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Introduction

AMREF has assisted a self help water project in Kibwezi Division, Eastern Province, Kenya since 1983. The project operates on a small scale and on average has assisted ten self help groups a year to construct shallow wells. The overall objective of the project has been to transfer the technology for construction, operation and maintenance to the local people, an objective which is now being achieved. By March 1990 over 70 groups have been assisted and, as a result of this experience and the collaboration of local people in well design, an almost standard design has been reached. This design is now being copied by local artisans independently of the project—an indication of its appropriateness to the local conditions. The purpose of this paper is to explain in simple terms the well construction technique being adopted by the project in Kibwezi.

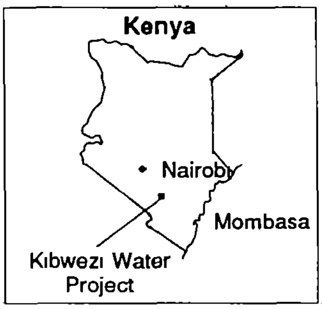

Fig. 1 Location of project

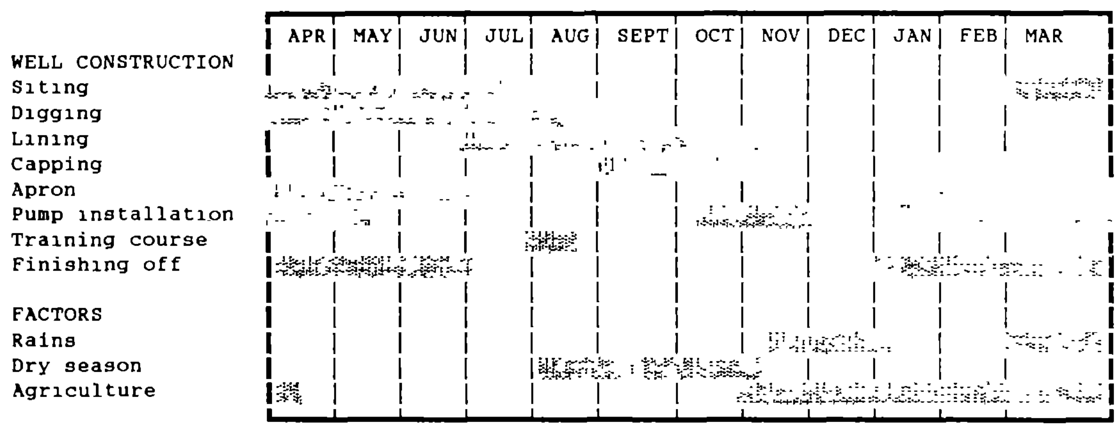

Fig. 2 Well construction calendar

Siting a well

Settlement in Kibwezi Division is a recent event, the major influx of people occurred in the 1970s. Well construction is still a new technology in the area. The first wells assisted by this project were mainly at sites—a total of five—where people had successfully dug for water themselves. Further sites were identified from a technical point of view based upon local topography and seasonal river courses. Limited geological information for the area was also available. The geophysical methods available in the country at that time had been tried in the area with little success. Therefore attention was paid to natural signs to identify suitable well sites which would in the long term constitute a community-based method without reliance upon external input. At present, using topography, surface geology, and local vegetation, a success rate above 70% is being achieved by the local people (1). However, some 14% of the wells have high salinities (above 2500 µS) and a detailed investigation is now being carried out to try to identify and map possible saline aquifers. With the recent advancement in electromagnetic geophysical techniques, these new methods may prove successful in the area. Local ground water is located in a discontinuous gneiss aquifer. Although the gneiss band is some 60 km long and some 6 km wide, its local characteristics are highly variable. In general, at a good site there is an overburden of some 4 m of laterite soil, below which there may be a thin layer of calcrete followed by gneiss. The gneiss has been found to be still productive at a depth of 26 m; however, the average well depth is 9.4 m. The gneiss varies in its quality as an aquifer but generally it is poor.

Well digging

The wells are all hand dug. With only one exception the wells were dug first and lined later. The exception was a well caissoned into sand in a river bed. Due to the poor quality of the aquifer and its low productivity, a large storage capacity is required below ground. This, together with poor soil stability in the rainy season, led people to make enormous excavations of 100 m^3 or more to reach water at 9 m. The practice was soon modified by starting to dig at the end of the rains and, even though food is scarce as the dry season continues, people put in considerable effort to dig as deep as possible. Once the well is yielding, work on lining can begin so that the lining is above ground before the rains come. By using this technique the local people soon began to dig much smaller holes when exploring for water, and as soon as water is found the upper section of the hole can be widened to enable the lining to be built. If time allows in the dry season, the lower section can be deepened and widened below the rest water level to create more storage. Now the average diameter for the exploratory shaft for a well is 1.5 m. The technique was successful when the well was lined before the rains because there was an enormous reduction in the amount of work required.

No hard and fast rules have ever been applied to the construction techniques for the project since ultimately, what the people like will succeed. Thus, early in the project—some groups dug square wells, probably because they were more familiar with the shape—and some square wells were completed. However, as more groups became involved, and as more masons were trained, the people themselves asked the project staff to promote only round wells. This was because they found that round wells use less lining materials, hence they cost less and are much quicker to build. There is also the other technical advantage that a round lining is better suited to resist the compression forces from the over burden.

Safety in digging is taken seriously although it is often difficult to ensure that advice is followed. Even so, protective hats and good ropes are always given to groups. Advice is given on safety procedures and a brief resumé on the subject is provided (2).

Digging is done using 4-lb and 10-lb sledge hammers with cold chisels. Good chisels are essential but very difficult to obtain. In some cases crow bars and pick axes can be used in soft gneiss. Spoil is raised from the well by rope and a metal bucket and is dumped on the uphill side of the well to prevent any rain wash entering. Tripods and pulleys have been used to raise spoil but were abandoned as people were not particularly happy using them and pulleys were expensive. From a safety point of view only 11-litre buckets are used to raise spoil.

Dewatering is carried out manually, which is possible if the group is large and active, but often, however, assistance is given by the loan of a modified hand pump or a centrifugal petrol pump. In fact, the centrifugal pump is used during early construction stages to keep water levels below the level of fresh concrete and motar. It is also useful when cleaning prior to capping. This practice also serves partly to develop the well.

At some sites the overburden is black cotton soil. In the dry season it generally remains stable once dug and a vertical face of 3 to 4 m will remain stable for over 12 weeks. However, if this face is exposed to water it becomes treacherous and this situation is avoided as far as possible. In the rare case of a face still being exposed in the wet season, wooden forms are used to support the face whilst the well lining is completed.

Efficiently organized groups generally complete digging in three months of part time work.

Well lining

A variety of materials have been tried out to line wells including concrete well rings, lava rock and local burnt brick. Well rings were not liked by the people as the internal diameter of the rings is limited and in a well lined only with rings it is very difficult to deepen or widen the well. Lava rock is a good building material but requires a great deal of cement in building and plastering (37% mortar by volume in building alone) and is not always locally available. The preferred choice of construction material is therefore local burnt brick. The bricks are 4" x 6" x 12" (10 x 15 x 30 cm) and are of varying quality, thus care has to be taken in selection. The bricks are commonly available but much work could be done to improve their quality.

The lining is built on top of the gneiss on a concrete foundation. A level surface of gneiss has to be prepared 2.5 bricks wide. In some cases it is easier to build up with brick to the level of a particularly hard rock rather than attempt to remove the rock. Once the level is caught a ring beam can be cast. In exposing a sufficient area of gneiss it may be necessary to dress back the wall of overburden. Once a suitable flat surface is prepared, a circular ring beam of 1:2:4 concrete 10 cm thick, 1.5 bricks wide and containing two hoops of 8-mm round iron bar is cast and cured *in situ*.

Fig. 3 A header bonded well

In cases where the quality of brick is good and the overburden stable, bricks are laid in stretcher bond, but in difficult cases, header bond is used. The first courses of brick are laid with 6-mm round iron bar hoops every five courses. The initial diameter of the lining at this point varies greatly from well to well and is almost impossible to standardize. However, as diggers are get-

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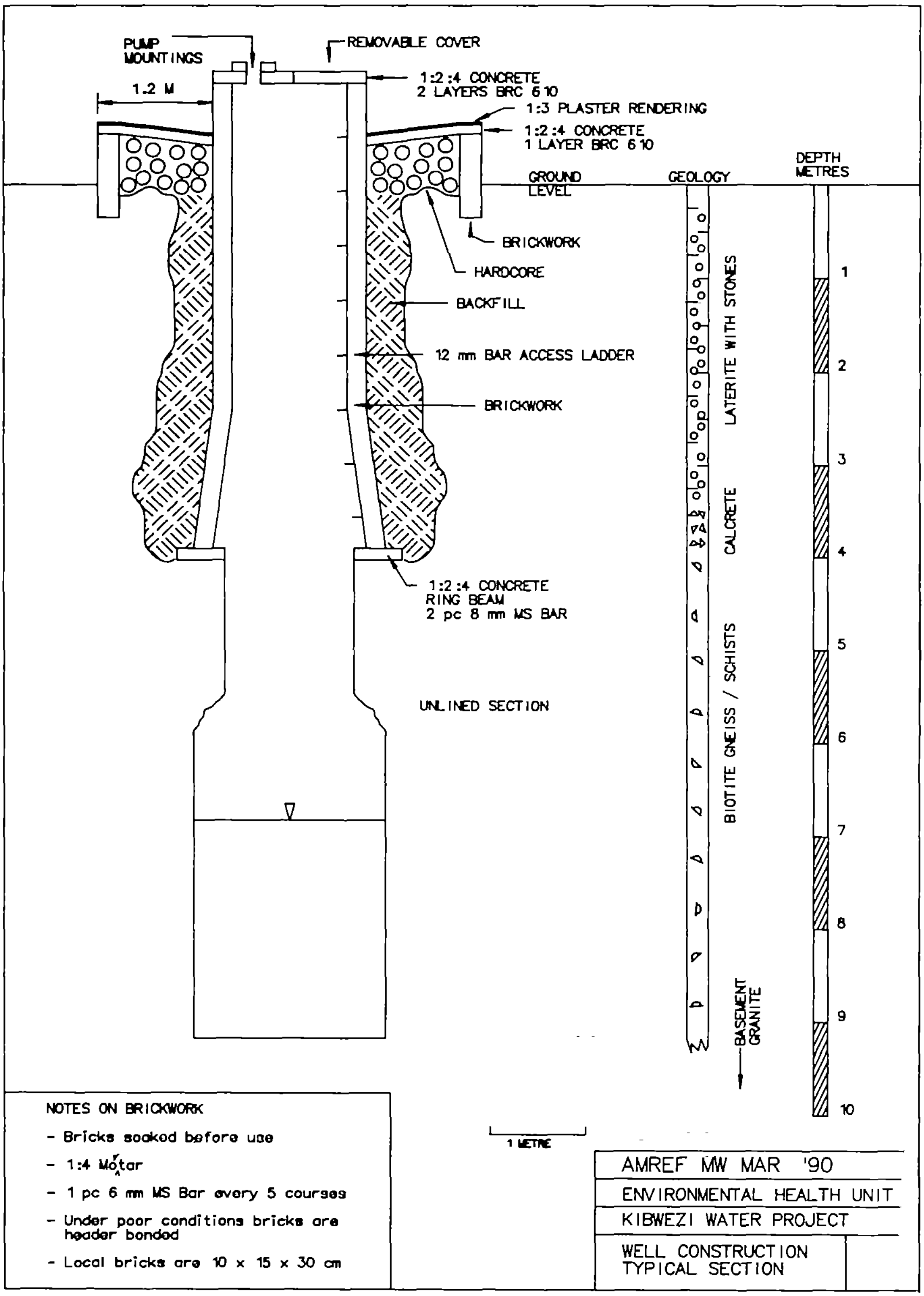

Fig. 4 Drawing showing section through a typical well in Kibwezi

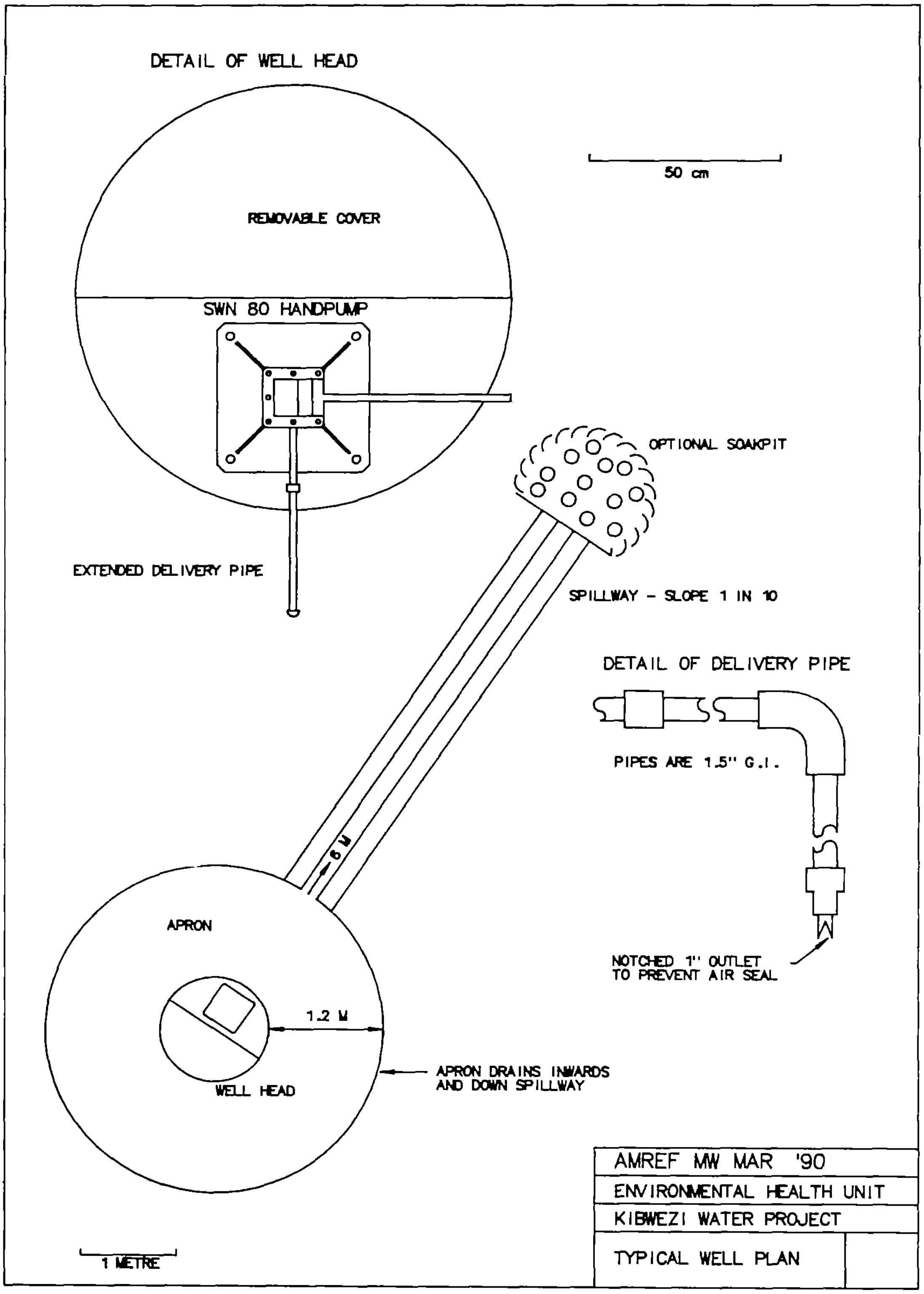

Fig. 5 Drawing showing typical plan of well in Kibwezi

ting more experienced the diameters are now, with few exceptions, less than 2 m. In an attempt to reduce the time and cost to build the lining, local masons were shown how to corbel the brickwork in until the internal diameter is reduced to 1.2 m. If done gradually it presents no problems in stability or when climbing into the well and is accepted by the well groups. Ladder rungs are bent from lengths of 12-mm twisted square iron bar and are cemented between brick courses at suitable spacings. The lining is extended at least 1.3 m above ground level to ensure an adequate final level above the reinstated spoil. On average, local masons are using 3.7 litres of 1:4 mortar to cement each brick in place, which is high due to the poor shape of the bricks. A number of methods have developed to assist the work at this stage. Strong poles are placed across the well and building continues above them. The poles are used to stand on like scaffolds (putlogs). When the poles are later removed the holes in the wall are filled with concrete. Some groups have built wooden cradles which can be raised and lowered inside the well. Some methods have been used to check the centring of the brick work, include using a full length of water pipe to mark the centre and to fix a wire to it to check radii. Also, circle forms cut from wood and board have been used, but in general a good mason with plumb line, tape and spirit level is able to do the job satisfactorily.

The inside of the lining is plastered to a depth of at least 3 m below ground level.

Once sections of the lining become firm, backfilling behind the lining can go ahead. There are no suitable local clays for this job and usually spoil is used. As the backfill takes a long time to consolidate, care should be taken to place it carefully and to tamp it down evenly, backfilling only a small amount at a time.

Usually by the time this stage is reached the rains are near and groups are eager to return to their agricultural work. Where possible, well covers are cast and pumps fitted at this time so that groups can get the benefit from their work immediately. During the peak of the rainy season (December) project staff take leave and local people are busy weeding their fields. The backfill usually requires a period of 2 to 3 months to consolidate before an apron can be built on it. Consolidation usually occurs during the rainy season when the ground is wet.

Capping the well

Well covers are cast in excavated moulds, they are 10 cm thick 1:2:4 concrete with a double layer of BRC 610 reinforcing mesh inside. After trying several designs, people said that they prefer not to have manhole covers on the well head but would rather have a cover which splits in half enabling a whole half to be removed. The reasons for this are that it would take a group decision to remove a well cover, that manholes are difficult to manoeuvre in and out of, and that removing half the cover lets in more light when deepening the well.

Therefore the covers are made as two halves. At the junction they are rebated to allow a weak, removable plaster seal to key. One half cover carries the anchor bolts for the pump and a plinth 5 cm high is cast as part of the slab upon which the pump base-plate will sit. Keeping the pump base above the slab level is one way of preventing spilled water from getting sucked back into the well. The former used to make the hole for the pump string is usually a suitable tin can or a piece of PVC pipe. The anchor bolts for the pump are welded into a frame to ensure correct alignment in casting.

The apron

The apron around a well is often overlooked as a minor detail whereas, in fact, it is the place where all users stand when drawing water; it therefore has a very significant sanitary function. An apron should provide a stable surface upon which to stand when drawing water, it should be designed to remain clean with a minimum of attention and it can also act as a physical barrier to prevent flood water from damaging or entering the well.

Several designs have been tried out in Kibwezi and the final version is still evolving. At present, an apron of width 1.2 m (outside the well lining) is built by building a brick wall around the well and backfilling with rock and spoil. The wall is usually 50 cm high. Once backfilled, a slab of concrete, reinforced with one layer of BRC 610, is poured on top to the approximate slope required. In the present design, drainage is directed in towards the well lining and down towards a spillway. This method of draining water towards the well does not require a perimeter wall to be built around the apron to catch spill, but it does mean that the seal between the apron and lining has to be good or else spill water could penetrate the lining. The apron is then plastered, taking care to catch the correct levels for drainage. The apron is not given a cement nil coating as such a surface would be slippery when wet.

The spillway is built in a similar way on a rubble foundation from brick. Siting the line for the spillway is done with care to ensure that it will not be damaged by any stream flows and that the ground beyond the spillway continues to slope away, otherwise spilt water could form a pond. Where possible the spillway should be 6 m long with a slope of 1 in 10. It should be wide enough to be swept clean and should be plastered. In cases where the spill water is not directed away for another purpose a soak pit is dug at the end and filled with rock.

The size of these aprons may seem extravagant but in use they appear to remain clean, even when not well maintained, and they keep the area around the well stable. The visual impression is good. People appreciate this and come to expect cleanliness around their wells.

Some serious problems with cracking of aprons have been observed and corrective actions have been taken. These have included reducing the width from 1.5 to 1.2 m and introducing reinforcement into the slab. However, the main cause of major cracking is when the apron is built on an unconsolidated backfill. Thus adequate time of at least two months through a rainy season must be allowed before building. Minor cracks can result from poor plaster mixes or poor curing, both of which can be easily corrected by adequate supervision.

Pump installation

The pumps used in this project are Dutch SWN 80s, now made in Kenya. Three-inch cylinders are used as standard. The most important consideration taken in installation is to ensure a watertight seal between the base-plate and the concrete plinth. At present this is achieved using bitumen applied with a building trowel. One drawback with this method is that subsequent pump removal after the bitumen has dried out can be difficult. In future it is hoped to cut mats from rubber sheet to form the seal.

Finishing off

The well is chlorinated when the pump is installed. Due to the difficulties of on-site determination of the amount of chlorine required, a trial and error method is used. Chloride of lime is made into solution in a bucket and poured into the well. The well is pumped. If chlorine cannot be smelt in the outflow, more solution is added. This method also ensures that the pump is chlorinated. Once a discernible level of chlorine is reached the well is left for 6 hours and then pumped to remove any excess. When a suitable chlorine level is reached the remaining cover is put in place and sealed with a weak plaster, thus sealing off the well head.

Fences from living local trees are usually built around the well during construction to prevent accidents. After completion, these fences are reinforced with barbed wire to protect the trees whilst they establish themselves.

Advice is given to encourage paths to the well to be aligned in such a way that they will not direct storm water to the well in future.

A guarantee is issued on the work for one year after the date of pump installation. This practice enables groups to begin a savings fund for future repairs and, during that year, two members from each group attend a training course to learn how to maintain their well.

Comments

The techniques used have been developed specifically in Kibwezi and should be used with caution in other areas. The techniques appear to have been accepted by the local people. In a recent survey (3) of bacterial contamination, 20% of wells were found to contain more than ten faecal coliforms per 100 ml of water. Possible reasons for each specific well were visible, for example, an unsealed well cover, but, by comparison with other wells, this rate of occurrence is quite low.

The author welcomes comments and questions on this article.

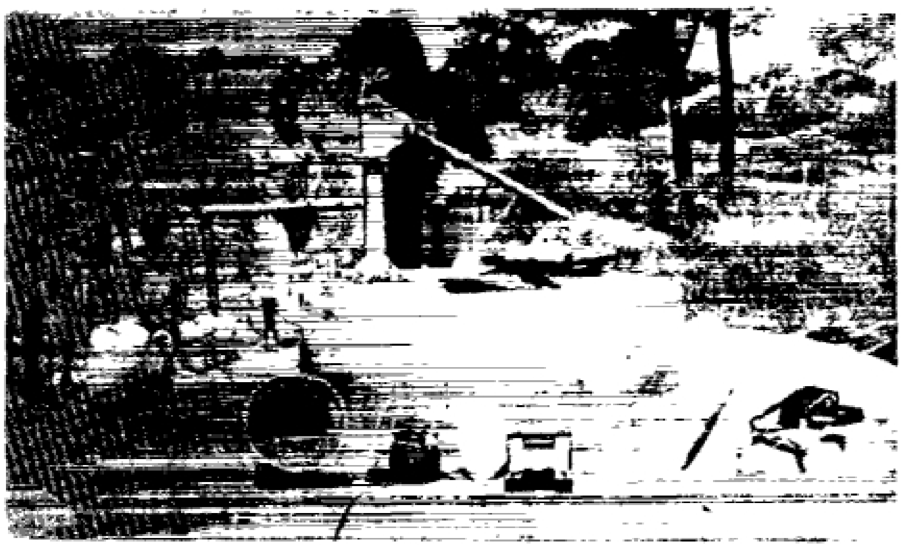

Fig. 6 A completed well being chlorinated

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(1) Woodhouse, M. 1990. Natural Signs of Groundwater in Kibwezi Division Kenya. AMREF in press.

(2) Woodhouse, M. 1988. Safety in Well Construction. *RNC Bulletin* No 4. AMREF

(3) Woodhouse, M. 1990. Consumer Involvement in Bacteriological Testing of Well Water in Kibwezi. *Waterlines* in press.

Glossary of terms

Caissoning Sinking a well by digging inside the lining. The lining sinks as digging continues and the lining is extended at the top.

Calcrete Gravels which have been naturally cemented together by calcium carbonate.

Corbel Laying bricks not directly on top of each other to widen a wall or to reduce the diameter of a circular wall.

Gneiss A general name for banded metamorphic rocks.

Putlog A horizontal scaffold to support boards used to stand on when building.

BILL OF QUANTITIES FOR A 9.5 M WELL IN KIBWEZI (JULY 1989)

ITEM	UNIT	UNIT COST KSHs	NO.	TOTAL COST KSHs	US $ (1US$=20K
TOOLS					
bucket	pc	80	3	240	12
hammer 4lb	pc	150	1	150	7.5
hammer 8lb	pc	210	1	210	10.5
hard hat	pc	70	2	140	7
pick axe	pc	95	1	95	4.75
rope 16 mm	M	7	15	105	5.25
shovel	pc	60	2	120	6
stone chisel	pc	110	3	330	16.5
CONSTRUCTION					
brc 610 mesh	m2	15	20	300	15
cement	bag	98	30	2940	147
round bar 12 mm	m	20	12	240	12
round bar 6 mm	pc	80	8	640	32
ENGINEERING					
barbed wire	roll	380	1	380	19
bitumen	kg	30	1	30	1.5
chain 3/16"	m	30	2.5	75	3.75
miscellaneous	*	*	*	500	25
padlock	pc	45	1	45	2.25
pipe fittings	*	*	*	100	5
pipe gi 1.5"	m	10	2	20	1
ptfe tape	roll	12	1	12	0.6
PUMP					
swn 80 complete	pc	*	1	12000	600
pump spanners	pc	*	2	250	12.5
pump tools	pc		2	120	6
SERVICES					
chlorination				120	6
training course	people		2	3000	150
guarantee				1500	75
TOTAL				23662	1183.1

Fig. 7 Bill of quantities

AMREF's Environmental Health Unit houses the East African Regional Network Centre for Water and Sanitation, which forms part of the International Training Network.

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