 wash bore by clear water jetting method at Gakpanfadama. 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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