Positive Implications of Hand-Dug Wells in Water Resources Planning and Management in A Developing Economy Such as in Nigeria

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ABSTRACT

Hand-dug wells are circular holes, about one metre (m) in diameter and 10 to 30 m in depth, dug with human labour. The wells tap water from shallow aquifers for domestic water supply, small-scale industries, and small irrigation schemes. Many hand-dug wells exist in Nigeria and in many developing countries. They are important in both urban and rural communities.

The wells are dug with hoes, shovels, pickaxes and diggers. Water and cuttings are removed from the hole using a human-powered bucket-rope-pulley arrangement. Three to four men dig the well in shifts. Well construction cost is cheap, as low-scale technology and manpower are used.

Problems with hand-dug wells include susceptibility to pollution/contamination; drastic declines in water level during the dry season; low well yields; silting-up of wells, and caving-in or collapsing of well walls, etc.

New designs are suggested to improve the efficiency and performance of this ancient technology. In Nigeria, wells should be completed in March when the water level is deepest. Well yield is improved by using slotted concrete rings to screen the aquifer. Anti-pollution devices are also proposed for better water quality. Such wells would provide more potable water to the urban and rural poor.

An improved type of slotted concrete ring has been designed for use in the screened portion of the well. Non-perforated concrete rings are used in the non-productive portions of the aquifers or above the water table, to prevent caving or collapsing of well walls. A convex cover forms a protective rim extending beyond the circumference of the well, to prevent the entrance of surface contaminants. Water from the dug-wells is pumped through an external filtration system into an overhead storage/treatment tank using an inexpensive pumping system.

All of these designs are suggested to improve the efficiency of the wells; to provide stability to the wells and better well yield, and to lessen the incidence of pollution/contamination within the well and its surrounding environment.

INTRODUCTION

Historical Importance of Hand-dug Wells

Water, which is almost synonymous with food and hence life, is a basic component in the essence of any being and sustenance of all living things. This indispensable role of water to life has been recognized and appreciated since earliest man.

On one hand, because of the various uses and needs for water, it has been extensively exploited as a surface water source. On the other, where surface water was not available, man learned intuitively that water could occur underground. As a result, groundwater was prospected for by "hocus-pocus", water-witching or dowsing. It was exploited by ditches and tunnels dug to shallow depths to intersect the water table.

An advancement on the above methods of groundwater exploitation is the digging of cylindrical holes of about one metre in diameter and 10 to 30 m in depth to shallow aquifers. These holes obtain water from considerably deeper sources than would ditches or tunnels. Such structures are called hand-dug wells.

The hand-dug well derives its name from the primitive methods, tools and non-sophisticated machinery that are used in well construction. Usually such local implements such as diggers, hoes, shovels/spades, and cutlasses are employed in digging the well. The digging crew comprises about three to four men but normally not less than two. The men work in shifts or work together, but only one man digging at a time. Rock cuttings, soil and dirty water are bailed or carried out of the hole using a bucket, rope and pulley system manually operated by the digging crew members on the ground surface.

The digging is terminated at a depth minimally penetrating the aquifer, because flooding and possible

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drowning are potential well construction hazards when digging at depths below the water table. The shallowness of the intersected water table causes the usual poor performance, drastic water levels declines during the dry season and potential pollution problems. However, such hand-dug wells provide considerable information on the available groundwater resource of a region and have been used in regional groundwater investigations [1, 2].

Flooding and possible drowning are potential well construction hazards when digging at depths below the water table.

The side walls of these wells are generally covered with a thin film of cement after they have been dug. Either a round wood or iron slab is used to cover the well at ground surface. The water is bailed out of the well using a bucket with a sinker-system.

The siting and successful production of hand-dug wells are controlled by the geology, stratigraphy, and geochemical history of the area (Figures 1 and 2). Such wells may be located in sandy shallow aquifers, weathered basement rocks, buried stream channels, weathered zones of fractured hard rock (sandstones, limestones, lava flows, etc.). This readily explains why hand-dug wells are found in great use over a wide area, such as in Nigeria.

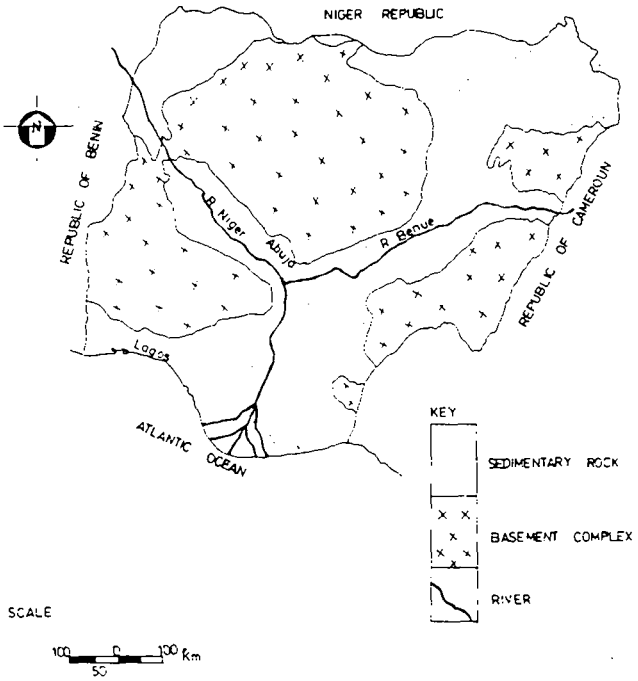

Figure 1. Geologic map of Nigeria.

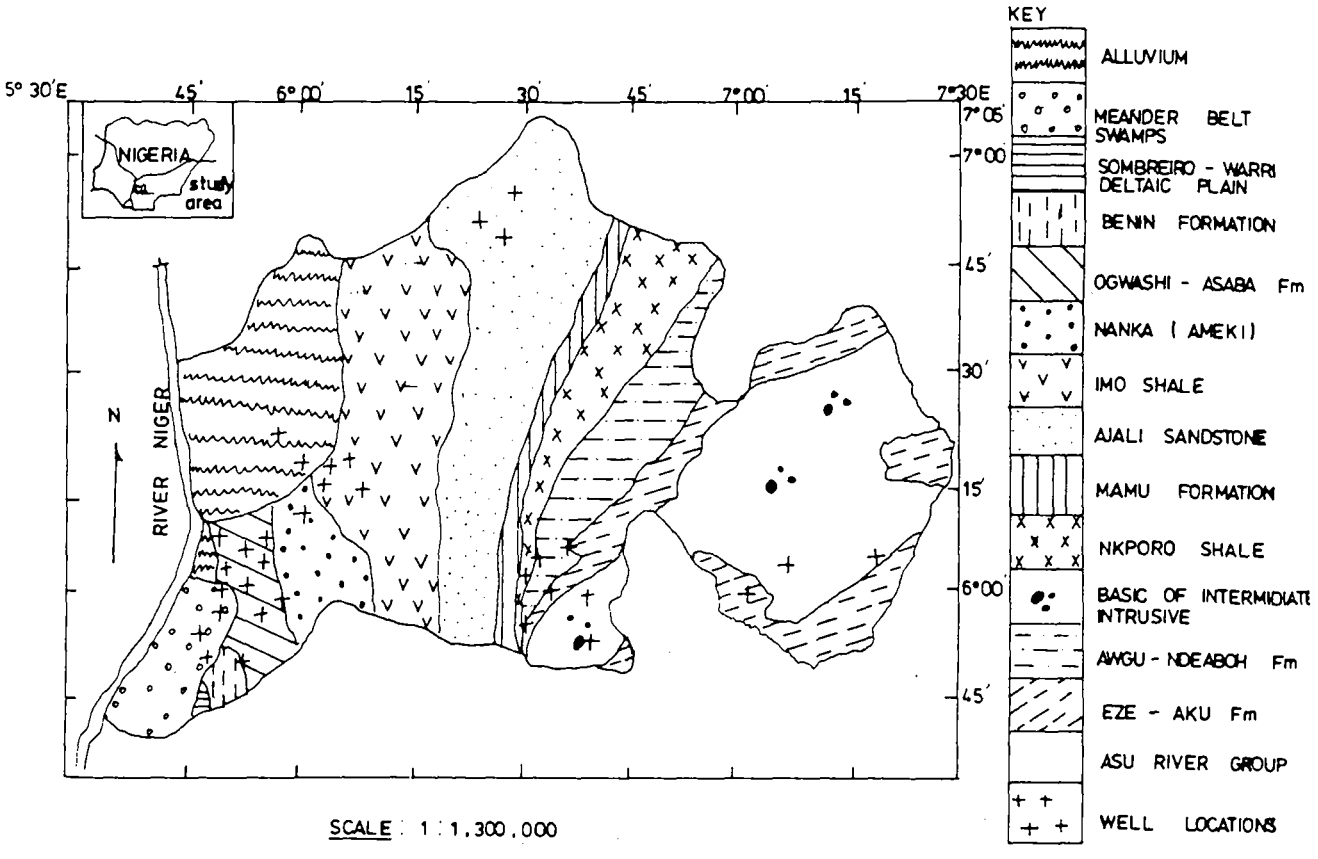

Figure 2. Geologic map and well locations in Anambra State.

Increasing demand for additional water has necessitated the search for water from more remote sources and hence deep groundwater from boreholes. In spite of the marked improvement in groundwater exploitation techniques, there are still parts of some developing economies that cannot afford the cost of the high technology that is involved in water exploration, exploitation, planning and management. Where surface water is not available for economies such as remote rural areas or sub-urban centres, hand-dug wells have provided a cheap alternative source of water.

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The use of hand-dug wells as dependable water supply sources has been looked down upon as a very poor or primitive technology and, hence, has been, unfortunately, neglected. Despite this fact, a great number of people continue to construct and own hand-dug wells no matter how crude they might be.

In this wide-scale research study, attempts are made to look into the problems of hand-dug wells and to find ways and means of improving their construction and exploitation techniques and to establish engineering designs to improve performance.

PURPOSE AND SCOPE

Hand-dug wells in Anambra State in particular and Nigeria in general provide water to the rural, sub-urban and parts of the urban communities. The source is from shallow water table aquifers at depths between 15 and 30 metres. The wells are plastered with cement. Water is bailed from the wells by a bucket-rope-pulley system. The water in these wells is susceptible to contamination and pollution.

The wells are commonly dug in sandy areas, with less found in shaley, clayey or hard rock areas. These wells serve all types of people from all levels of society. The wells cost between 5,000 to 8,000 Naira (N4 = US$1). Construction is usually completed in less than two weeks. They are either shallow (<15 m) or deep (>15 m).

The primary objective of the research was to carry out investigations into the uses and attendant problems of hand-dug wells and establish possible ways of improving and enhancing their usefulness, particularly in a devleoping economy. The scope of the project covered a survey of the historical importance of these wells, development of methods of investigation, man-made and natural factors influencing well yield, and a study of hand-dug wells in Nigeria. Engineered improved design and construction methods were explored and a comparative analysis of hand-dug wells with boreholes was done.

Unfortunately, a painstaking search through the poorly available hydrogeologic literature does not show any description or discussion of hand-dug wells or their technology, despite their apparent benefits to people of low income. The present work may be a first attempt to critically look into the usability of hand-dug wells.

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Because of the high cost involved in sinking boreholes and constructing surface water reservoirs or dams, it is hoped that under certain conditions water may be provided to the people of a developing economy by the improved method of using hand-dug wells that this research was to produce. Since the hand-dug well technology was familiar to rural communities, such modified wells and construction techniques could readily provide solutions to the acute water supply shortage being experienced in those areas. Local government authorities, town councils and unions could use this new technology on a larger scale to provide water to the scattered populations of many rural communities where large-scale surface water reservoirs or boreholes are not possible. Private individuals, governments or water resource consulting services and agencies could provide financial assistance for further investigations, test studies of designs and execution of the new hand-dug well technology.

METHODS OF INVESTIGATION

The investigations to date have lasted for two years, covering two wet/dry season sequences. Responses of water levels in hand-dug wells to seasonal changes during the dry and rainy seasons were monitored. Visits were made to dug-well and borehole sites where work was in progress.

Discussions were held with personnel of the Imo State Water Board and the Anambra State Water Corporation, the Anambra State Task Force on Water Supply, the Federal Department of Water Resources, various local government and town council authorities and private water companies in Anambra State. Interviews were also held with owners of boreholes, owners of dug wells, and with people of rural

communities.

A comparative analysis of the effectiveness, services (people served), technology, merits and demerits of hand-dug wells vis-a-vis boreholes in the groundwater industry was made. Some concrete cement block moulding industries were visited. Discussions were held with some civil, mechanical and production engineers on possible improvement designs in digging methods, construction, water withdrawal and treatment to enhance the performance and effectiveness of hand-dug wells. Efforts were also made to show the possibility of using hand-dug wells to fill in a need between large-scale surface water reservoirs and large deep boreholes, both of which are costly for small rural communities scattered in groups over larger areas.

HAND-DUG WELLS IN NIGERIA

The following describes the geologic conditions affecting the construction and yield of hand-dug wells in Nigeria. Common depths of the wells and the seasonal response to drought are discussed.

The location of hand-dug wells in Anambra State in Nigeria is controlled by the geology. The lithologic units are composed predominantly of sandstone and shale, striking roughly 5 degrees due north and dipping at 5 to 7 degrees westward (Figure 1). Rock strata east of the Abakaliki anticlinorium dip by about the same amount, eastward.

Many wells are found in the Onitsha urban area and environs, and in the areas of Idemili, Njikoa, Awka and Awgu. Anambra Local Government, Nsukka, Enugu and Abakaliki areas have fewer and deeper wells, where they occur at all (Fig. 2). Some of the wells at Nsukka terminate at 31 metres depth [3].

The formation tapped at Onitsha is the Ogwashi Formation, a sequence of sandstone, siltstone and lignite units. In the Idemili and Njikoka Local Government areas, the wells terminate at depths of between 22 and 28 metres, in the Nanka Sandstone. In the area of Awka and Awgu the wells are shallowest, 8 to 15 metres. The aquifers for the Awka wells are composed of the Nanka Sands and sandy members of the Imo shale (Ebenebe and Isiagu Sandstones). The hydraulic head in some of the wells at Awka stand (July, 1985) one metre below ground surface [2].

Where the geologic formations have thick, sandy aquifers with a deep water table or where the surficial deposits are shaly or hard rock units, wells do not exist or may be scarce. Conversely, where the sandy water-table aquifer or confined aquifer have shallow water levels nearer to ground surface, many hand-dug wells are found. These findings were noted during the course of these investigations. And, apparently, well diggers are aware, inadvertently, of the positive implications of the geology on water resources availability.

The hand-dug wells at Abakaliki and Ohaozara, where they exist, are not deep, reaching depths rarely exceeding 10 metres. The reason for this is the widespread occurrence of the Abakaliki Shale and the shaly and fractured Asu River Group, which are both poor water-yielders. Some of these wells dry up in the rainy season.

Hand-dug wells are also smaller in number, but deeper, in Nsukka, Udi and Oji-River where thick beds of Ajali Sandstone and Nanka Sands outcrop. In these aquifers the water table is very deep, ranging between 5 and 65 m during the rainy and dry seasons, respectively.

In Imo, Cross River, Bendel State and Rivers State hand-dug wells are widely used, both in rural and urban areas. Uma [1] and Iwuji [4] have described the beneficial uses of these wells. Performance of these wells compares favourably with the UNICEF Shallow Borehole Programmes in the Ohozara area of Imo State [5].

The extensive use of hand-dug wells has been reported in the capital city of Lagos and surrounding area, by Iwugo [6] and Oyegoke [7]. These wells often suffer from environmental pollution and contamination from wastewater and sewage disposal or from saltwater encroachment.

In parts of weathered zones or fractured, weathered horizons or buried channels of the Basement Complex of western and northern Nigeria, hand-dug wells are very dependable during both the dry and rainy seasons. In some parts of the north in the Sahel area, particularly during the dry season, hand-dug wells have served as the only dependable source of water as shallow streams and dams dry up. Small but scattered rural communities, nomadic Fulanis and their herds of cattle and goats get supplies from these wells. Many of these animals die, particularly during drought periods when even these shallow wells dry up.

Human suffering through disease and water scarcity in this area becomes tragic, on a periodic basis. Even though hand-dug wells have been of regional importance in terms of water supply potential in these Sahel water-scarcity areas, there have been no officially sponsored programs to encourage the useful nature of hand-dug wells. Rather, individuals, groups or some local government authorities have dug wells

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in various areas to supply community water. These wells are rarely maintained and their performance never monitored.

PROBLEMS OF HAND-DUG WELLS

Construction of hand-dug wells is hazardous work. Accidents include caving of soil materials on the person digging; breaking of the rope used to haul up the cuttings and dirty water, with injury to the individual at the bottom of the well, and workers falling into the well while climbing into or out of the well. Also, there is the danger of drowning from sudden large inflows of water during well construction.

Because of partial caving or total collapse of the side walls of the wells and possibly large water inflows, wells are not dug deep enough into the aquifers. This results in either frequent drying up of wells during the dry season or drastic declines in water level and, hence, low yields. This has caused affected well owners to periodically deepen wells during the dry season, with resulting loss of money and a slowing down of their economic activities.

Many of the wells' cemented side walls fail or collapse after a few years time due to expansion of shales or penetration of the walls by the roots of nearby trees. This, combined with the fact that water flows into the wells only from the bottom, accelerates the problems of silting, and of mud and sand filling these wells.

There are many known instances of animals, humans and other material falling into the wells. This happens particularly when the wells are communally owned, with individuals leaving the well in an uncovered state.

Another detrimental feature of hand-dug wells is their susceptibility to contamination and pollution. The methods of construction, development and maintenance of the wells are potential sources of contamination/pollution. The well water is very muddy upon completion of the well. There are no arrangements for proper well development.

The human and animal traffic around the wells, their shallow nature, the method and equipment used for water withdrawal, and the non-treatment of the withdrawn water are additional factors contributing to the contamination/pollution of the majority of hand-dug wells.

Decayed wood and rusted iron covers are also sources of contamination and pollution. Most of these dilapidated well covers leak dirty rain water from their tops and sides into the wells.

Despite these problems, there is a good opportunity for the improvement of the water quality and quantity of hand-dug wells to make them more acceptable and better for use by both rural and urban communities. Improvements in construction methods, development, maintenance and pumpage would greatly reduce potential pollution and contamination threats, thereby increasing the performance, usefulness and life of these wells.

ENGINEERED IMPROVEMENT METHODS FOR HAND-DUG WELLS

Engineered methods of construction and controlling pollution problems are the major handicaps in the hand-dug well industry. An attempt is made to suggest possible improvements in performance and effectiveness.

Hand-dug wells should be constructed during the dry season when the water table is at its greatest depth below ground surface. Digging becomes near impossible during the rainy season as there is often a rapid rise in water level and large inflow into the wells. Thus, digging is safer during the dry season, and deeper wells can be dug.

Hand-dug wells should be constructed during the dry season when the water table is at its greatest depth.

To enhance safe construction to greater depths into the aquifer and to effect proper well development after the digging and construction of hand-dug wells, the groundwater should be continuously pumped out of the well while digging is in progress. This reduces possible large water inflows and caving of the sidewalls. Small electric or hand pumps can be used for pumping. This technique was successfully employed at a well at Ajaefo-Okwuosa Hospital and Maternity, Ogidi, and at Tracy's Hotel, Awka, both in Anambra State.

Two types of concrete rings have been designed for supporting the sidewalls of the well. The ring design for the water-bearing or aquifer portion of the well is shown in Figure 3. The windows or apertures or screen-slots are precast perforations to screen the aquifer material and allow additional seepage flow from the side walls of the wells. These "windows" would cover about one-third of the surface area of the concrete ring. The design materials shown in Figure 3 should consist of a skeletal iron framework cast or firmly coated with concrete into the ring finishings. Research is planned to test the durability and longevity of these materials and design.

The design for the non-screened portions of the wells is shown in Figure 4.

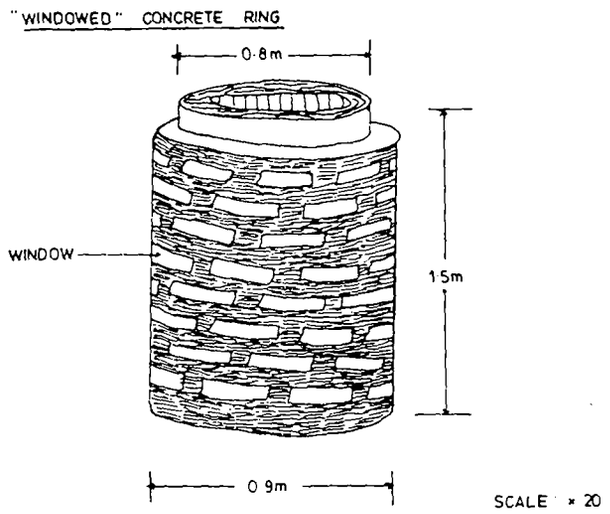

Figure 3. "Windowed" concrete ring for lining well.

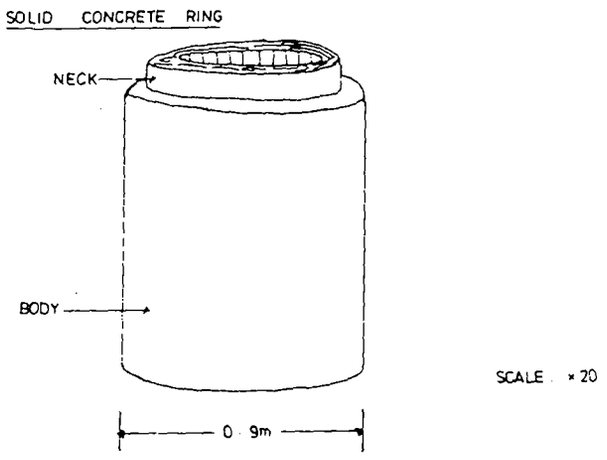

Figure 4. Solid concrete ring for lining well.

The well is further improved upon by gravel-packing between the concrete rings and the side walls of the well. For gravel pack size selection, the diameter of the gravel must be larger than the slot sizes of the windows in the concrete rings. The top part of the casing-rings are grouted with cement to the side walls of the well. Each concrete ring has a neck and a groove, respectively, at opposite ends. These are for proper anchorage with overlying concrete rings. A cemented platform structure at ground surface encircles the opening of the well to a radius of about 3 metres. The complete design is shown in Figure 5.

The problematic, old-fashioned bucket-rope-pulley system is then replaced with an electric or hand-pump device. A small horsepower pump is used to pump the well water through an external sediment filter into an overhead storage/treatment tank.

The design for the filter is also shown in Figure 5. The filter is shown as cylindrical in shape. Filters of other shapes can be used; there should be enough capacity for filtration between the entrance point and the exit point. The filter brush or pad, which should touch the walls of the filter casing or holder is placed at the exit end. The filter can be of any non-contaminating

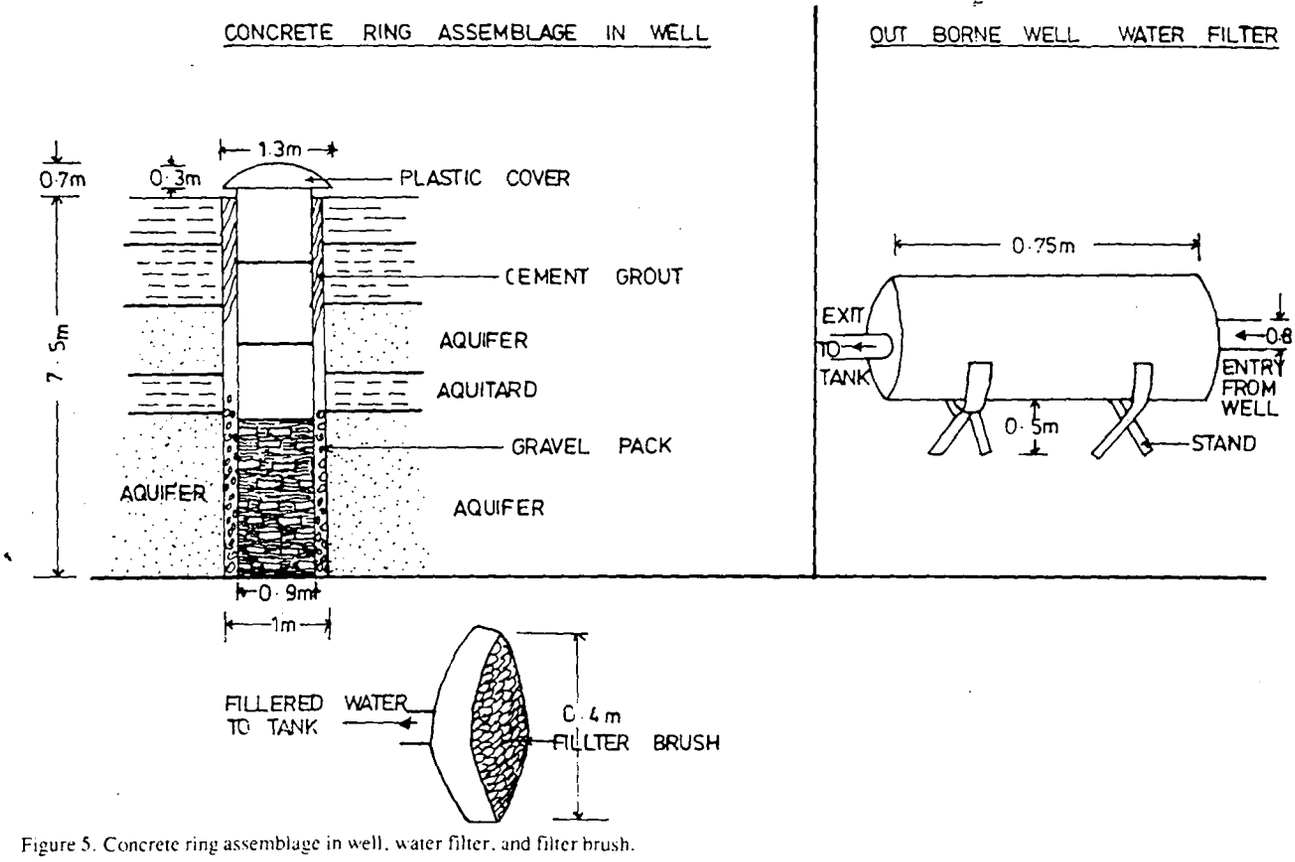

Figure 5. Concrete ring assemblage in well, water filter, and filter brush.

material. The filter holder can be moulded from plastic or welded into shape from sheet aluminum. The actual filter should be removable for servicing as needed.

After treatment, water can be fed from the overhead tank to pipes for distribution to utilities. In this manner the water arrives at the point of filling containers without contact. The screened portion and well bottom provide enough yield; the well is reinforced and stronger, and contamination is prevented or minimized, while water quality is greatly improved. All of these factors greatly enhance the performance of the well (Figure 6).

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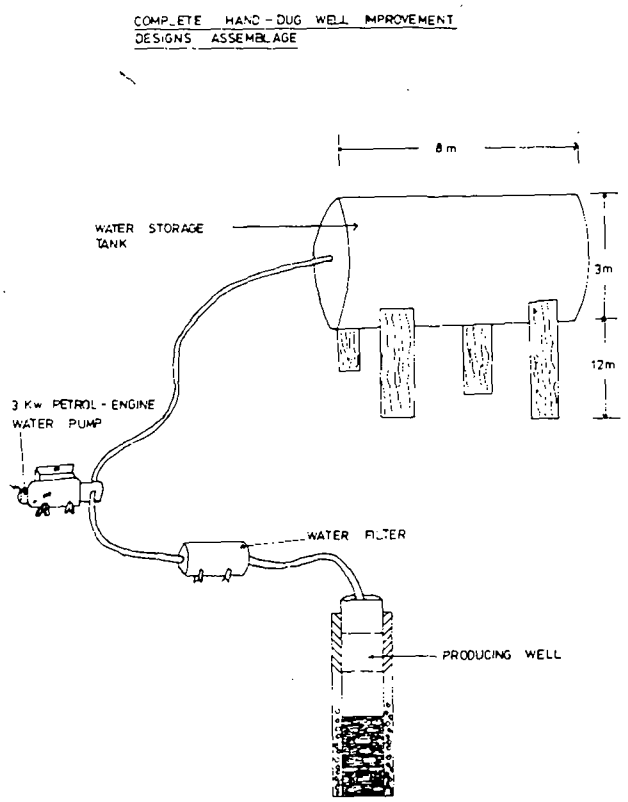

Figure 6. Complete assemblage for hand-dug well of improved design.

DISCUSSION, COMPARATIVE ANALYSIS AND SUGGESTIONS

During this investigation it was noted that about 70 percent of the people of Anambra State make use of surface waters. This percentage includes people who live in urban and suburban towns but whose water taps are dry all year. These taps are either damaged or are not supplied with water at all. Consequently, these people buy their water from water-carrying tankers that fetch water of questionable quality from streams, rivers, lakes, etc. Only about 2 percent of the populace actually benefit from pipe-borne water from boreholes and water treatment plants. As much as about 28 percent of the population make use of hand-dug wells for domestic supplies, small-scale industries and irrigation purposes. Similar statistics are known to exist in the other states of Nigeria.

Another point of interest is the distribution of the ownership of and use of hand-dug wells. These wells are owned by a representative cross-section of the society, the rich and the poor, the learned and the illiterate, individuals and groups/communities, and homes and industries.

Detailed interviews were held, especially with the wealthy and/or learned ones who own hand-dug wells for their water supplies. The most recurrent reasons given by these individuals in defence of their hand-dug well ownership are two-fold: the excessive and prohibitive costs of sinking boreholes and the cheap construction costs, reliability and easy maintenance of hand-dug wells. A medical officer who owns a producing hand-dug well for water supply to his private hospital claimed that, from his own experience, borehole drilling is a waste of time and money or mere gamble. He preferred two more hand-dug wells for his hospital, if need be, to sinking a borehole. He reported of a large hospital in Onitsha that gets its regular water supply from two hand-dug wells. Many learned individuals share his view, unfortunately.

The above claims necessitated the inquiry into why some boreholes are unreliable or have failed. Drilling companies in Anambra and Imo States were visited. Drilling crews were interviewed at drilling sites. It was found that some boreholes have failed for either or both of the following reasons. Many of the boreholes were wrongly located at politically favourable but hydrogeologically barren localities. Politicians gave boreholes to communities freely, without expert advice. These boreholes tended to fail outright.

The remaining boreholes that failed were those of drilling companies that have no qualified field personnel, hydrogeologist or water experts in their employ. In most of these cases, the lithologic logging was not accurately performed. Borehole sites were located through "hocus-pocus", wildcatting or a water-witching approach. Erroneously, aquitards instead of aquifers were sometimes screened. Consequently, the pump stopped soon after well development had started. Although there are some very good producing boreholes in Anambra and Imo States, the cases of borehole failure are many and varied. The failure rate of boreholes is more than 60 percent in Nigeria.

A price analysis of hand-dug wells as compared to

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boreholes was carried out. On the average, a 4-inch diameter borehole to a depth of between 200 and 250 metres would cost between N48,000 to N50,000 (N4 = US$1). Hand-dug wells to depths ranging from 22 to 30 metres would cost about N4,000, an amount readily available to a group of people, a small community, wealthy individuals and small-scale industries for a water supply.

In the face of global economic recession and because of the peculiar financial problems of an underdeveloped or developing economy, the improved hand-dug wells can serve as a reasonable alternative to surface water reservoirs and groundwater boreholes. The improved hand-dug wells can even serve small groups such as schools and hospitals in both rural and urban communities.

At present, hand-dug wells are constructed using primitive technologies. Improved performance and better yield of potable water could be obtained if private entrepreneurs, individuals, governments and international aid agencies would provide funding for more research into hand-dug well engineering and technology.

A well executed hand-dug well programme scattered through rural communities on a regional basis could serve to provide relief to the water-hungry and poor in developing economies. The technology is already in place, working, part of the culture and is well accepted by people who need them. It only needs improvement and, probably, some modernisation.

The UNICEF shallow borehole schemes in the Ohaozara areas of Imo State are a great success story [5]. Improved hand-dug wells already supported by local culture could be more beneficial and greatly accepted by the people. The local, state and federal governments in Nigeria and other developing economies with similar potable water supply problems can exploit in an organized way groundwater sources through hand-dug wells to save their people from acute water shortages, hunger and water-borne diseases.

SUMMARY

Hand-dug wells have been found to be one of the main water supply sources for rural communities and sub-urban centres. The technology for their construction is crude and disorganized, but cheap. The wells are acceptable to the people and the pattern of water supply is rooted to the people's cultural background, hence their popularity. The usefulness of these wells has not been recognized by any of the local or federal governments.

Though engineering and pollution/contamination problems hamper the usefulness and life of hand-dug wells, means and designs for tackling these problems successfully have been suggested here. The role played by area geology has also been outlined.

It is believed that if funds are available for conclusive research into the technology of hand-dug wells, it would be possible to prolong their lives, protect them from environmental pollution and contamination, and give good, continuous yields. Governments of developing economies and international aid agencies should carry out a coordinated programme on the use of hand-dug wells in a regional manner as veritable water supply sources, encouraging development, monitoring and maintenance.

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REFERENCES

1 Uma, K.O., 1978. The Water Resources of Owerri Area and the Environs. Unpublished M.Sc. Thesis, University of Nigeria, Nsukka, 89 p.

2 Okpoko, E.I., 1986. Water Resources of Awka Area and the Environs. Unpublished M.Sc. Thesis, Department of Geological Sciences, Anambra State University of Technology, Enugu, Nigeria, 117 p.

3 Egboka, B.E.C., 1983. The Groundwater Resources of Nsukka Area and the Environs, Anambra State, Nigeria. Nig. J. Min. Geol., Vol. 20, Nos. 1 & 2, pp. 1-16.

4 Iwuji, W., 1986. Water Resources of Aba Area and the Environs. Unpublished M.Sc. Thesis, Department of Geological Sciences, Anambra State University of Technology, Nigeria, 85 p.

5 Egboka, B.C.E., and K.O. Uma, 1986. Hydrogeochemistry, Contaminant Transport and Tectonic Effects in the Uburu-Okposi Salt Lake Area of Imo State, Nigeria. Hydrol. Sciences J., Vol. 31, No. 2, pp. 205-221.

6 Iwugo, K.O., 1986. Groundwater Quality, Treatment and Pollution in Nigeria - The Lagos Metropolis Case Study in "Groundwater Resources in Nigeria", Proceedings of NIWASA Symposium, pp. 258-285.

7 Oyegoke, E.S., 1986. The Hydrogeology of Lagos Metropolis, in "Groundwater Resources in Nigeria", Proceedings of NIWASA Symposium, pp. 68-80.