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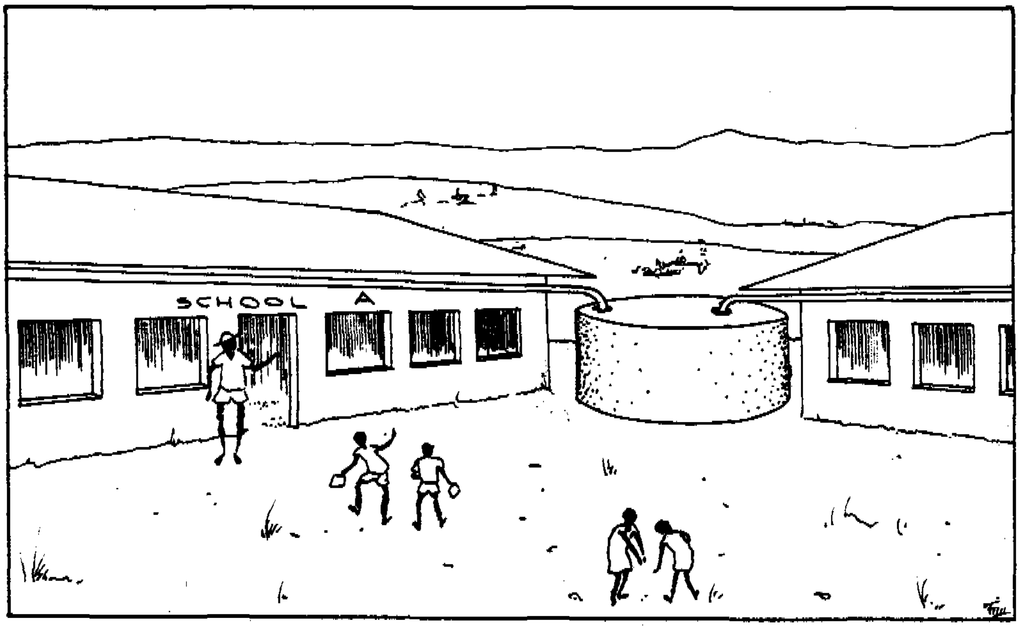
Water Harvesting in Five African Countries



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Water Harvesting in Five African Countries

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Preface

This report for UNICEF, reviews the current status of water harvesting in five African countries: Botswana, Kenya, Mali, Tanzania and Togo. It focuses on appropriate technologies, socio-economic aspects, project methodologies and prospects for the 1990s. The purpose of the review is to support the wider application of water harvesting by presenting experiences from the five countries.

If runoff water was to be collected efficiently, millions of women in developing countries would be saved the burden of trekking to far away water sources and many communities would have a better water supply. Even in the arid regions of Africa, there is often sufficient water available to supply drinking and agricultural needs through the dry season if only rainfall and runoff are captured and stored for later use. Runoff collected from rooftops in a storage tank can provide a very good source of water for a family. On a larger scale, enough water may be captured for a whole community by building a dam to catch runoff from a rock outcrop. Runoff farming complements this harvesting of drinking water, boosting crop yields by catching runoff on fields, improving direct infiltration, and preventing soil loss.

Experience with water harvesting has a long history but most ancient systems have fallen into disuse. In recent years, the techniques have regained interest and several organizations are now looking at their potential applications. Significant attention has been addressed to rooftop catchment harvesting experiences in the Far East. Much less attention has been paid to, and much less information is available on water harvesting techniques in Africa. Information on the use of surface catchment harvesting is largely neglected. To redress this imbalance the review focuses on the technical, social, economic and organizational aspects of water harvesting in the five African countries. An overview of the situation for the five African countries is given in Part I of this report, followed by the five individual country reviews in Part II. Particular emphasis is given to the socio-economic aspects because it is becoming very clear that water harvesting programmes can only be successful if these are sufficiently taken into account.

This report has been written by Dr. Michael Lee and Mr. Jan Teun Visscher of IRC. Additional inputs were made by Dr. Joseph Christmas of UNICEF. It is based on a review of available literature by Dr. Lee and particularly on field reports resulting from fieldwork carried out in Kenya, Tanzania and Botswana by Dr. Lee, in Togo by Mr. Peter de Vries and in Mali by Ms. Evelyn Kamminga. Financial support was provided by UNICEF and valuable field assistance and information was received from UNICEF offices, private individuals and government officials in each country. Mr. Jo Smet and Ms. Christine van Wijk of IRC commented on the draft manuscript and the sketches were drawn by Ing. A. Figee. The authors are grateful to Ms. Lauren Wolvers of IRC for desk-top publishing this manuscript and to other IRC staff who contributed to its finalization.

Summary

Individual communities have long practiced water harvesting on a small scale as a traditional method to improve the availability of water. Over the last ten years, increased attention has been directed towards water harvesting systems as a possible supplement or alternative to piped and pumped water schemes in developing countries. Yet its potential has only marginally been utilized.

Information supporting the development of water harvesting systems has largely focused on the technology of rooftop catchment harvesting in the Far East. Much less information is available on the range of rooftop and surface catchment harvesting, and runoff farming systems practiced in Africa. This review carried out for UNICEF, therefore, focuses on experiences with water harvesting in five African countries: Botswana, Kenya, Mali, Tanzania and Togo. It includes technical and organizational as well as socio-economic aspects, since water harvesting requires a relatively high degree of community involvement.

The different water harvesting technologies used

All three main types of water harvesting systems: the rooftop catchment, the surface catchment and the runoff farming system are being applied in the five countries.

Rooftop catchment systems

Rooftop catchment systems consist of a rooftop catchment area, usually of iron-sheet but occasionally of thatch, connected by gutters and downpipes to one or more storage containers ranging from simple pots to large ferrocement tanks.

Surface catchment systems

Surface catchment harvesting systems consist of four main types: rock catchments; earth dams and excavated reservoirs; which harvest water running off the catchment during rainstorms; and sub-surface dams which capture water flowing through the ground in the sandy beds of river channels. In each, water is collected and stored at strategic locations before it can rush away as floodwater or seep away out of reach into the ground.

Runoff farming systems

Runoff farming involves the management of surface runoff to increase direct infiltration into fields, promoting crop growth and boosting yields in otherwise unfavourable soil moisture conditions. The main systems encountered were micro-catchments and variously-sized check barriers combined with contour ploughing. Larger external-catchment diversion systems in which runoff water is collected on barren areas and transported to adjacent farmland were seldom found.

The impacts of water harvesting systems

Water harvesting has three clear impacts: it preserves water during times when it is plentiful for use when it is scarce, or when normal supply is interrupted; it provides a more convenient distribution of water closer to population centres or individual households; and it provides higher quality water than would traditionally be available from unimproved sources.

Time-saving benefits

The development of additional or improved water harvesting sources for drinking, livestock and household needs improves the ease of access to water. This is particularly important to women who are relieved from some of their daily burden of water collection. Time saved is often used in agriculture, particularly at ploughing and planting time. This, coupled with the use of runoff farming, can lead to a better and more secure annual harvest. More time is also spent on child care.

Improvements in water quality

Water harvesting usually provides water of high acceptability to users both in terms of taste and appearance. It fits in well with traditional sources and collection practices. The quality of water provided is usually considerably better than most unimproved water sources. However, it does not always reach nationally approved standards. Some contamination by faecal coliforms, turbidity and insect larvae is common, particularly with surface catchment reservoirs. The potential for disease transmission can be raised if the water point is not managed carefully. For instance, breeding of mosquitos next to the home can increase the incidence of Malaria, and earth dams are considered high-risk sites for guinea worm or bilharzia transmission. The review has seen that these problems can be largely solved by providing various forms of protection, from a sealed roof for a household tank, to fencing an open-reservoir to keep people and cattle out, and providing a draw-off pipe and tapping station downstream. Local solutions are sometimes adopted to keep the water clean, such as the practice of growing fish in rock catchment dams in Kenya. Fish help keep insect larvae to a minimum, particularly mosquitos.

Yield increases from runoff farming

Over a longer period, widespread use of *runoff farming* is beneficial to the environment, reducing soil erosion (thereby improving farming), reducing reservoir silting and promoting groundwater recharge. It is frequently needed, but not always applied, in the below 800 mm annual rainfall belt, since in this zone, rain fed agriculture becomes risky. Considerable grain yield improvements from 40-700% have been noted.

The socio-economic aspects of water harvesting

A high community input is needed

High and sustained community inputs to water harvesting system management are generally required. Catchments and reservoirs need frequent cleaning and good protection from deterioration. Many runoff farming systems are labour intensive and require annual repair and reconstruction. Larger, external catchment systems require hands-on control of water flow rates and direction. Such high inputs may not always be feasible, for example, under local conditions of semi-nomadic agro-pastoralism and where there are off-season demands on male labour as migrant workers.

Risks exist for social conflict

When large catchment systems are introduced, a high level of community organization is required. The organized division of water amongst users and its sensible use through a dry period is necessary to ensure that equal benefits are received. This can create considerable potential for social conflict. Conflict can also be created between villages where those downstream complain of loss of water due to dam construction. Failure to adopt runoff farming soil and water conservation on farms upslope may result in the erosion of farmers fields downslope as gulleys deepen and encroach upon the lower fields.

The management capacity of communities is under-utilized

Community involvement in current projects is predominantly encountered as unskilled 'free' labour during construction and as local materials suppliers. This has negative effects where it prevents people from leaving to take up paid employment during the dry season. There has been only limited involvement of communities in need identification and problem definition, choosing appropriate technologies and designs, selecting and supporting community members to be trained, organizing effective financing and carrying out sustainable after-care.

The potential for women's involvement is greater

Despite the fact that women select, use and maintain traditional water sources and have the most direct interest in their improvement, women are still rarely involved except as beneficiaries. Women undertake many technical tasks such as house-building and plastering, but they have not yet been involved in training for building of household water harvesting facilities. Since there are few fundamental differences between construction of a house and construction of a tank, there is no basis for this gender bias towards male skilled labour. This is also true for the larger communal surface catchment systems. In Kenya, although women have been successful in selecting sites and organizing their labour to prepare the sites for rock catchment construction, they have not been trained in the technical aspects of dam construction.

System coverage levels can be improved

To get the maximum benefit from household systems in terms of health and social welfare, the review suggests that the best strategy is to use them for drinking and washing water only. This allows smaller, lower-cost systems to be built. However, on its own this only slightly reduces women's burdens since they still must walk to distant dry-season sources for the remainder of their needs. Communities appear to prefer to use household systems for all purposes until they run out and then revert to traditional collection patterns. They then feel the impact of the water development more strongly for a few weeks. Significant improvements can be made by:

- enabling every household to own a water harvesting system, thus putting less load on local communal sources which then can supply water for longer periods;

- developing a larger communal surface catchment system closer to the community which can be used for other domestic needs over the whole dry season.

Intervention strategies

Short-term versus capacity-building approach

Two basic external support approaches have been adopted. More commonly there are the short-term, construction-oriented approaches, designed to meet existing demands and to create future demands by promoting a particular technology or range of technologies. Less frequent are the capacity-building approaches which test-out and offer a range of designs proven appropriate to local conditions, needs and resources.

They pay attention to user attitudes and create capacities to continue (construction and management) of water harvesting systems past the period of external involvement. This is important because due to their fixed storage capacity, systems must be enlarged or replicated to allow for increasing consumption rates, family growth or migration into the user community. If not, they can only provide a diminishing service level.

The financing aspects need greater attention

Most external support agency (ESA) projects rely on providing significant subsidies. Recipients have mainly contributed 'free' labour and local materials worth between 10% and 40% of real construction costs. The cost of most systems is relatively high and heavily weighted to the capital side with the need to create a catchment and/or storage facility. Even with cash-cost reductions from self-help inputs of labour and local materials, costs are still too high for most rural households where the cash-economy is underdeveloped. Because of this, only a few projects have managed to develop a self-sustaining, community-based programme of water harvesting system construction. However, it is clear that in areas where the environmental conditions are difficult for the development of surface or groundwater reticulation systems, and where they have considerable recurring costs, water harvesting becomes more cost-beneficial, especially when viewed in annual equivalent terms. Spreading out cost repayments using loans or cooperative funds, and linking to income generation (especially for women's groups) would improve the affordability of systems.

The technical aspects of water harvesting

Designs need to be adapted to local conditions

Designs need to incorporate materials, skills and construction methods that are compatible with local conditions if systems are to be replicable and sustainable. Quality control in construction is important and has sometimes been difficult to achieve due to local unfamiliarity with construction techniques and poor supervision and selection of materials. This has caused rooftop tank and rock catchment dam leakage, and earth dam erosion in the five countries.

With rooftop catchment tanks, standardized, technically proven designs are available. However, many appear too sophisticated for community craftsmen who first require a period of specialist training. Instead, already skilled workers from outside the community have often been used, contracted and subsidized by ESAs. In Kenya, there is a move towards selecting and training local graduates from rural training polytechnics to try and boost village skill-levels. Some designs need to be modified to take account of local shortages in materials or cost differences. For example, chicken-wire for ferrocement tanks is scarce in Tanzania.

Proven designs for sub-surface dams and rock catchments have been developed and most widely applied in Kenya. Basic mistakes in siting and construction could be overcome by better training and supervision of craftsmen. The situation with regard to small earth dams is more worrying. A range of labour-intensive design instructions are in circulation but they are weak concerning adaptation to site specific conditions. Site identification and protection aspects are inadequate. The safest locations for dam construction are not described clearly and catchment and stream protections against erosion, severe flash-flooding and siltation are ignored in many technical guides. There has been a history of rapid reservoir siltation and frequent washing away of dams as seen in Kenya and Mali.

Operation and maintenance leaves much to be desired
Effective operation and maintenance practices have not received sufficient attention for each of the different water harvesting systems. Little formal training is given on system management and water quality protection. Simple steps that could be taken to prevent deteriorations in water quality are often ignored. Few guidelines are issued in local languages or using simple drawings, and recipients are seldom given a seasonal timetable of cleaning or maintenance actions to be performed. Where these have been issued, and where communities receive formal training, systems are generally looked after better. However, too many projects provide only verbal instructions, if any, to a community leader or official and not to the daily users.

Future considerations for water harvesting

A range of environments are suited to water harvesting

Although there are a number of difficulties associated with water harvesting systems in the five countries, the review has shown excellent potential for their wider application. Areas with between 200 and 1000 mm of rainfall annually are the prime zone for water harvesting, and those with two rainy seasons are the most favourable. Areas with more or less rainfall are also potential sites depending on the severity of the water shortage or contamination that causes a need for water harvesting. Where torrential runoff occurs during rainstorms, followed by the drying up of ponds, streams and rivers as water flows away to other areas and into the ground, surface catchment systems and runoff farming can drastically improve the local situation. Sites generally exist in most semi-arid landscapes for rock catchments or earth dams, and/or for sub-surface dams.

There is particular potential for the use of water harvesting as a supplementary source within a multi-source system, for instance in a number of Botswana and Kenya towns. It can be used as a back-up where there are unreliable reticulation systems, or as a major supply source for scattered populations not suited to a reticulation system. This is especially true where groundwater cannot be exploited. The rapidly increasing numbers of households having iron-sheet roofs as well as the growth of lower-cost roof and guttering technologies are bringing rooftop catchment systems into the reach of more households.

Improvements are possible in intervention strategies

There is potential to improve on the design, construction and financing aspects of water harvesting systems. Site selection, quality control in construction, and site protection could all be improved by observing a number of relatively simple and known guidelines. The awareness of these need to be boosted for each technology and promoted more effectively to a grass-roots level. There seems to be little immediate potential for significant lowering of capital costs in rooftop and surface catchment systems other than by being aware of and adopting the lowest cost designs applied successfully elsewhere, since they already contain a significant proportion of self-help inputs. However, there is considerable potential for the improvement of financial management strategies to make such systems affordable. The present system relying heavily on subsidies by projects must be replaced by a more sustainable financing system. Aspects to be taken into account include:

- income generation;
- easy access for users to sources of capital funds such as rural development banks and revolving funds;
- effective community-based financial management strategies; pooled resources, mutual assistance schemes;
- risk-mitigation; flexible repayments, disaster insurance.

Where projects have created community capacity to replicate and sustain water harvesting systems, most notably roof catchment schemes, they have addressed one or more of these financial issues successfully.

Even with increased spending levels, national governments and ESAs cannot expect to make a real impact until communities develop installation, maintenance and financing capabilities. This requires channelling more funds into capacity building. More emphasis must be given to involving communities and individuals in making informed choices about water harvesting systems they will finance, use and maintain. Often, finance implies income generation which requires national governments and ESAs to be active in creating markets for surplus crops and livestock.

Women can be better involved in water harvesting

Women need to be consulted more about which water harvesting technologies and implementation strategies are most appropriate for their needs and allow their direct involvement. Approaches that go through local leaders may by-pass women and their involvement may be met with resistance or hostility. As proven in other developments such as hygiene and health care, women must be involved in a culturally acceptable manner. As prime users, they are more likely to be constructive in their approach to water harvesting than men folk. Several projects have shown that it is not enough just to have women on committees. They can still be excluded from decision making by more dominant males as shown in Togo. Women must receive technical information and training to enable them to make informed decisions and function confidently in decision making.

Experience exists from which others can learn

Transfer of the wide range of experience already amassed is important for the future of water harvesting. The review has shown the considerable need for organized information exchange between countries, which appears less effective than it should be. Practical information from projects, especially concerning the socio-economic, rather than the technical aspects of developing systems, is seldom forthcoming to the wider community and lessons learned are not passed on. This is a major weakness that needs to be more effectively addressed if others are to learn of successes and failures.

Recommended actions for the 1990s

A guide for project intervention is needed

A guide should be provided for external support agency (ESA)/local non-governmental organization (NGO) project design and implementation that summarizes the present knowledge concerning the most effective intervention strategies.

Information and experience must be transferred

A number of expanded activities are required to achieve the organized transfer of information and experience between countries and between projects. These include: the more aggressive targeting of active and potential water harvesters, for example through the WASH Raindrop or IRC Newsletters; wider publication and dissemination of literature; new publications to fill existing gaps; meetings between people active in water harvesting, for example using the African NGO network, national or regional seminars, exchange visits; promotion of project experiences, good and bad, to a wider audience.

Applied research is required

Applied research into currently weak areas of water harvesting implementation is required, particularly: community participation; women's involvement; the true cost of systems; community-spread financing; national financial support systems; actual impact measurement, especially on women and health; and non-ferrocement roof catchment tank technologies.

Training activities are necessary

Training activities are required both at the project management and at the community level. They need to be directed towards: programme sustainability; community participation in design selection and project management; the involvement of women in technical aspects; local design modifications; information reporting and exchange; and proper evaluation of the functioning and use of completed systems.

Monitoring must be strengthened

A review of current monitoring systems on the functioning, water quality, use and maintenance of completed water harvesting systems is required for the purpose of providing guidelines and improvements.

The real impacts on the lives of women must be known

An inventory is required of how women are currently involved in water harvesting projects, what the impacts are on their lives in real terms and where and how these two aspects of involvement and impact could be strengthened.

PART I: OVERVIEW FOR THE FIVE AFRICAN COUNTRIES

1. Introduction

Water harvesting involves the collection, concentration and storage of rain water that runs off a natural or man-made catchment surface. It has three main functions:

- it is a method of smoothing out variations in water supply availability by storing it in times of plenty for use when it is scarce or interrupted;
- it is a method of providing a more convenient and acceptable distribution of water where it is otherwise limited or sparsely distributed;
- it is a method of providing higher quality water than would traditionally be available from unimproved natural sources.

For farming, rainfall that would otherwise run off a field is collected and directly infiltrated into the soil for use by the plants during the growing season. This is usually termed runoff farming.

1.1 Background

Water harvesting has most often been carried out in the five countries as a last resort option in areas where environmental conditions are difficult and where there has been little history of successful government, or ESA involvement in local development. The availability of water sources is not evenly distributed and is highly seasonal due to low, infrequent and uneven rainfall. In many regions permanent surface water is not present and the exploitation of underground water is not possible due to the hydrogeological structure or chemistry. Many of these areas have poor rural infrastructure, dispersed population groups and low income, often at or below subsistence economic levels. Women are subjected to long journeys to collect or buy water in the nearest village, or else they resort to taking water from unimproved traditional water sources. Increasing crop production is a high priority since rainfall alone usually does not produce secure harvests where annual totals are less than 800 mm.

1.2 Attitudes towards water harvesting

Interests and attitudes towards water harvesting vary considerably in the five countries reviewed: Botswana, Kenya, Mali, Tanzania and Togo. Rudimentary water harvesting is being practiced in most rural areas as part of the traditional water supply strategy. Many planners consider it a low priority for a number of reasons including high capital cost, fixed supply limits, high user management needs, perceived quality problems and the need to work at a small scale within communities. Groundwater is the major source for drinking water supply and is increasingly being abstracted by handpumps although motor pumps are still used widely in Botswana and in some areas of Tanzania. Motor pumps are high cost supply systems and in Tanzania, for example, they have a poor record of sustainability that is pushing the government towards more appropriate lower-cost systems (Rutashobya, 1987). Gravity-flow piped systems are also a commonly used option where springs are present.

Gradually, however, water harvesting is receiving greater emphasis, particularly in areas where groundwater is difficult to access or is saline, and where springs do not occur. For example, in Togo, it became an option in the 1980s when several rural water supply projects had a large number of unsuccessful drillings (30% to 40%) and 15% to 20% of targeted villages could not be provided with a reliable water supply by wells. As well as using it for drinking water supply, it is also becoming more popular to use water harvesting to increase the availability of water for farming by constructing small dams for livestock and irrigation, or by enhancing direct infiltration into fields through runoff farming. Throughout the five countries, water harvesting seems to be developing quite strongly as increased resources are being channelled into its development as more planners accept its usefulness, although the pace at which it is being adopted varies considerably. For example, the action plan for Kenya's arid and semi-arid lands from 1989-93 aims at providing 25% of drinking and agricultural water needs through water harvesting by spending US $50 m. Contrastingly, in Tanzania its use has only reached an embryonic stage, with the government and ESAs intending to apply water harvesting technologies more widely, but as yet there is only piecemeal experience.

A range of ESAs are developing water harvesting in one or more of the five countries and include: UNICEF, Danida, SIDA, USAID, the EC, the World Bank, the Peace Corps, Oxfam, CARE, World Neighbours, Plan International, CAFOD, Amref, CUSO, WaterAid and Action Aid amongst others. The exact nature of government and ESA activities and the water harvesting technologies adopted are described in detail in the five individual country reviews.

2. *Water Harvesting Systems*

Different types of water harvesting systems are being applied in the five countries. They can be grouped into the following three categories: rooftop harvesting systems, surface catchment systems, and runoff farming systems. There are both traditional and modern applications of these systems. The number and range of system types used vary considerably. Construction details of some of these systems are presented in the literature, but unfortunately, little information on the socio-economic aspects of their development is available, particularly concerning maintenance and extension.

2.1 Rooftop harvesting systems

Rooftop and tank systems consist of a rooftop catchment area, usually iron-sheet, connected by gutters and downpipes to a storage container. In each of the five countries, it is traditional to practice rudimentary harvesting into pots, pans or drums positioned below the roof eaves to catch runoff (Figure 1), although most mud and thatched roof homeowners do not. No data exists as to what proportion of households practice this or how much water is collected.

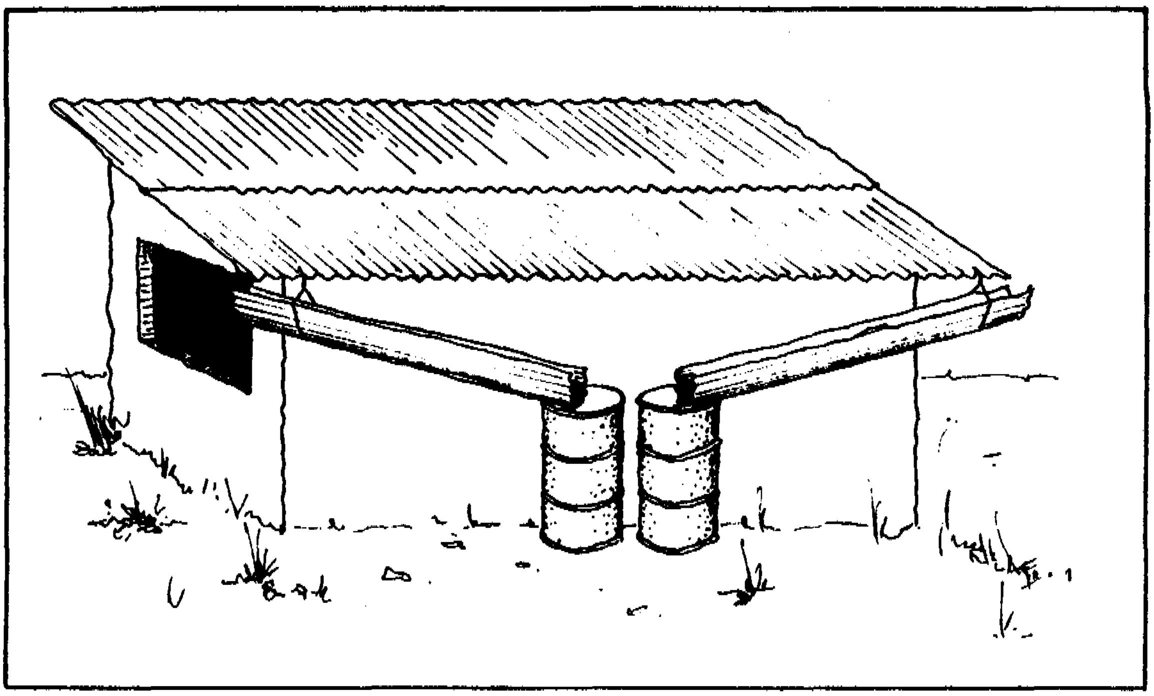

Figure 1: Rudimentary water harvesting (after Pacey and Cullis, 1986).

Improvements have been made to traditional systems. Householders have used a larger storage vessel such as an oil drum or have dug and lined a pit. They have then fixed a simple gutter to their roof to channel water into it. Larger tanks are also more commonly being introduced ranging from small cement-jars (0.5 to 2 m^3) to large ferrocement ground-tanks (up to 110 m^3). In Kenya tens of thousands, in Botswana thousands, in Tanzania and Togo hundreds and in Mali somewhat fewer of these introduced tanks have been built. The exact numbers of each type of rooftop system are not known.

Cement water jars

These 0.5 to 2 m^3 tanks are made by plastering around moulds such as a wet sack full of sawdust. They were promoted by UNICEF in Kenya in the 1970s and several thousand tanks were built to upgrade the householder's rudimentary storage. They are not always of good quality due to inappropriate cement mixing and curing.

Basket tanks

These 4 to 10 m^3 tanks are built from granary stores plastered on the outside and inside so as to make the structure water tight. Several thousand were built in Kenya following publication of construction guides by UNICEF but production mostly stopped in 1987 due to fears of low life-expectancy as cracking was common. Similar tanks are being built by Ghanaian contractors for householders in Togo.

Sub-surface groundtanks

These 10 to 110 m^3 tanks are generally roofed hemispherical excavations lined with ferrocement made from chicken-wire, barbed wire and mortar. A handpump is often fitted for hygienic extraction. In Botswana they range from 8 to 29 m^3, in Kenya from 60 to 80 m^3, in Tanzania from 80 to 110 m^3 and in Togo, more sophisticated reinforced cement is used to build tanks up to 163 m^3. The tanks are being used with both rooftop and surface catchments, the larger ones mostly for schools, health centres or large family groupings. They are considered the best technical option by a number of Kenyan workers due to their relative ease of construction and cost. Aspects of construction are shown graphically in Appendix I.

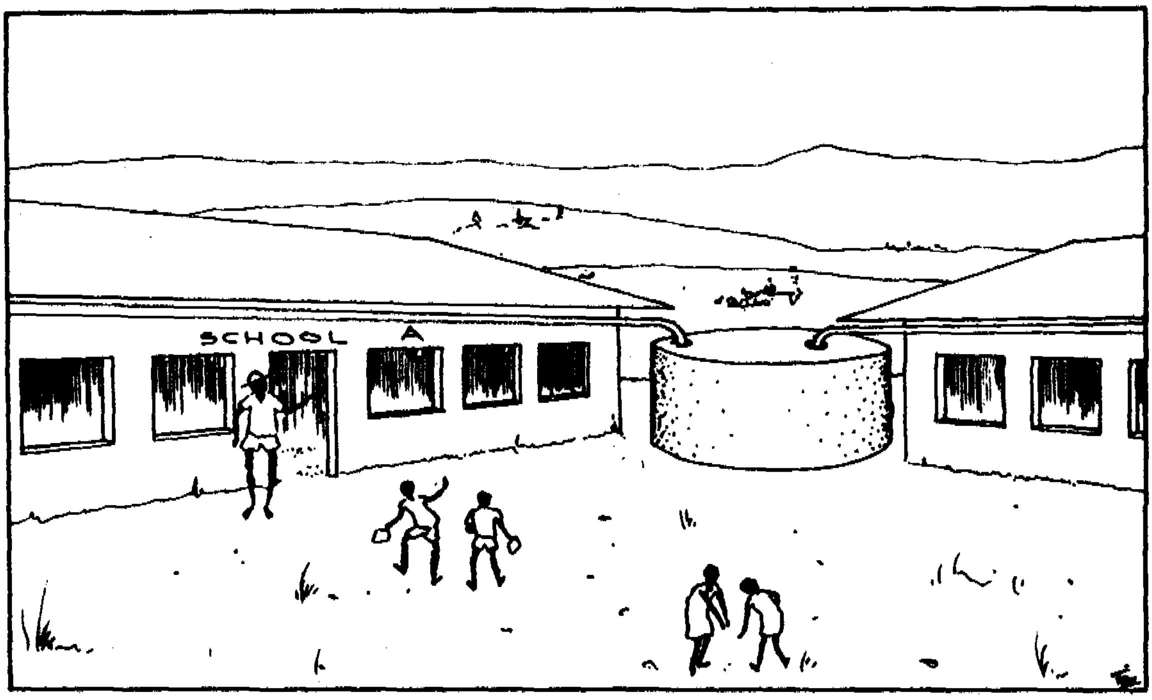

Figure 2: Cylindrical standing tank (after Hasse, 1989).

Standing tanks

There are two main types of cylindrical standing tanks (Figure 2), 4 to 13.5 m^3 tanks made of ferrocement or cement blocks built around reusable formwork, and 20 to 40 m^3 tanks using fairly rigid iron grid-mesh as both a framework and reinforcement. Thousands of the smaller tanks have been built in Kenya, Botswana and Togo. They perform well and appear to be of reasonable quality requiring limited repairs. An example of the costing and construction of a well-proven design from Kenya is included in Appendix II.

Factory-made tanks

Additionally, there are the pre-fabricated 5 to 10 m^3 standing tanks made from galvanized iron. They are increasingly considered poor investments due to their short lifespan and relatively high cost. In Botswana, 7 m^3 polyethylene tanks are being tested by the Ministry of Agriculture as a possible component of a water harvesting package offered to farmers.

Roofing

In many rural areas of the five countries, traditional housing predominates with either thatch or mud roofs. Increasingly, householders are switching to iron-sheet, thus increasing the potential for roof catchment harvesting. To further accelerate this process, some projects are providing roof catchments on pillars to accompany tanks. Recipients can use this structure as the basis of a new home or storage building. An example of such a system from Botswana is illustrated in Appendix III.

Guttering

An integral part of an effective rooftop harvesting system is the guttering. At their simplest, gutters are a short length of iron-sheet suspended in wire hoops below the roof eave, or positioned at an angle by two forked branches stuck in the ground below (Figure 1). The iron-sheet gutters are often too short to harvest sufficient roof area for a large tank and commercial gutters are expensive and unsuited to many low-cost housing designs. In Kenya, a Danida project has therefore pioneered simple, improved low-cost gutters, deflectors and hangers out of iron sheet and wire (Figure 3). In Tanzania, experiments are taking place with equally cheap sisal-cement gutters and deflectors.

Design considerations

Project experiences suggest that the most important factors that should be taken into account when selecting a tank design and size, depending on local circumstances, include:

- the rainfall amount, its distribution and annual variation;
- the length of dry season, particularly in drought years;
- the size and type of catchment area;
- the number of users per tank;
- the water need/use of tank users (drinking, animals, washing, gardening);
- is it what people want?
- the skills of local labour and need for specialist training;
- the distance from material suppliers and availability of transport;

- the affordability of the tank;
- the expected lifespan of the tank;
- the maintenance needs;
- the need to prevent contamination;
- the need for safety (especially with open groundtanks).

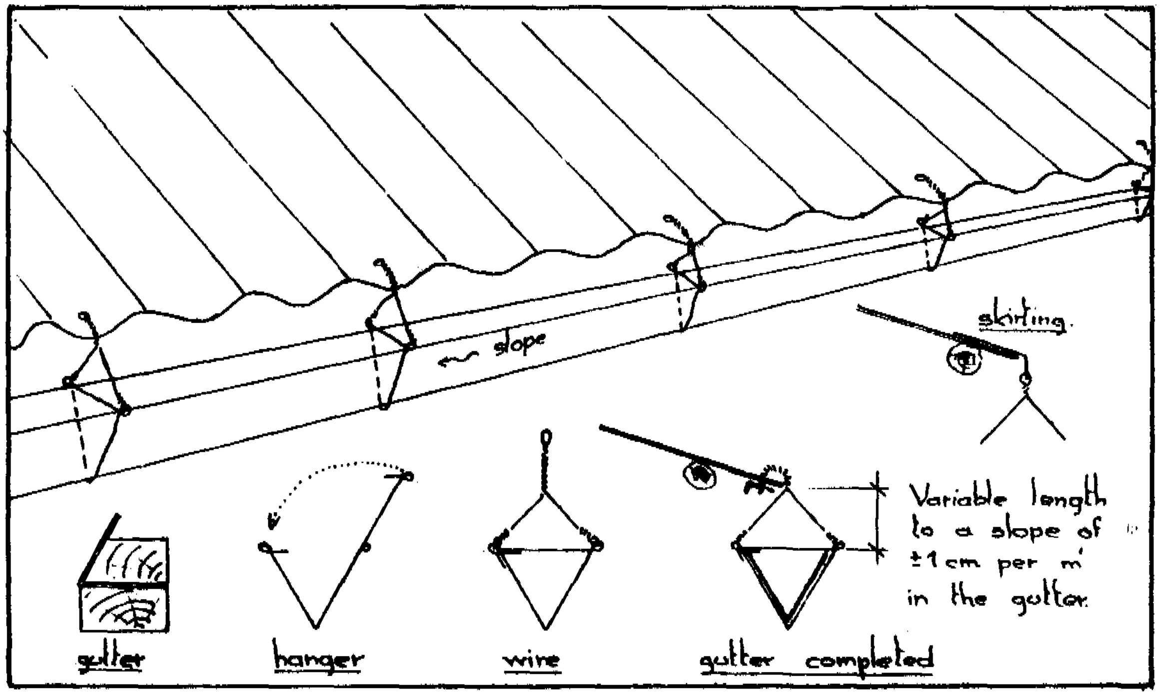

Figure 3: Simple iron-sheet gutters and wire hangers (Danida assisted Mutomo Project).

Recommended standard design features and construction practices

From the review, a number of features and practices can be highly recommended for rooftop tanks both to ensure and preserve water quality and to promote longevity. These are:

- removing overhanging tree branches from above the rooftop;
- provision of an inflow screen between the roof gutter and tank, and a first-flush capacity (such as a detachable downpipe section);
- provision of a sealed roof and lockable sealed entry hatch for cleaning purposes;
- use of a reliable, sanitary and lockable extraction device;
- construction of an hygienic soakaway channel and screened overflow pipe;
- positioning of the end of the outlet pipe above the base of the tank to allow sedimentation;
- inclusion of a flushing pipe at the base of the tank (for cleaning the standing tank);
- provision of effective guttering and deflectors to harvest a sufficient roof area;
- ensuring of an even and solid reinforcement with sufficient reinforcement density to allow good mortar binding;
- use of the correct sand-cement-water mix, careful and even plastering and careful curing;
- application of waterproofing cement solution on the inside of the tank;
- carrying out of swift repairs to leaks or cracks either with bitumen paste or by chipping out, reinforcing and mortaring.

2.2 Surface catchment systems

There are four main types of surface catchment and storage systems: rock catchments, earth dams, excavated reservoirs (which includes groundtanks not linked to roofs) and sub-surface dams. In the case of the first three, rapid runoff from natural or man-made surfaces is concentrated into and collected at strategic locations, harnessing water that would otherwise leave the area or be dissipated through infiltration. The last system harvests water already infiltrated and concentrated through natural hydrological processes into sand-rivers that fill valleys in dryland areas.

Rock catchments

Simple rock masonry gravity walls up to five metres high are constructed on rock outcrops in valleys or around hollows (Figure 4), and stone and mortar gutters are built across contours to channel water from the rock surface. The rocks are normally bare, with only a few small patches of earth and vegetation.

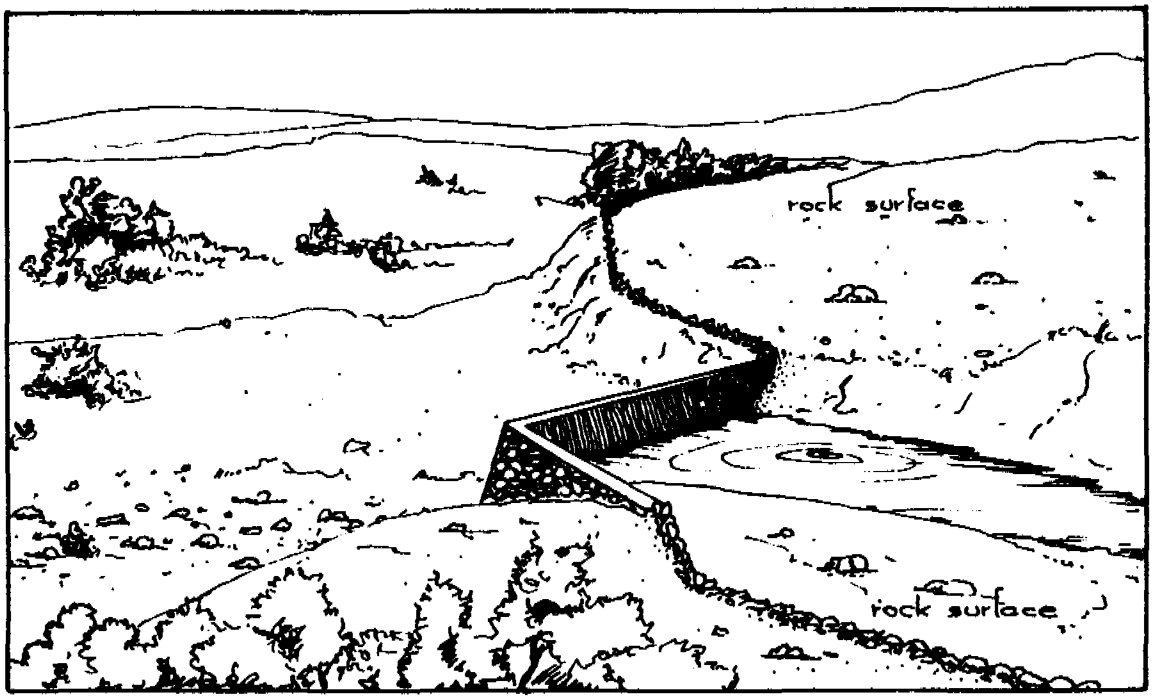

Figure 4: Rock catchment.

With each construction, it is important to ensure that:

- the rock face is cleaned and roughened where the dam is built to allow a solid bind between the dam and rock;
- fissures in the rock are sealed to prevent water loss;
- any earth pockets on the surface are scraped-off along with the vegetation to increase reservoir storage volume and prevent siltation;
- the perimeter of the rock and reservoir is surrounded with a cut thorn-bush fencing to keep out animals;
- the rock is cleaned periodically to prevent contamination;

- water is extracted through a filter box and out-take pipe down to a watering station and not directly by hand;
- the reservoir is as deep as possible with a small surface area to minimize evaporation loss.

Several hundred rock *catchments* have been built in southern Kenya but are virtually unknown in the other four countries although there may be considerable potential for them.

Excavated reservoirs

These are depressions deepened or excavated to hold a larger volume of runoff water from natural catchments or from man-made surfaces such as village compounds, threshing areas or concreted slopes. At the smaller end of the scale they include the dug and plastered pits used in Tanzania and Togo and the ground tanks used in Kenya and Botswana, and at the larger end, they include Charco dams in Tanzania (excavated reservoir downstream of an earth dam), and banco pits in Mali (large excavations made during mud-brick manufacture). In many cases, due to seepage and evaporation loss these systems only provide seasonal supplies.

Earth dams

Earth dams are raised banks of compacted earth, often with a clay core and stone aprons and spillway, holding back water in a small valley or depression. They are used in each country, usually supplying water for livestock or for irrigation, but often also used for domestic purposes. An example of the design details for a dam built in Mali are included in Appendix IV. Kenya, Tanzania, Botswana and Mali all have on-going earth-dam construction, with up to 50 per year being built. Recognizing their multiple function, many are now fenced and provided with out-takes and downstream water stations for people and livestock. It is common in each country to find many poorly designed, sited or maintained dams which are quickly washed-away or silted-up.

Sub-surface dams

Each sub-surface dam design involves placing a vertical impermeable barrier of either compacted clay or masonry across and into a seasonal river bed. The masonry barrier can be built up gradually in small 50 cm stages. This results in sand being trapped whilst silt is washed downstream. The reservoir of sand is increased and more water is stored in the shallow aquifer created by the dam. It is accessed by a hand-dug lined well and sometimes a gravity pipe. These dams are being widely adopted in Kenya, where perhaps as many as 100 have been built, and have considerable potential in all areas with seasonal sand-filled rivers, particularly Botswana. The principles of sub-surface and sand-dam construction are illustrated in Appendix V.

2.3 Runoff farming systems

A range of runoff farming systems, both simple and complex have been applied in several of the countries to improve direct infiltration and boost crop yields. Their current use is still far below their potential. Each of the countries except Togo have large proportions of their farming populations in areas where conditions can be improved greatly by runoff farming. Sketches showing the principles and layout of different runoff farming systems are given in Appendix VI.

Runoff farming systems work on the principle of selective runoff and infiltration. There is a defined catchment (runoff) area, and a defined cultivation (runon) area. A distinction can be made between within-field systems, in which the runoff and runon area are small and occur within a single sloping field, and external catchment systems where water spread onto a particular area to infiltrate has been diverted from more distant sources such as a stream supplied by runoff from another area. These are generally larger in scale and are less common. In Mali there are about 20 projects currently involved with developing soil and water conservation and in Kenya it is a standard component of all development projects in the marginal areas. Although in Kenya and Mali, there has been widespread promotion and adoption of a range of within-field systems through NGOs and government agricultural soil and water conservation services, there are few reliable estimates on the number of hectares that have been developed. In both Botswana and Tanzania, pilot projects are now underway in the use of various crop improvement schemes on farmers fields.

Micro-pits and micro-catchments

Micro-pits are small water collection pockets that fill with surface runoff and into which manure and small pockets of seed can be placed. Micro-catchments are small earth-banks, usually a diamond shape with the apex pointing downslope. Water drains off the interior of the diamond to the lowest point in the apex where it is used to water a tree or a small clump of maize.

Small check-barriers

The fanya-ju is a small earth bank formed by digging a ditch along a contour and throwing the earth upslope to form a small bank (Figure 5). Fanya jus are generally spaced between 5 and 20 metres apart downslope depending on local gradients. One person can dig 3 to 6 metres per day. Bananas or fodder trees can be grown in the ditch and grass on the bank. Water running off the field collects upslope of the fanya-ju and gradually, any soil eroded further up the field is deposited to create a terrace.

Rock and trash strips are built along contours by raking crop residues or stones from the field into lines. These act as permeable barriers allowing runoff water through, but at a much slower speed and preventing concentration into gullies. Similarly, contour bunds are built along contours but they trap water, leading excess flow away to the side of the field. They are generally 0.3 m high with side slopes of 1:3. Assuming the catchment area to cultivated area ratio (CCR) to be 2 to 3 for 1% to 3% slopes, each hectare would require between 150 and 430 cubic metres of earthwork to be completed. Sometimes they are fitted with spillways made of stones to allow water to safely discharge down the field without erosion. In practice, for instance in Turkana, they have been largely unsuccessful. Unless they are built perfectly level, water trapped during heavy rains can flow over the bank at its lowest point creating erosion.

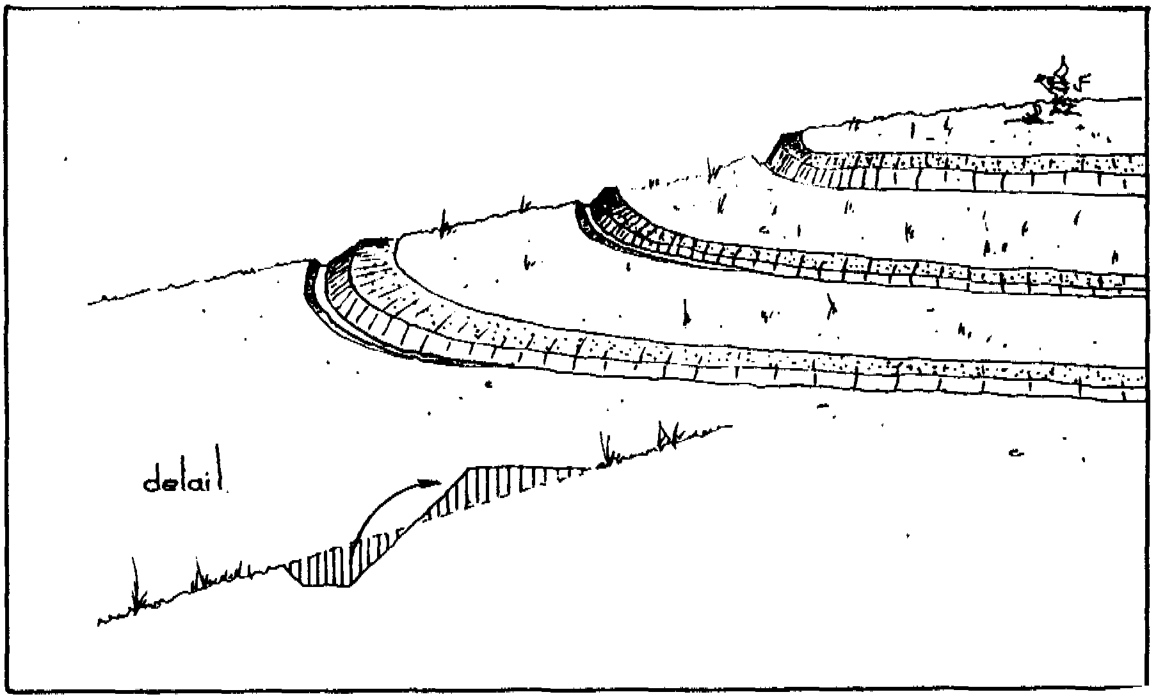

Figure 5: Small earth check-barriers in Kenya.

Medium check-barriers

Semicircular bunds are within-field systems built to cross part of the field, trapping surface water. Banks in the shape of a halfmoon are built, with the round part facing downhill and the two ends of the semi-circle positioned level with each other on the same contour. Assuming a rainfall of 550-700 mm, they should be 10 metres in radius providing a cultivated area of 160 square metres taking 6 to 9 person days to construct. Assuming a CCR of 3, each hectare would contain 16 bunds. Any excess water flows out around the edge of the tips. Bunds are built in staggered formation across and down a sloping field so that the water running out of two upper bunds runs into the lower bund positioned with its apex below their two adjacent ends.

The trapezoidal bund is similar to the semicircular bund except that it is larger and has a u-shape, with a straight bottom and angled sides. The bottom of the u is built along a lower contour and the tips of the sides finish level on a higher contour. Again, excess water flows out around the sides and not over the top of the bank. Trapezoidal bunds are generally 0.6 metres high with 1:3 side slopes and assuming a CCR of 5 to be suitable for 0.5% to 2% slopes, this would require 250 to 840 cubic metres of earthwork per hectare.

Large check-barriers

Large permeable rock barriers have been used in Mali to slow down water moving across alluvial valley bottoms, reducing its erosive force and enhancing infiltration. Application of these external catchment systems has not been widespread or the cost-effectiveness determined.

It has been found in Mali and Kenya that the introduction of runoff farming systems is a slow process. Their labour-intensive construction, coupled with the often high annual labour demands for maintenance seems to be a major constraint on their widespread adoption, especially within communities who have a high seasonal out-migration.

3. Socio-economic Aspects

The cost of systems, the service level provided to user communities and the potential for conflict over water use vary between systems and between the five countries.

3.1 Cost aspects

Preparing cost statistics for water harvesting systems is a difficult exercise. Costs are quoted loosely, with few detailed breakdowns or current valuations. Factors affecting the applicability, reliability and comparative value of cost figures include:

- inflation since time of calculation;
- exchange rate conversions;
- exclusion or inclusion of project costs which vary according to whether it is research, demonstration, pilot or implementation in nature;
- exclusion or inclusion of the following cost components: commercial materials, skilled labour, local materials, self-help labour, transport, equipment, technical advisor;
- different pricing in different countries (for example in Tanzania the shadow wage for self-help daily labour is $0.25-0.5, in Kenya $0.7-1.0, in Botswana $1.5 and in Togo and Mali $1.5-2.0).

Because of these difficulties project managers in Kenya recommended never to accept anyone else's cost estimates or calculations and that prior to technology selection, a full, local, up-to-date breakdown of costs should be made before any decisions are taken (Limuru conference, 1987).

Rooftop and tank systems

In Table 1, the costs of rooftop catchment systems are presented. Tanks are assumed to last 30 years. No recurrent costs have been added to these figures. Most projects have assumed that the costs are negligible because repairs and cleaning are generally carried out whenever required on a self-help basis. However, the cost imposed on household members in terms of time, energy and materials and the possibility of major damage to roofing and gutters from storms should be borne in mind as important considerations when considering the real cost of systems.

Where there are two rainy seasons, it is assumed that the tanks supply triple their capacity each year (i.e. they are filled and emptied three times) and where there is one rainy season it is assumed that the tanks supply twice their capacity. The annual equivalent cost (AEC) per m^3 of water supplied is calculated on this basis for each tank. The cost details are taken from project literature and quotations by project managers, and are as up-to-date (1989) as possible.

Clearly there is a considerable range of differences in cost for the same size tanks, both in terms of capital cost and in the cost per m^3 supplied (AEC). This is determined by the differences in labour costs, material costs and the number of rainy seasons. There is not necessarily a decrease in per unit price as tank size is increased, since the use of more expensive construction techniques cancel out any economies of scale.

Table 1: Costs of rooftop catchment tanks (US $)

System	Vol m^3	Cost $	AEC $/$m^3$	Country
Small jar standing	1	25	0.42	Togo
Ferrocement standing	5.5	180	0.36	Kenya
Cement stave & rooftop	6	627	1.74	Togo
Ferrocement ball	7	168	0.27	Kenya
Polyethylene & rooftop	7	750	1.87	Botswana
Basket standing	8	250	0.35	Kenya
Ferrocement standing	9	221	0.27	Kenya
Granary standing	10	167	0.28	Togo
Round hut standing	10	222	0.37	Togo
Ferrocement standing	10	250	0.28	Kenya
Brick standing	10	500	0.83	Botswana
Ferrocement standing	10	750	1.25	Botswana
Ferrocement standing	13.5	630	0.52	Kenya
Ferrocement standing	20	925	0.77	Tanzania
Ferrocement standing	21	534	0.28	Kenya
Ferrocement standing	25	1111	0.49	Kenya
Ferrocement standing	30	1073	0.39	Kenya
Masonry standing	50	3500	0.78	Kenya
Ferrocement groundtank	70	1750	0.28	Kenya
Ferrocement groundtank	75	1937	0.29	Kenya
Ferrocement groundtank	78	872	0.12	Kenya
Ferrocement groundtank	80	2000	0.27	Kenya

Remark: the AEC is the annual equivalent cost.

In Kenya and Botswana, ferrocement rooftop catchment tanks have proven to be feasible for building by locally trained craftsmen and volunteer labour. Technologically they pose no real problem except in terms of insuring quality control is carefully maintained. However, in many situations in which they have been applied they have proven too expensive unless heavily subsidized.

Table 2: Roof costs (US $)

Description	Area m^2	Cost $	Unit Cost $/$m^2$
Roof and Supports, Togo	80	937.6	11.7
Roof and Supports, Kenya	36	137.0	3.8

In some situations, the costs of roof catchment construction or upgrading and the cost of guttering must be added to the cost of tanks if the existing housing stock cannot support an improved system. Column one states which tank costs include roofing. An indication of costs of roofing and guttering is included in Tables 2 and 3.

Table 3: Gutter costs (US $)

Description	Unit Cost $/m
Commercial Gutter, Kenya	$4.0
Danida Gutter, Kenya	$1.8
Sisal-cement, Tanzania	$2.4

Surface catchment reservoirs and other communal supply systems

The cost of a number of surface catchment systems identified in the review and, for comparative purposes, a number of other communal supply systems are presented in Table 4.

Table 4: Costs of surface catchment reservoirs and other communal supply systems (US $)

Description	Vol m^3	Cost $	AEC $/$m^3$	Country
Groundtank	17	325	0.54	Botswana
Pavement/cistern	294	35811	2.00	Togo
Shallow well	2300	2000	0.06	Kenya
Sub-surface dam	3500	8250	0.11	Kenya
Sub-surface dam	3500	13793	0.43	Tanzania
Charco dam	8000	19316	0.27	Tanzania
Rock catchment	13000	21000	0.09	Kenya
Small earth dam	30000	57716	0.26	Tanzania
Medium earth dam	60000	125269	0.28	Tanzania
Medium earth dam	80000	17000	0.05	Mali
Urban piped supply			0.69	Botswana
Rural piped supply			3.30	Botswana

Remarks: The AEC is the annual equivalent cost;
Costs detailed for Tanzania are based on estimates given in a 1989 proposal by ILO for Dodoma region.

Earth and charco dams are assumed to have a useful life of 10 years whereas the other sources have 30 years. Recurring costs are calculated for all these water sources (except those for the Botswana piped supplies which are known) using the estimate of $0.033 per cubic metre adopted by UNDP/IFAD (1989). They assume maintenance and management costs vary directly with size. The AEC figures are worked out on this basis considering supply equals capacity. It is often assumed that rooftop catchment systems are comparatively highly expensive methods of water supply compared to larger communal systems. However, comparing the AEC costs in Tables 1 and 4 shows the picture is not so clear. Water harvesting systems differ considerably in the unit costs of water supplied and can be quite competitive compared to conventional water supply systems as shown for Botswana.

Runoff farming systems

Table 5 provides only broad, general estimates of the costs of labour-intensive water harvesting for crop, fodder or tree improvement. They depend on labour costs and productivity and take no account of any recurring costs incurred through operation and maintenance of the structures. Some runoff farming systems may need repair work each year and so incur annual costs in labour time to the farmer. The latter costs largely depend on environmental conditions such as storm intensities, slope gradients and soil conditions, but in general, appear not to offset benefits from increased production.

Table 5: Cost of runoff farming systems (US $)

Description	Unit Costs	Hectare Costs
Microcatchments, Kenya	$0.35 - 0.47 each	$218 - 294
Fanya-jus, Kenya	$0.12 - 0.23 per metre	$ 60 - 460
Contour bunds, Kenya	$0.35 - 0.47 per m^3	$ 52 - 202
Semicircular bunds, Kenya	$4.00 - 6.00 each	$ 64 - 96
Trapeziodal bunds, Kenya	$0.35 - 0.47 per m^3	$ 87 - 395
Rock barrier, Mali	$5.20 per m^3	$450

3.2 System achievements

Many of the water harvesting projects are still in a developmental stage and often have only tested the construction feasibility of systems. They have not paid attention to long-term requirements such as the development of local skills and financing capacity. They have not always effectively demonstrated the desired impact. For example, several projects in Kenya have been designed to provide safe water to schools and demonstrate the effectiveness to parents and teachers of water harvesting from rooftops. However, many of the tanks are too small for the purpose and dry up before the end of a dry period. Both the goals of providing safe water and demonstrating the value of water harvesting are seriously compromised by this failure to provide appropriate storage.

Service levels

The service level which is being provided by the systems varies strongly between and even within the five countries. It largely depends on the environmental conditions such as rainfall amount and distribution, the size and availability of suitable catchment areas and the design criteria being applied. The design criteria adopted vary considerably between countries and include:

- design to the maximum potential of the site (common with systems such as rock catchments or earth dams);
- design on the basis of average expected conditions (average annual or seasonal rainfall, length of dry season, required daily water consumption - common for tanks);
- design on the basis of empirical models of required system density and size (for runoff farming systems);

- design on the basis of some dominant factor (project managers preferences, community preferences, existing technical capability, funding availability, etc.).

Those design decisions based on average conditions cannot guarantee reliable service levels where there is significant climatic variation. Because of extremes, there will be periods when water shortages will occur as virtually all water points dry up before the end of the dry season. To satisfy needs on a long-term basis, systems need to be over-designed for the majority of the years, geared to providing minimum requirements for the worst-year scenario conditions. Realistically, this may not be possible. Additionally, rising populations or increased water use may result in deteriorating service levels. Some systems are actually planned as a supplementary supply, providing a limited but very useful service at a reasonable cost. There is a mainstream movement towards recognizing and accepting these limitations and realizing that only a partial supply may be possible using water harvesting.

In contrast, runoff farming has its greatest impact when rainfall conditions are worse than average. In many cases, when above average rainfall occurs, fields with runoff farming improvements produce no greater yields than purely rain fed fields since the latter are sufficient to support the crops. However, when low rainfalls occur, the yield improvement from runoff farming systems ranges from 40% to 700% depending on the species, rainfall and soil type (Reij et al, 1988). The added advantage of crop improvement systems is that they inhibit soil degradation and erosion by reducing runoff and soil loss.

Quality of water supplied

Valid assumptions are being made on the quality of water provided by water harvesting systems on the basis of a good understanding of the causes of possible pollution. Yet little factual data is available on the real water quality. In general, rooftop catchment tanks are assumed to provide high quality water, both standing tanks fitted with taps and groundtanks fitted with handpumps. This is confirmed by a study in Botswana showing that coliform counts lay within WHO norms except for high streptococci counts probably resulting from bird excreta flushed off the roof. Tanks without sanitary extraction, tank roofs, first-flush diverters and filters are assumed to supply poor quality water as are tanks fed from surface catchments, rock catchment dam reservoirs and earth-dammed reservoirs. Some examples of first-flush systems are illustrated in Appendix VII. The same Botswana study showed extremely high faecal coliform counts in surface catchment groundtanks.

Earth dams in Tanzania are widely assumed to be breeding grounds for bilharzia and guinea-worm contamination of surface reservoirs is of concern in West Africa. All open water stores are potential breeding grounds for mosquitos and could aggravate the problems of malaria and other mosquito-carried diseases. Sub-surface dams are assumed to provide high quality water due to the sand filtering effect of the sandy bed although since the aquifer is so shallow, contamination could occur, especially if access is made through an unlined dug-pit.

Attitudes differ towards the use of water harvesting systems that provide water that is of low quality by international standards. Some government and ESA staff reject them for this reason. However, many others argue that because water harvesting systems considerably increase the availability of water, they very much contribute to the well-being of people in difficult areas and lessen their daily burdens. However, it is agreed that wherever there is the opportunity, systems should be adopted which can provide adequate quality water.

3.3 Social conflicts

Social conflicts have arisen as a result of the development of water harvesting systems:

- conflicts over ownership, water allocation rights and unequitable abstraction have appeared where communal sources are provided to a non-cohesive social group;
- upstream-downstream conflicts of interest (flooding of farming areas upstream, cutting-off supply downstream, falling groundwater levels) have appeared where system construction alters the natural hydrology;
- all or part of a community have been alienated by external agencies who may:
    - target only parts of the community;
    - offer preferential subsidies to a particular group;
    - exclude communities from decision making and so give them a technology they do not want;
    - provide a static supply to a community which does not allow for new migrants to take water;
    - experience bottle-necks with their support which causes frustration and dissatisfaction if communities have already provided financial or labour inputs.

With communal systems there is considerable potential for inequitable supply and conflicts to develop unless this is carefully taken into account when developing the system. The long-term implications with any system that does not have a built-in capability for replication and expansion of water supply capacity is that the rapidly increasing population cannot be assured of drinking water in the future.

4. Intervention Strategies

When reviewing the different programmes in the five countries, a number of key issues can be identified which have had an important impact on project results. These issues particularly relate to: technology selection; community involvement and capacity building; and approaches to financing.

4.1 Programme objectives

Both short and long-term programmes have been carried out within the five countries. Projects that work with water harvesting on a short-term basis are usually most concerned with the hardware aspects of water development. They focus on the development of a certain number or capacity of systems within a particular region in a given time, often only as long as it takes to organize and carry out system construction. Many of these projects can be classified as promotional, providing a standard technology to a pre-determined target in order to demonstrate the use of water harvesting and to hopefully encourage wider interest and local initiatives to develop similar systems. The construction of rooftop catchment systems for schools or health centres is an example of such an approach.

Longer term projects are usually more concerned with capacity building and the creation of both demand for and abilities to create appropriate water harvesting systems at a local level. Programmes continue for a number of years, often creating a local community infrastructure of technicians and decision makers. A range of technologies is selected and attempts made to refine or develop technologies through trials of the acceptability or efficiency of particular designs. More attention is given to the software aspects of system development, and creation of local capabilities to continue system construction and effective management past the period of programme involvement. Attempts are usually made to integrate developments in water supply with other socio-economic and environmental developments in a region.

4.2 Technology selection

Strategies adopted

Programmes are often technology oriented, promoting externally designed systems with goals decided prior to community involvement, communities active only in the provision of self-help labour and all financing provided from external sources. Many programmes, especially small-scale ones, have chosen a single water harvesting technology and work with just one community grouping or a small region of one country. This is a common approach, adopted by many ESAs in the five countries. However, larger programmes with greater resources usually apply a range of water supply technologies of which only a proportion may be water harvesting systems. They do so because of wide variations in the human and physical environments in their area. Some groups could be supplied by a spring protection and gravity pipe, others by a shallow-well or rock-catchment, and some only by an individual source such as a rooftop catchment tank.

Design selection guidelines
For rooftop harvesting systems, the choice of tank designs is wide, based on construction techniques and materials, cost and service levels provided. Selecting the size of tanks to go with a given rooftop catchment and user group in a given climatic zone is not straightforward. Generally, sizes selected for households are between 4 and 13.5 m^3, and for institutions between 25 and 80 m^3. There have been efforts to provide more scientific ways to determine appropriate tank sizes although they have not been widely applied. They range from relatively simple empirical formulae to more complex computer programs based on roof size, rainfall, water use and the rainy-day distribution.

For surface catchment harvesting systems such as earth dams, sub-surface dams and rock-catchments, each design is somewhat site specific although standard engineering guidelines are used. In some cases, these guidelines have been inaccurate or badly applied resulting in system failure. This, in turn, has had a negative effect on communities' willingness to participate in future projects. Earth dams have been the least successful of the technologies due to these reasons. Many are breached or silted up in a short space of time and often new projects must deal with the question of whether to rehabilitate them. Some rock catchments have been built on earth foundations and rapidly lose stored water. Left in this state they are bad examples and uselessly occupy valuable sites. Danida projects in Kenya decided they had to rehabilitate a number of these earth dams and rock catchments. In Tanzania, a proposed ILO project in Dodoma region plans to do the same for earth dams there.

A number of runoff farming systems have been tested in different physical and social environments. Smaller, within-field systems have proven suitable for adoption and have been generally recommended for use. Larger, external catchment systems have not been sufficiently tested. However, it is felt that they may not be suited for use in rural Africa because of the need for sophisticated technical input during construction, and high runoff management demands on farmers during storms.

4.3 Community aspects

Capacity building
Communities have been used most frequently as a source of free labour. They are seldom involved in technology selection and programme management. Widening community involvement in these aspects requires capacity building and the transfer of planning and construction skills to people based in the local community, preferably selected by the community themselves. Many programmes have sacrificed capacity building for quick results, choosing a short period of assistance for a village such as a year or less, and bringing in alien and imported skills. This of course has serious implications for replicability and sustainability of the technologies selected.

The more sensible strategy that incorporates capacity building has been adopted by programmes in Kenya which train local graduates from local craft polytechnics who are much more likely to stay within an area and to act as private contractors. When the programme stops supporting construction it can maintain a register of approved contractors who can carry on the work for private individuals.

Target groups

Broadly, within the five countries, programmes seek to work with two key groups within a community. The first is the rural poor, and particularly the sub-group of rural women. They are relatively disadvantaged lacking capital, labour, draft-power, are often in poor health and live far from a clean water source. They are difficult to reach due to their relative isolation from mainstream development activities and their lack of resources to participate in joint ventures. Additionally, women are often excluded from participating due to socio-cultural constraints.

The second group are influential individuals or already formed community institutions. The assumption is that by assisting these groups or householders, it is more likely that a demonstration or diffusion effect will be created, and the technology will spread more readily through the community. Providing catchment tanks to schools through parent-teacher associations or to model farmers in a particular agricultural extension region are examples of this approach. Providing systems to them helps raise local perceptions of the potential of water harvesting to provide water, or increase crop yields.

Involving communities

The method of working with the community varies enormously, some programmes adopting very formal procedures with elected counterpart organizations, and others operating a very loose structure working haphazardly with individual householders or institutions. Some programmes rely on formal channels to involve communities, such as the Kenyan District Focus Strategy, whilst others rely on random requests from innovative farmers, village leaders or headmasters. Occasionally, projects issue questionnaires to identify the characteristics of their assistance groups, their preferences and opinions and help them target their assistance more effectively. A useful example from Kenya is enclosed in Appendix VIII. The most formal arrangements have been made in Mali and Togo where communities are made aware of their responsibilities before assistance begins by the issuing of a contract. The contract between the programme, any government services and the village regulates the obligations of each of the parties in the construction and maintenance of the water harvesting system being introduced.

On a number of occasions in Kenya and Botswana, it has proven necessary to provide incentives as well as subsidies to householders to encourage their involvement in developing water harvesting systems, particularly runoff farming. This is often the case when the technology being promoted is a departure from their normal practices or where they are not used to working with outside agents. It is particularly true for systems that involve a significant input of time and labour by the householder. As the benefits of a particular system become apparent, however, it is clear that incentives can be reduced and even removed altogether, as seen in Kenya.

Communities and system after-care

It is surprising how many programmes in the five countries only seem concerned with the construction aspects of system development and take little practical interest in the after-care aspects of the systems they help develop. Many water harvesting systems involve quite a high management input to maintain water quality and ensure it lasts out the dry season. It is surprising how many project managers questioned said they did little to formally instruct individuals or groups in these matters and few attempted to consolidate operation and maintenance practices through provision of permanent written instructions. An example of one of these few initiatives is provided from Plan International, Kenya in Appendix IX. In many cases, water users are unaware of the links between themselves, their activities in the catchment area, the stored water, and the water quality. Without such knowledge, it is unlikely that users of an earth dam, for instance, will practice soil and water conservation in the catchment area or keep their livestock from drinking directly from the reservoir. This has been the major contributing factor to water source deterioration in past projects.

4.4 Approaches to financing

Contributions to costs

Costs of water harvesting systems can be broken down into material costs, skilled and unskilled labour costs, direct assistance and supervision costs, and additional support costs. Most programmes have asked for contributions from users to offset these costs. Most frequently, this has comprised unskilled labour and the proportion of materials that can be obtained locally from free sources. Currently, if self-help labour and the provision of local materials are taken into account, community contribution to construction of rooftop and tank, and surface catchment and reservoir systems varies from between 10% to 40% depending on the technology. For labour intensive runoff farming systems, more of the total cost falls on the farmer, although this decreases as the technical complexity increases and assistance is required. In some cases, the strategy of requiring unpaid labour inputs has resulted in users actually losing monetary income where men are prevented from taking up the opportunity of earning a migrant wage during the construction period, as seen in Mali. In some cases, there is a lack of male labour to carry out these tasks as most men are absent working in the urban areas, as seen in Kenya, or in South Africa, and in Botswana. An added socio-economic concern is that although a programme might be targeting the rural poor by promoting simple systems and providing large subsidies towards the total costs, the actual groups reached are often not this group as shown in Kenya and Botswana. Because users are required to provide some financial contributions, in cash or kind, often only the most able in the community can participate.

Payment mechanisms

There has been little experience of full cost-recovery with water harvesting system development. The capital cost of water harvesting systems are comparatively high when compared to conventional water systems in which more of the costs are incurred as recurring expenditure. For water harvesting systems, recurring costs are often negligible. Whilst the annual equivalent cost of each cubic metre of water may not be much higher, a tremendous burden is placed on whoever pays for water harvesting systems because of this weighting of costs towards construction. Virtually no programmes have developed financial intermediaries or developed systems from which users could take out loans and spread payments and also through which users could generate income to make payments. There is a definite financing vacuum in the five countries, especially for individual households. In Kenya and Tanzania in particular, there is no easy source of financing, no facilities for community saving, few financial advisors, and no easy repayment schedules. In Kenya and Botswana, loans have been largely unsuccessful. Many householders are unwilling to take on loan commitments due to the lack of title deeds on property and the unpredictability of their annual cash-income. In Togo and Mali, there appears to be a more highly developed basis for community financial management, many villages having bank-accounts and joint money-raising activities like communal fields. However, these funds are not always used productively or effectively. In Togo, villages with water harvesting systems have contributed considerable sums of money to finance possible major repairs. Since there are low maintenance costs during the first years this leads to an unproductive hoarding of large sums of money which is continuously decreasing in value because of inflation.

Requirements for user financing

If communities are expected to accept a larger proportion of the financing burden for water projects then this requires that certain pre-conditions will need to be met:

- communities must want a system enough to pay for it, must be made aware of its benefits and it must be affordable;
- financial management must be improved by supporting institutions for savings and credit at small, rural scales;
- communities must feel secure enough to make a commitment and so must be sure of ownership rights, land-tenure, etc.;
- any financing repayment scheme must be flexible and linked to socio-economic improvement and income generation to prevent the exclusion of the poorer groups in society. Some selective subsidies may be required.

5. *Conclusions and Wider Considerations*

Conclusions can be drawn concerning the environments having the greatest potential and need for water harvesting, the potential of different systems, the role of women in water harvesting and the transfer of information on experiences within and between the five countries. The wider concerns of improving service levels, financing and sustainability are clearly important issues.

5.1 Environments of application

High-potential situations

It is clear that water harvesting systems can be applied usefully in a range of environmental situations:

- as an alternative where conventional supply systems such as drilled wells, pumped systems or gravity-piped spring flow are not possible;

  Such situations include dryland areas with no perennial rivers, springs or potable groundwater or where alternative supplies are polluted.

- as complementary or supplementary supply systems in areas where conventional supplies are under pressure or unreliable;

  This was the case with many of the municipal piped supplies in the five countries which suffer interruptions or insufficient yields.

- as an alternative where conventional supply systems are technically feasible, but because of socio-economic considerations they are not possible;

  For remote villages where connection of a branch line is too expensive, or for hill towns where piped supplies need expensive pumping and reliance on machinery, a programme of water harvesting based on household and communal systems may provide a more effective solution.

In addition, runoff farming systems can be used wherever rainfall is insufficient to produce acceptable crop yields and where erosion damages the productive potential of farmland requiring soil erosion control and water management. Supplementary water can be provided either through direct infiltration on the fields or by irrigation from surface water reservoirs created by other water harvesting systems. This is generally required in areas with less than 800 mm annual rainfall and where there is high evapo-transpiration.

Broad zones for application

There is no established minimum annual or seasonal rainfall below which water harvesting systems are considered inappropriate. At any rainfall level, the water provided usually makes a valuable contribution to local supply. For rooftop and surface harvesting systems, where rainfall is lower a larger catchment area is needed to fill a given storage volume and with runoff farming systems, a larger catchment to cultivated area ratio is required. Where the catchment is more permeable, very low rainfall amounts or small individual rainstorms may result in there being no runoff at all. Obviously in this situation, surface catchment systems such as earth dams are not suitable. Runoff farming systems would also not function. For rooftop and surface

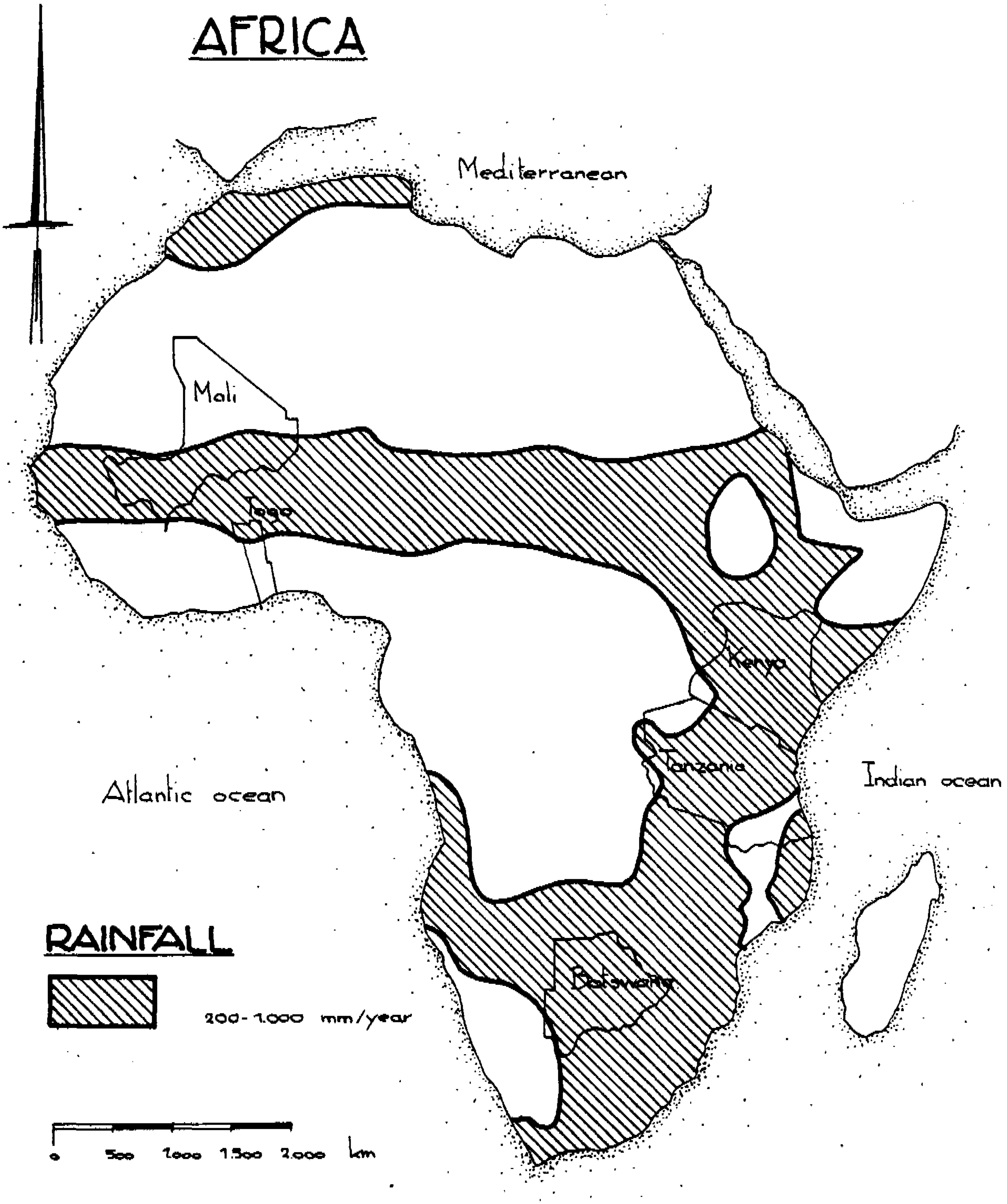

Figure 6: Broad zones where water harvesting can be well applied.

catchment systems, the longer a dry season, the larger the storage volume of the tank and reservoir must be to maintain a given service level. Thus environments with two rainy seasons separated by a short dry season are better suited to water harvesting use than one with a single, short rainy period.

Broadly, around about 200-250 mm total rainfall, the costs of harvesting a catchment area of sufficient size and storing water to last out a long dry season of six months or more becomes prohibitive and even with runoff farming, crop yields are too uncertain. At best, water harvesting may only provide a partial supply. Above 1000 mm, there is usually no need for water harvesting due to the plentiful nature of surface and sub-surface stores. However, there will always be special cases of areas where the environment prevents their exploitation due to water quality or cost of pumping, etc. Therefore, depending on local conditions, it is possible to say that the 200 mm to 1000 mm rainfall zones mark the areas where water harvesting has potential for wider expansion. This is illustrated for Africa in Figure 6. It accords with the conclusions of Ongweny (1979) who suggests that for drinking water supplies, surface catchment systems should be widely applied in the sub-humid and semi-arid areas, and rooftop catchment systems in the humid and sub-humid areas.

5.2 System potential

Promising technologies

The potential for the expansion of water harvesting systems in all of the five countries reviewed is considerable, each possessing large regions in which environmental conditions make conventional water supply systems inappropriate and agriculture marginal. This is largely recognized by external agencies and government organizations. However, support for the widespread adoption of water harvesting technologies is hampered by the perception that the technology is still somewhat experimental and unproven. The review shows this is not true. A number of well-tested, standardized technologies have been proven in particular landscape or climatic settings and design parameters are known. Technologies that seem most promising for supplying drinking water needs in terms of service levels or quality of water provided include the:

- 9 to 12 m^3 ferrocement standing tank for household use (assuming housing stock is suitable or upgrading possible);
- 70 or 80 m^3 ferrocement ground tank for institutions;
- sub-surface sand-river dam, especially when used in combination with a protected dug well.

Rock catchments have considerable potential for supplying a complete range of water needs, but are limited to specific geographical areas. Earth dams can be used to good effect but require a more rigorous approach to site identification, design and management if the history of rapid breaching and silting is to be changed. For agriculture, a range of simple runoff farming systems have been developed suitable for different purposes such as crop improvement, rangeland rehabilitation and agro-forestry. Most can be used for the dual purpose of erosion control. Several have been recommended for wider use by the FAO.

Current limitations

However, whilst the technical aspects of developing these systems are well known, it is true that some of the social aspects of their application are still not clearly defined, particularly related to financing and the bridging of the capital gap and this limits their potential. Additionally, with larger collective systems, the opportunity for conflict amongst users is high unless there is considerable social cohesion and organization amongst a community. Many of the more difficult physical environments where water harvesting is applied are those with the lowest levels of socio-economic development, and local management experience is often missing.

5.3 Women and water harvesting

Many intentions have been expressed about women and women's involvement as key targets/elements of water harvesting programmes. Traditional and cultural responsibilities often demand that they fetch water and manage its use. Because many men are absent earning a migrants wage, women are often the effective heads in the majority of rural households in the five countries. From an analysis of actual achievements in the five countries the reality of the situation is that women have only benefited indirectly, or have been recipients of assistance rather than partners in developments. Whilst women have contributed labour, fetched and carried materials or looked after technicians carrying out the work, they have not been involved in the technical aspects even though they constitute the majority of effective heads of households in many locations. It is generally agreed that it is necessary to overcome the lack of confidence that women can fulfil technical roles and manage programmes. Women must be trained in skills for which they have a natural basis. Water harvesting has great potential in this respect. For example, women build houses, tanks involve similar concepts and skills so they should be given technical training in tank construction. Women farm, often clearing fields and ploughing, so they should be given training in the laying out and construction of runoff farming systems. They must also be trained as extension workers in community and agricultural outreach to counter any bias.

5.4 Information transfer

Within-country exchange

One factor that has become clear from a consideration of the historical development of water harvesting in Kenya and from discussions in Togo, Tanzania, Botswana and Mali is the power and necessity of effective information transfer. This is particularly true for water tanks. In Kenya, rapid replication and an increase in organizations carrying out standing and ground tank construction followed the printing and dissemination of technical guides by the UNICEF Village Technology Unit in the 1970s and early 1980s. A whole range of hybrid designs were developed from these guides and from S.B. Watt's manual on ferrocement tank construction (1978). Some have subsequently appeared in Tanzania and Botswana (Hasse, 1989). However, no mechanism was created for feedback. Refinements such as the use of a cheaper reinforcement, a better filter, a simpler and more long-lasting roof, or a first-flush device are not well communicated except through rare conferences between project managers such as the 1987 Limuru workshop in Kenya. The forum of the four Rainwater Cistern Systems Conferences held in the Far East and Hawaii has not been widely used by Africans to publicize their experience.

Between-country exchange
Whilst there may be instances of information transfer within-country, there is little evidence of between-country movements. Planners and individuals in Tanzania and Botswana are generally not aware of the experiences in Kenya and vice-versa. In water harvesting programme proposals in Tanzania, it was requested that planners be allowed to go on fact-finding missions to the Far East rather than other African countries even though this review has shown the broad nature of experience existing within the continent. There appears to have been no exchange between Mali and Togo and very little information from the anglophone countries is transferred to the francophone countries.

Most information transfer focuses on the technical details of water harvesting system development and not on the socio-economic aspects. Few programmes bother or are able to publicize their experiences in the community aspects of water harvesting, especially the difficulties and limitations of adopting a certain approach. The focus on technology has led to insufficient analysis of methodology and to a lack of well-known, successful models for the promotion, implementation and successful management of community-wide water harvesting.

5.5 Wider considerations

Raising quantity and quality service levels

Water harvesting when used as a main supply, unless applied at a widespread scale at the household and communal level, may only be able to provide a partial service level. The consequence is that users may have to resort to traditional water sources for part of the year, negating some of the health benefits achieved through provision of improved water. However, this still constitutes a considerable improvement. Experience has shown that, wherever possible, a mix of systems is required providing water to households, small community groups and complete villages. This exploits the full range of water potential within the environment. Both temporary and permanent sources need to be developed recognizing that not all sources can be expected to last complete dry seasons and that convenience is as valuable as permanence.

For drinking water supply, the use of surface catchments raises the possibility of contamination by faecal bacteria and other disease organisms. Where storage is sealed or well managed, these possibilities are reduced to acceptable levels. The management and environmental hygiene requirements are quite high, especially with surface catchment reservoirs and serious attention must be given to raising community awareness to these dangers and their responsibilities with respect to water source protection.

Financing implications

Compared to conventional supply systems like stand-pipe connections, water harvesting involves considerable capital expense that is often outside the abilities of households or communities to pay. Instead of payment of a connection charge and then an annual water tariff, costs of the system fall almost wholly as capital costs and users are faced with paying the equivalent of 20 or 30 years supply in the first year. This makes the technology unattractive, especially to individuals used to collecting water for free from traditional water points. Many are unwilling to make these major investments, particularly if they do not own the land on which their home is built or the fields they farm. Consequently, many programmes have offered subsidies although only a few have had any systematic method for distributing these subsidies within a community. Even fewer have explored the more complex issues of loans, income generation and cost-recovery. This is one area that needs further exploration to determine the relative merits and potentials of different financing strategies.

Sustainable systems

A major objective of all projects including water harvesting as a community water supply option must be that system construction and management should be sustainable. Creating such a condition involves:

- creating real awareness about the importance of improved water supply and the benefits of the systems constructed;
- involving communities in decision-making from the beginning;
- training local community members in construction of the systems they prioritize;
- organizing a permanent financial structure and methods for cost recovery, re-investment and operation and maintenance;
- focusing on women as prime targets/agents for water harvesting system development through their involvement in management, technical and financial aspects of projects;
- developing and encouraging small cooperative societies.

If this is not accomplished, the development of water harvesting systems with static storage capacity provides a continuously diminishing service level which is not suited to the developing world conditions of rapidly increasing populations. This is an important observation. Technologies developed by some programmes, for instance those in Togo, are constructionally sound but are too complex or too expensive to be replicated at a village level. It is vital that technologies used are within the reach of the skills of local craftsmen although of course, some large-scale, complex systems must still be constructed to take advantage of large potential water sources.

Another important observation from the five countries is that at present, women are hardly involved in external intervention projects, despite their traditional roles in water management, homestead construction and agriculture. From water harvesting projects in which women are already involved as well as other rural water supply projects, much is now known about changing attitudes and the development of knowledge and skills that involve women (van Wijk, 1985). This knowledge is critical for the success of the more long-term, capacity-building oriented projects.

For governments, such a programme of water harvesting is difficult to contemplate, especially one using rooftop systems. Their use to provide safe water to households, especially in areas of low rainfall and long dry periods, involves: high capital expenditure, extensive community mobilization and skills training, technical support, and the development of a financing system linked to local income generation. Because of climatic extremes, water supply may not be assured and users may have to resort to traditional water points for all or part of their daily supply. Without effective user management of the supply system, water quality can deteriorate so that it may be only marginally better than the traditional points themselves. In the five countries it seems that many ESAs and governments are not geared up to working this way, trained manpower is in short supply, and communities are not used to taking such an active role in their own development, relying on the government to provide basic services. However, since there are areas in each of the five countries in which water harvesting seems to be the only viable technology to improve water supply and agricultural productivity, these issues must be addressed on a long-term basis if any kind of sustainable improvements are to be made.

PART II: INDIVIDUAL COUNTRY REVIEWS

6. Botswana Country Review

6.1 Introduction

The Department of Water Affairs has the main responsibility for domestic water supply in Botswana. It concentrates its attention at the village-scale on the preferred technology of pumped and piped groundwater to public standposts and house connections. Safe water has been provided to all of the 18 major villages and around 300 of the 365 rural villages, mostly from over 15000 boreholes. Yet during periodic droughts, many boreholes dry up and the government has had to use bowsers to supply a number of villages. Moreover, the village-level approach has failed to reach the smaller settlements in the "Lands" areas. Most families have rights to farm in the Lands and spend all or part of the year there relying mostly on traditional sources such as dug wells, pans, rivers or ponds. The average distance to permanent water sources for Lands homesteads was 10 km, with a range of 1 to 28 km (Ainsley, 1984) whilst the 1986 government statistics showed overall access to safe water in rural areas to be 46%. Rural health workers indicate that the incidence of diarrhoea rises when village-dwellers go to farm in the Lands each year and stop using reticulated water (UNICEF, 1989a).

Water harvesting is being promoted as a suitable water supply system for domestic and cattle water supply in the Lands by a number of government agencies. Climatically, the more heavily populated eastern areas are quite well suited to water harvesting. Average annual rainfall varies from around 300 mm to over 550 mm with most rains falling between October and April, many as heavy thunderstorms. The number of rain days range from 28 in the south to 51 in the north. This gives rise to large periodic amounts of surface water. However, the torrential flows produced soon leave the area and remaining surface waters evaporate or seep away leaving only the sub-surface stores. Collecting and storing this surface water can provide extra volumes of water for use in the five month dry season. This is already being done in a number of ways.

Use of rooftop harvesting systems is a traditional partial supply source in Botswana. A survey in four small villages (Gould, 1987) showed that 46% of households collected roof runoff as a supplementary supply at various times during the year. The Ministry of Agriculture, through its Arable Land Development Programme (ALDEP), has developed a groundtank storage system for harvesting water from farmers' threshing areas. In addition, its Small Dams Unit have built earth dams for the watering of cattle and increasingly as sources of domestic supply for the farmers. In larger villages and towns, the Ministry of Local Government and Lands (MLGL) provides rooftop catchment tanks as a back-up or supplementary supply for most new public buildings such as schools, health clinics or government houses.

6.2 Technology aspects

Rooftop catchment and tank systems

The traditional method of water harvesting practiced in Botswana is the positioning of pots and pans by families under the eaves of their thatched roofs. Additionally, thousands of roof catchment tanks have been constructed throughout the country by Town Councils to catch runoff from the iron-sheet roofs of public buildings such as schools. Designs are provided by the MLGL for either a 10 or 20 m^3 ferrocement or brick cylinder standing tank and are built by commercial contractors. Use of ferrocement tanks began with the Botswana Technology Centre (BTC) who promoted construction through the provision of formwork, manuals and training courses for artisans. Since 1987, they have not been active in promotion. Those previously involved now have reservations about the ferrocement tanks due to quality control, higher relative cost to brick tanks and the need for skilled or closely supervised labour. However, the ferrocement tank is still the preferred by the Chief Architect at the MLGL. Where contractors skilled in tank construction are not available, pre-fabricated iron tanks are used.

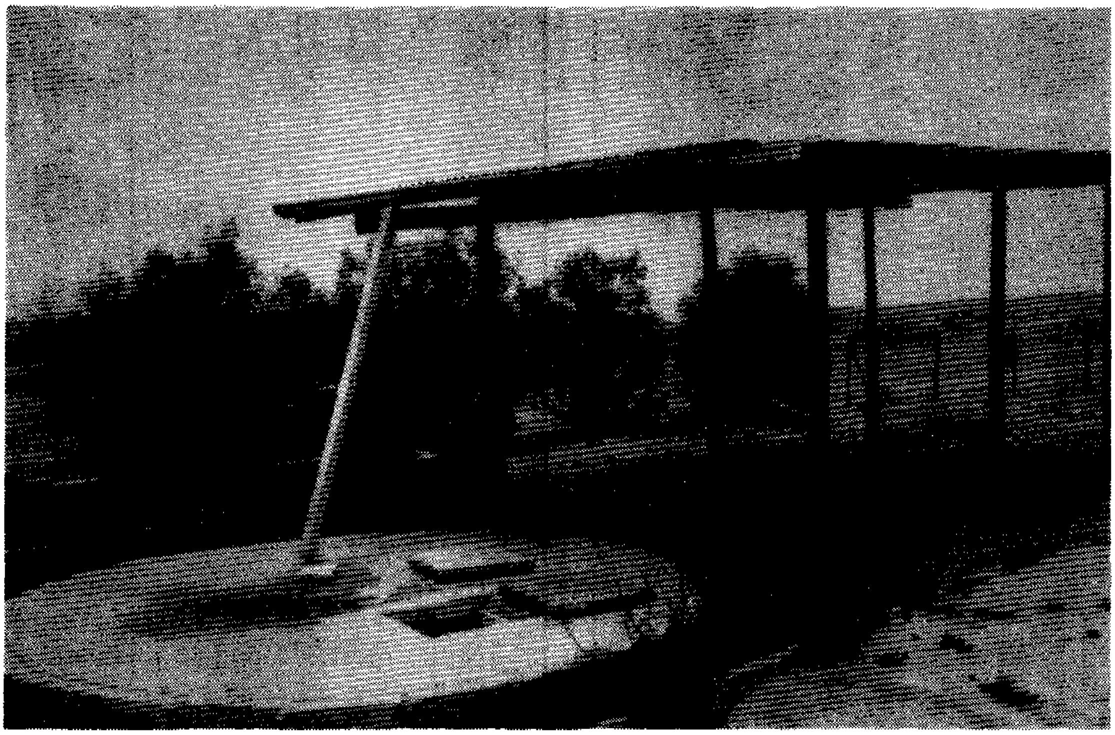

Figure 7: Prototype of new ALDEP groundtank/roof catchment (photo: Lee, 1989).

For application in rural areas, ALDEP is currently testing a rooftop catchment system for farmers that comprises a 40 m^2 iron-sheet roof supported by six poles (the skeleton of a new farmhouse), guttering, a downpipe, a 7 m^3 pre-fabricated polyethylene tank imported from South Africa and a small direct-action handpump for hygienic water extraction (Figure 7). This will replace its groundtank package if proven successful and attractive to farmers. The design details are illustrated and described in Appendix III.

Surface catchments and reservoirs

Although rural populations have used surface water sources and shallow groundwater as traditional supplies, there is little evidence that systems of improving, enlarging or organizing the use of these sources have evolved.

In 1982, ALDEP developed a design for a groundtank comprised of a hole in the ground lined with brick and mortar or ferrocement and fitted with an iron-sheet or ferrocement roof with a covered access hatch (Figure 8). Specialist masons skills are required for construction. Quality control is important otherwise tanks will crack and leak. Roughly 25% of tanks built in the first two years experienced these problems (Ainsley, 1984).

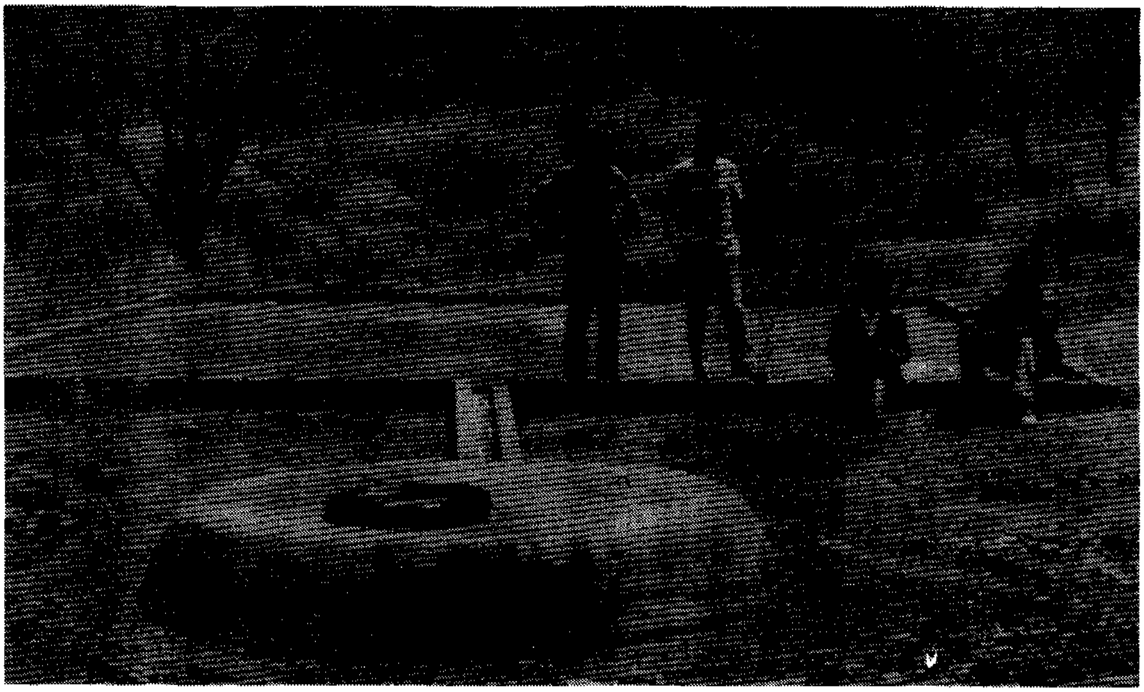

Figure 8: Existing ALDEP groundtank and surface catchment (photo: Lee, 1989).

The standard design is 10 m^3, but in reality sizes vary from 8 to 29 m^3 with an average around 17. The threshing area is usually plastered with mud and dung and measures around 150 m^2 although some farmers invest in a permanent concrete surface. The area has a raised edge and the drain is constructed at its lowest point. Water generally enters the tank through a pipe connected to a circular drain filled with rocks to act as a coarse filter. Some tanks have been built with a coarse wire mesh outlet rather than a drain and a fine mesh screen at the entrance to the tank. Water is extracted from the tank using a rope and tin. Without proper and careful hygiene and management of the tank, water quality is low.

Small earth-dams of varying sizes have been constructed with government support, usually in response to specific requests by local communities or as a crisis measure as part of the Drought Relief Programme. Little data is available on runoff and so broad estimates are used in calculating dam designs. The University of Botswana currently has a research programme designed to produce some hard data on runoff potential from Botswana catchment areas. Most earth dams have been constructed with heavy earth-moving equipment with a rock facing and reinforced spillway. Only a limited number of small dams have been built using labour-intensive methods.

Considerable numbers of sand-rivers cross the more populated eastern Botswana and there is a high, currently untapped potential for improved systems to be built where traditional ones are now used by around 65% of the rural population. These sub-surface dam technologies are not well known in Botswana. Similarly, there is a high potential for rock catchment construction in areas with large rock outcroppings.

Runoff farming to increase direct infiltration

ALDEP is trying to introduce soil and water conservation to Botswana and is developing standard systems to improve direct infiltration on fields. Systems being tried by model farmers include contour bunding and ploughing, and gully plugging. A few macro-catchments which use runoff water harvested outside a field have been constructed as part of a research project by Intsormil and the SADCC. So far, these systems, whilst increasing yields, seem to hold little potential for individual farmers because of the management requirements needed to prevent water logging and ensure equal supply to different field sections.

6.3 Social, economic and environmental considerations

Cost aspects

There is no clear insight into the costs involved with Botswana water harvesting systems, particularly in dam construction, as cost components are covered from different sources including ESAs, national and local government and local labour. The Small Dams Unit of the Ministry of Agriculture is planning to establish a cost overview on the basis of their previous constructions. Costs of the four main tank systems are better known and show considerable cost differentials (Table 6). Prices include material and labour but exclude the cost of government organized design, promotion and supervision. The annual equivalent cost (AEC) per cubic metre of water supplied assumes a useful life of 30 years and that the tank will fill twice during each year.

Table 6: Costs of catchment tank systems (US $)

Tank Type	Vol m^3	Cost $	AEC $/m^3
New Rooftop tank (ALDEP)*	7	750.0	1.87
Brick tank (MLGL)**	10	500.0	0.83
Ferrocement tank (MLGL)**	10	750.0	1.25
Groundtank (ALDEP)*	17	325.0	0.54

Remarks: The AEC is the annual equivalent cost
* includes cost of catchment
** excludes cost of gutters

Prices are dependent on imports from South Africa, transport and the cost and availability of local materials and labour. In particular, transport has an important influence such that an MLGL ferrocement tank built in Gaborone would cost $750, whilst in the north at Maun it would cost $1500 and in the west at Seronga it would cost $2250. A 1988 Interconsult tariff study provides comparative costs for the pumped and piped groundwater supplies (Table 7):

Table 7: Costs for conventional water supply systems (US $)

Village Type	Supply l/c/d	AEC $/m^3
Major Urban	30	0.69
Very Small Rural	30	3.30

Remarks: The AEC is the annual equivalent cost

As indicated, piped water supplies are designed to provide 30 litres per capita per day for the estimated population ten years ahead although actual average consumption per capita by piped supply users is 12 litres. The four tanks listed can provide between 6 and 14 litres per capita per day to a family of seven. Providing 30 litres per capita per day would incur greater capital costs through building a second or a larger tank, although the AEC per m^3 would remain roughly the same. In view of these cost comparisons and the actual per capita consumption levels, water harvesting systems can clearly compete with other more conventional systems used in Botswana.

System use

With both groundtanks and earth dams built in Botswana, the prime user of the water was originally designed to be cattle, either draft-power or ranch animals. ALDEP (1989a) still state that water tanks located on the Lands' farmsteads keep draft animals fit by providing them with water and thus help in timely ploughing, planting and other agricultural operations. However, it was found in an evaluation survey (Ainsley, 1984) that owners of ALDEP tanks used them exclusively for domestic supply without any treatment and continued to take draft animals to traditional sources. This appears still to be the case today. With earth dams, people and animals use the water side by side. Because of this, government opinion has now changed. Both water tanks and earth dams have been recognized as key sources of domestic water and attempts have been made to clean up the water source and separate out the water users.

Some water quality data is available for roof and groundcatchment tanks in Botswana (Gould, 1987). Data from ten rooftop catchment tanks indicated that the total and faecal coliform counts lay within WHO limits of acceptability for all but one tank which had no cover. The high streptococci counts are probably a result of bird droppings flushed off the roof. The groundtanks, however, presented a serious health risk since the water is not treated before drinking although the Ministry of Agriculture advises water boiling. In five ground tanks tested, three contained coliform bacteria too numerous to count and all had faecal coliform counts in the range from 15 to 1000. The main source of pollution appeared to be the direct introduction of coliforms during extraction by ropes and tins. The observations concerning unhygienic extraction and lack of water treatment from tanks were confirmed on visits to three groundtanks in Ramotswa, Mahalapye and Maroka. In each, the water was dirty, with a range of fauna present from insect larvae to large toads, and with much vegetal debris. Each tank had one or more poorly maintained features allowing contaminants to enter and the user placed the extraction rope and tin on the ground after use. No user boiled or filtered the water nor expressed any dissatisfaction with taste, appearance or smell.

Their opinions are that the water provided by the tank is of a higher quality than they would drink from traditional sources. No comparative data is available on the water quality of drinking supplies from earth dams although it is recognized that unless steps are taken to prevent contamination, the quality will be as low as that of traditional surface sources. Generally these steps involve fencing off the reservoir area from livestock and providing water to humans and cattle wherever possible via separate watering points.

Socio-economic impacts

No data exists about the number of rooftop harvesting systems developed in Botswana's urban areas, either for private individuals, or for government offices, institutions and homes. There is little information too about the number of earth dams constructed in the rural areas. The Small Dams Unit could not provide figures on how many earth dams have been built, how much storage has been provided, and how many people or livestock have been served by these projects. Gauging the impact of these two technologies on a country-wide basis is not possible. However, the Small Dams Unit admit that the impact of earth dam construction is limited due to the shortage of site investigation crews, and hence the number of dams they can design and build each year. Technicians are currently being sent for studies to university first-degree level to try and solve these shortages.

For the groundtanks introduced to the Lands area, more information is available. The original target for the number of tanks for 1982-89 was set at 2% of the 43000 eligible farming families. Only 475 were taken up by farmers during 1982-89, approximately 400 below target. In addition, this represents only 1.5% of the assistance grants given out indicating that in practical terms, only a low priority was given to water tanks in comparison to other farm technologies such as ploughs. This is in contradiction to views expressed in official circles that water is a major problem for farmers in the Lands. The real impact of the groundtanks is that in total they provide roughly 8075 m^3 of storage, equivalent to a single small earth dam.

According to many organizations including UNICEF and SIDA, women in Botswana should be a major target group in water development projects (Ahlberg et al, 1988. UNICEF, 1989a). Women's traditional and cultural responsibilities demand that they fetch water and manage its use. Female headed households in rural Botswana constitute 48% of the total. They are generally the poorest households due to poorer access to the means of production such as labour and draft power. Although they are recognized as a key, immediate interest group in rural development issues, they are generally excluded from decision making processes on a socio-cultural basis. Earth dam construction has not been geared towards women nor have women's groups been formed. Groundtanks have often been beyond reach of women-headed households due to the required 15% downpayment, and the need for considerable manual labour to prepare the tank excavation and during construction. In male headed households, the men are often content that their wives can get water from traditional sources and many do not want to invest in water.

6.4 Intervention strategies

Technology selection

Up until now in Botswana, technologies have been selected by specialist technical advisors and built for the community or individual households using pre-determined standard designs. Earth dams are designed according to accepted engineering criteria by a specialized team of engineers provided to the Ministry of Agriculture by the FAO/UNDP. Catchment tanks are built in the villages according to designs specified by MLGL architects and in the rural areas from designs provided by ALDEP advisors. Ferrocement structures are preferred by both.

With the current approach to technology selection for tank construction, the use of standard, pre-determined designs takes no account of the resource potential from catchments, nor does it attempt to provide a target service level. Regardless of the family size, water use patterns or the size of catchment, the same tank sizes are built. To provide a better design parameter, a study of how efficiently tanks in Botswana used the available water resources was made. Using an analysis of mean monthly rainfall data from 10 stations and a computer model developed by Latham (1983), Gould (1987) stated the optimum storage tank capacity for Botswana to be that with a volume equal to 40% of the annual runoff from the catchment area. This would provide an annual supply equal to 70% of the annual runoff when considered over the whole year. Primary schools examined had stores equal to only 5% of the annual runoff, although this approach too takes no account of actual water needs which may be much less than the theoretical optimum supplied by 40% storage capacity.

Community aspects

For both small earth dam construction and groundtank construction in rural areas, the Ministry of Agriculture relies on individuals or communities presenting themselves as candidates for assistance. This process of requesting water supply projects should be strengthened by the activities of Agricultural Demonstrators who act as extension agents. However, their role in promoting water developments, particularly the groundtanks, has been largely ineffective due to their small numbers, the large areas they must cover, and their lack of specialist knowledge in water-related issues (Ainsley, 1984a).

To promote tank acceptance and demand for the package, ALDEP makes use of model farmers, who's lands areas are selected as District Demonstration Farms (DDF). They demonstrate the use of tanks to other farmers from the surrounding areas on open-days. Those who apply for groundtanks must fulfil the criteria of having no permanent source of water within one km of the family farmstead and fall into the Model 1-3 farmer categories (ALDEP, 1989a):

Model 1 - no oxen or cattle and less than P3600 total income per annum;
Model 2 - 1 to 20 oxen and cattle and less than P3600 total income per annum;
Model 3 - 21 to 40 oxen and cattle and less than P3600 total income per annum.

With earth dam construction, local groups apply to the Small Dams Unit. Once a local dam-site is recognized, the unit goes on to appraise suitability, designs a dam and fits it into the unit's schedule of operation. The unit finds that demand is often clustered, resulting from a previous project in a given area that has caught the attention of surrounding groups who feel they should also be entitled to government assistance in developing water facilities.

It is clear that the most attention is directed towards the hardware aspects of construction and less to community participation. Additionally, the post-construction aspects of management and maintenance had received little attention as indicated by the poor upkeep of ALDEP tanks and lack of effective activities in catchment protection related to earth dam constructions. Although technically sound, dam construction is not accompanied by a programme of soil conservation and surface water management carried out by the user community to protect the catchment area from erosion. This has led to the silting up of many dams since their construction. The numbers of ALDEP groundtanks built have been limited by a range of factors. Those related to poor community involvement or motivation include acute local shortages of skilled builders and farmers being reluctant or unable to provide labour to dig holes and transport sand and gravel to the tank site. Women-headed households in particular lack manual labour which may exclude them from assistance because they cannot prepare the site for construction.

Financing strategies

Whilst all the water harvesting systems developed in Botswana have a heavy government hand in financing, it differs considerably. There are three main strategies. Water systems are either provided free-of-charge (tanks for institutions), through subsidies (85% for farmers' groundtanks), or by paying the recipient to help build his own system (earth dams), usually $1.45 per person per day. These approaches are consistent with piped water supply financing in which only 4% of all water supplied is paid for directly by the user (Interconsult, 1988).

The goal of ALDEP is to target the poorest of the poor farmers through preferential financing. However, it has done little as yet to achieve this aim. In the rural areas, 70% of the female, and 62% of the male headed households earn less that P100 ($52) per annum (UNICEF, 1989a). The upper ceiling for Model 3 farmers includes a wide range of income groups all receiving the same assistance. Since 1983, each farmer must contribute 15% of total costs as a single initial downpayment. Whilst a Model 3 farmer with an income of P3000 could easily afford the P150 downpayment for a water tank, it is generally beyond the means of poor Model 1 farmers. Because of the lack of success in targeting the poorest households, serious thought is being given by ALDEP to providing a 100% grant to those with incomes below P300.

In all the approaches to financing water harvesting systems, there has been concentration on the construction aspects. In several cases, this has created problems because there has been relatively little attention paid to the aspects that facilitate construction. These include the training of a large body of skilled workers capable of building larger numbers of MLGL or ALDEP tanks or investigating and supervising dam construction projects. They also include the training and equipping of an effective extension team able and qualified to promote water systems to potential user groups. Most officials agree that the major bottleneck in construction has not been the lack of funds but the manpower gap between the largely expatriate designers and planners in the ministries and the communities being served.

6.5 Future perspectives

Botswana's population continues to grow at an annual rate of 3.6% in the country as a whole, and migration increases urban population growth rates to 6.9% (UNICEF, 1989a). Increased attention will be focused on water supply technologies such as water harvesting although as yet, no national coordinated policy for their expansion and promotion has been formulated. In fact there is still a long-running dispute between the Department of Water Affairs and the Ministry of Agriculture over how water should be supplied to the small settlements, the official government policy being the provision of common, centralized services rather than individual household supplies (Ahlberg et al, 1988). However, because of the high cost of extending piped water systems to smaller villages and the need for costly upgrading and maintenance of systems already built, it is unlikely that the piped network will be widened.

Recognizing these difficulties, a 1988 evaluation suggested that wherever a simpler technology could be adopted, it should be, even if the target service level of 30 litres per capita per day could not be satisfied (Natural Resources Services, 1988). Given that the actual average daily consumption in Botswana is 12 litres per capita, this is sensible. A number of water harvesting systems have considerable potential to provide this lower requirement, including existing rooftop and surface catchment systems and others so far not utilized in Botswana such as sub-surface dams and rock catchments. More rooftop catchment tanks in towns and villages could also reduce the load on piped supplies to essential drinking water, making expensive upgrading unnecessary.

There is considerable potential for the use of runoff farming systems to improve direct infiltration and boost Botswana's agricultural productivity. These techniques are currently almost wholly under-utilized. The marginal rain fed agriculture could benefit greatly from simple structures such as earth-bunds and micro-catchments to retain and manage water on the fields. It is likely that the Ministry of Agriculture will begin full-scale promotion of soil and water conservation after the current field-trials end in 1990 or 1991.

7. *Kenya Country Review*

7.1 Introduction

There are twenty-two districts in Kenya that are designated as arid and semi-arid (ASAL) and together they constitute 51 million hectares or 88% of Kenya's land area. In 1986 they contained 7.2 million people subsisting typically on below one hectare of cultivated land and eight units of livestock per family (UNDP/IFAD, 1988). Access to safe water is a reality for only around 15% of the population and many water related illnesses including diarrhoea, intestinal worms, schistosomiasis, eye and skin infections are common (UNICEF, 1989b).

In most ASAL rural locations, providing water for drinking is the overriding priority. Increasingly, attention is turning to various forms of water harvesting as a possible village-level technology option. To date, water harvesting has generally been carried out as a last resort in areas where environmental limitations make the development of conventional sources such as groundwater or spring protection impossible.

7.2 Technology aspects

Rooftop catchments and tank systems

Throughout Kenya, thousands of tanks have been built to catch runoff from rooftops. Most have been based on designs taken from UNICEF promotional guides or from the manual of S.B.Watt (1978). The smallest storage systems include cement water jars (0.5 to 2 m^3) and basket tanks (4 to 9 m^3). Thousands of cement jars have been built following promotion by UNICEF in the 1970s. They are built by plastering mortar around a wet sacking mould stuffed with wood chips. In some cases, alternative catchments are used for these small tanks. At Kamujine, women make Sarisa catchments by sewing four plastic sacks together and suspending them from four poles (Iles, 1989). This forms a 6 m^2 catchment and water runs off into a simple gutter and down to the storage vessel (Figure 9). The basket tank is based on a Thai design and introduced to Kenya by UNICEF. A Kenyan granary store made from woven sticks is positioned on a pre-cast concrete foundation and plastered inside and out over a wrapping of reinforcing binding wire. Tanks up to 9 m^3 were constructed. Building was recently stopped due to problems with cracking and worries about tank lifespans. More recently, the Catholic Diocese in Kitui has been experimenting with a 9 m^3 tank reinforced with sisal pieces. In Muranga, local craftsmen use the basket technique to rehabilitate leaking iron tanks, wrapping them with chicken wire and plastering both sides.

Medium-size storage systems are commonly ferrocement standing tanks (4 to 40 m^3). There are two main types in Kenya. The first are smaller ones built for individual households usually using formwork made of jointed pieces of iron-sheet. Appendix IIa contains illustrations of the principle of construction of standing tanks made by the plastering of an iron-sheet mould wrapped with wire. Appendix IIb contains an example of the costing and construction of a proven Catholic Diocese of Machakos 13.5 m^3 tank made by filling the space between inner and outer formwork with mortar and reinforcement. Larger tanks are built by plastering around a cylinder of BRC weld-mesh coated with chicken-wire and used for institutions such as schools. With both, a pipe and tap is fitted at the base.

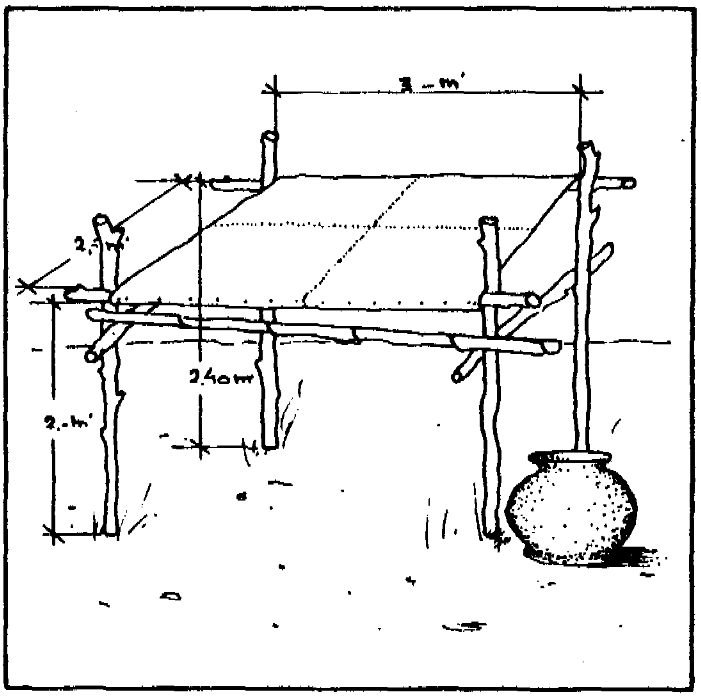

Figure 9: Sarisa catchment system (after Iles, 1989).

The largest systems are sub-surface groundtanks with volumes from 50 to 80 m^3. In Kenya they are generally ferrocement-lined, excavated hemispheres with a 60-100 cm high cylindrical extension and an iron-sheet roof. Appendix I illustrates aspects of the construction of the groundtanks built by the Danida Mutomo project (Lee and Nissen-Petersen, 1989). The tank design was originally promoted by UNICEF through their village technology unit. Those built by KWAHO/WaterAid in Kibwezi have a domed ferrocement roof made using BRC weld-mesh reinforcement. The best designs use a handpump for sanitary water extraction. Many consider the ferrocement groundtank to be the best technical option to date. It is relatively cheap for its size, materials are more easily obtainable, skill requirements are lower, self-help input is larger, and curing is better because partial filling with water and the damp earth outside prevents cracking (Waterkeyn, personal comment, 1989).

A recent initiative designed to overcome the fact that many potential users of this technology do not have a suitable roof surface has been adopted by the Catholic Diocese of Kitui. They are promoting a 9 m^3 ferrocement standing tank combined with a 35 m^2 iron-sheet roof supported on six poles. By building up walls, this structure can be used by families to create a new home. For a general illustration see the example from Botswana in Appendix III.

Surface catchments and reservoirs

Sub-surface ferrocement or soil-cement lined groundtanks have also been paired with surface catchments such as compounds, roads and rock outcrops as well as rooftops. With these, the design sometimes omits the wall extensions and roofs.

Rock catchment reservoirs are created by the construction of a simple rock masonry gravity wall around a hollow or across a valley in a rock outcrop (Figure 10). They are designed using a simple formula based on safe ratios of base thickness to dam height. Dams up to 5 m high have been constructed. The rock catchment areas are tapped to their maximum extent by simple stone and mortar gutters stuck to the rock face bringing runoff water from across the rock to the reservoir.

Figure 10: Rock catchment dam, reservoir and rock gutters (photo: Lee, 1988).

Sub-surface dams are also quite common in southern Kenya. They consist of a vertical impermeable barrier through a cross-section of a sand-filled seasonal river bed. A ditch is dug at right angles across the river and into each bank, preferably where a rock dyke protrudes. This provides a solid, impermeable base onto which a simple masonry wall, mortared on the outside, can be built in the trench (Figure 11). In some situations, the height of the wall is raised by 50 cm increments to form a sand-dam, gradually building up the sand level upstream by catching the moving grains whilst allowing silt and clay to flow downstream. Where the river is not underlain by rock, a trench is dug down until more impermeable fine clay material is found. The trench is filled with an impermeable barrier of compacted clay. Care is taken with each to ensure there is a seal between the vertical barrier and the impermeable layer beneath the sand. If not, water is lost. The barrier is extended into the banks to prevent lateral seepage and side erosion. Dams are not built in rivers where the course of flow changes wildly or periodic erosion of the river bed by deep gullies occurs. Where sand-dams are constructed, care is taken to protect the downstream side from scour erosion by the overflow water. Water is taken out by a protected shallow well situated upstream where the sand is deepest and water will collect, or by seepage through a filter box into a gravity pipe that runs through the dam to a point downstream. The principles of sand and sub-surface dams are shown in Appendix V.

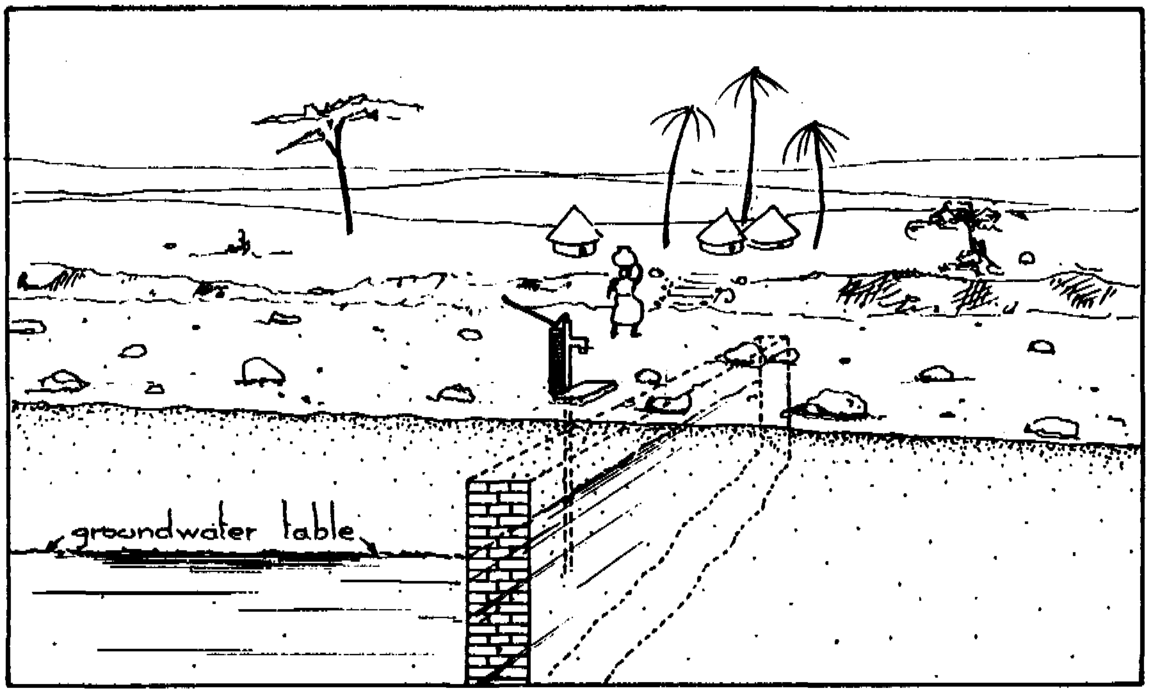

Figure 11: Sub-surface dam (after Nilsson, 1988).

Earth dams are built around the downstream end of natural depressions or across the valleys of small seasonal streams in Kenya. Most have been built by bull-dozers and are equipped with a concrete spillway. Some have been built by labour-intensive methods using animal traction to move the earth. The latter are not more than 3 metres high and have a stone covered spillway and apron. Dam construction must be carried out within a single dry season so that floods will not erode the unfinished structure. Each dam needs a fenced perimeter, gravity out-take pipe and some catchment protection to prevent erosion. The maximum capacity is designed to be greater than the estimated supply needed to allow for evaporation and seepage losses. Many dams have a design life of 10 years because of the high potential for erosion and siltation in the arid areas where they are constructed.

Runoff farming to improve direct infiltration

A number of systems for improving direct infiltration into farmers' fields have been used with some success in Kenya. They work on the principle of selective runoff and infiltration. There is a defined catchment (runoff) area, and a defined cultivation (runon) area. The ratio of their sizes depends on a number of factors including the total and type of rainfall, the slope gradient and the infiltration capacity/runoff potential of the soil. It is quite site specific and can be expected to vary also according to the plants grown and their water requirements. Whilst more research is required on this subject, some broad guidelines have been produced for the ASAL zones of Kenya. The recommended ratios of catchment to cultivated area (CCR) required to ensure improved harvests for at least two out of every three years in the different agro-ecological zones (AEZ) of Kenya are shown in Table 8 (UNDP/IFAD, 1988). The additional water from runon can be considered equivalent to extra rainfall on the cultivated area.

Table 8: Recommended catchment to cultivated area ratios

AEZ	Annual Rainfall	CCR
iv	700 - 850	1 - 2
v	550 - 700	2 - 5
vi	300 - 550	5 - 10
vii	200 - 300	10 - 30

Remarks: The AEZ is agro-ecological zone
CCR is catchment to cultivated area ratio

The five major types of systems used around the country are in order of size: micro-catchments, fanya-ju terraces, contour bunds, semicircular bunds and trapezoidal bunds. They have previously been described in the main report.

7.3 Social, economic and environmental considerations

Cost aspects

Project managers in Kenya recommend that prior to technology selection, a full, local, up-to-date breakdown of costs should be carried out before any decisions on system affordability are made because cost estimates are notoriously unreliable. However, a number of cost data were identified during the review (1989 wherever possible) for different water harvesting systems and are listed in Table 9.

The annual equivalent costs (AEC) per m^3 supplied is calculated for rooftop catchment tanks by assuming that the tanks are filled three times each year over two rainy seasons, that all water is used and that the tanks last for 30 years. Recurring costs are assumed negligible as explained in the main report, but the possibility of high costs due to serious maintenance problems should be kept in mind. Rock catchments, and sub-surface dams are also expected to last 30 years but their supply is assumed equal to their capacity. The average Kenyan well is assumed to cost $2000 to construct and equip and serves 250 people with 25 litres per capita per day over a lifetime of 30 years. Thus the well supplies approximately 2300 m^3 per year. This does not take into account the fact that the amount of water taken is often less than the capacity and therefore costs per m^3 can theoretically be reduced if consumption is increased. In contrast, consumption in the dry season is limited to the residual storage for all the water harvesting systems listed. UNDP/IFAD assume that rock catchments, sub-surface dams and shallow wells have recurring costs for operation and maintenance proportional to the amount of water supplied, and use $0.033 per m^3 as appropriate based on their experiences in Kenya. This cost is included with construction costs to give the AEC figures.

Table 9: Costs of some water harvesting systems in Kenya (US$)

System	Vol m^3	Cost $	AEC $/$m^3$	ESA
Ferro standing	5.5	180	0.36	Plan Inter. Embu
Ferro ball	7	168	0.27	Danida, Mutomo
Basket standing	8	250	0.35	WaterAid, Muranga
Ferro standing	9	221	0.27	CD Kitui
Ferro standing	10	250	0.28	CD Meru
Ferro standing	10	250	0.28	UNDP/IFAD estimate
Ferro standing	13.5	630	0.52	CD Machakos
Ferro standing	21	534	0.28	Danida, Mutomo
Ferro standing	25	1111	0.49	CARE, 10 Districts
Ferro standing	30	1073	0.39	UNICEF, Kitui
Masonry standing	50	3500	0.78	Plan Inter. Embu
Ferro groundtank	70	1750	0.28	UNDP/IFAD estimate
Ferro groundtank	75	1937	0.29	UNICEF, Kitui
Ferro groundtank	78	872	0.12	Danida, Mutomo
Ferro groundtank	80	2000	0.27	WaterAid, Kibwezi
Shallow well	2300	2000	0.06	UNDP/IFAD estimate
Sub-surface dam	3500	8250	0.11	UNDP/IFAD estimate
Rock Catchment	13000	21000	0.09	UNDP/IFAD estimate

Remarks: The AEC is annual equivalent cost
ESA is external support agency

The table shows that for Kenya, the AEC of rooftop catchment systems is considerably higher than surface catchment systems, which themselves are higher than a more conventional rural water supply system such as a shallow well with handpump. It also shows that there is considerable variation in the cost of water supplied from different rooftop tanks of similar sizes and methods of construction. Partly this will be a result of differences in costing between ESA managers, but also reflects the fact that designs are not standardized, and constructions vary in the amount and type of materials they use and how much skilled labour they employ. The AEC varies from 0.12 to 0.27 for ferrocement sub-surface ground tanks, and from 0.22 to 0.49 for ferrocement standing tanks. The masonry tank built by Plan International provides an anomaly against other similar sized tanks built from ferrocement, indicating the unnecessary additional expense incurred in using this type of technology.

Additional cost data for Kenya is available for various runoff harvesting techniques for agriculture (UNDP/IFAD, 1988) and listed in Table 10. It is based on knowledge of the cost of self-help labour ($0.7 per day), the amount of earth that can be dug and moved per day by one person, and the dimensions and densities of structures. The density depends on the catchment to cultivated area ratios.

Table 10: Costs of runoff farming system construction in Kenya (US$)

System	Unit Costs	Hectare Costs
Microcatchments	$0.35 - 0.47 each	$218 - 294
Fanya Jus	$0.12 - 0.23 per metre	$ 60 - 460
Contour Bunds	$0.35 - 0.47 per m3	$ 52 - 202
Semicircular Bunds	$4.00 - 6.00 each	$ 64 - 96
Trapezoidal Bunds	$0.35 - 0.47 per m3	$ 87 - 395

System use

Several thousand rooftop and tank systems have been built with the help of ESAs during the 1980s and their types and numbers are listed for different areas in Kenya in Table 11. A number of tanks built at institutions are designed to promote the benefits of water harvesting from rooftops to the surrounding population as well as providing much needed cleaner water for school children or clinic patients. However, many of them are clearly too small to achieve both of these aims. Tanks of 25 to 50 m^3 built at schools have run empty early into the dry season. For schools with 250 pupils such as the Ngini Primary School in Kitui, a 30 m^3 tank provided by UNICEF which is full at the start of a hundred day dry season will provide only 1.2 litres per child per day. In contrast, larger 80 m^3 litre ground tanks have kept water all year round.

No universal method has been developed for determining which size of tank to select for a given situation. As with the UNICEF example, the volume provided is often determined more by the technology selected than the water need. More systematic rules are available. SIDA in Tharaka built multiples of 20 and 40 m^3 ferrocement tanks for schools to supply 10 litres per child per day by using:

$$\text{Storage Capacity} = 0.03 \times D \times T$$

where 0.03 is a constant, D is demand in litres per day and T is the longest dry spell in months. To fill this requires a:

$$\text{Roof Area} = 450 \times N/R$$

where A is width x length, R is the 90% probability annual rainfall and N is the total number of students x the rural water demand (D). Meanwhile two AMREF workers are also trying to provide systematic rules for tank sizing relative to roof size and rainfall, water use per day, and the average number of dry days. Data has been taken from Meru, Mandera, Kitale, Makindu and Marsabit. The rules are to be used by public health technicians and will be as simple as possible.

Table 11: Numbers of rooftop catchment systems built in the 1980s.

Area	ESA	Approx No.	Vol m^3	Tank
Embu	Plan Intern.	40	50	standing
	Plan Intern.	~200	5.5	standing
Karai	UNICEF	~300	9	basket
Kibwezi	WaterAid/KWAHO	~42	80	ground
Kitui	CD Kitui	~1000	9	standing
	UNICEF	70	30	standing
Kwale	SIDA	~10 /yr	30	standing
Machakos	MIDP	~500	25-225	standing
	CD Machakos	1500	5.4	standing
	CD Machakos	~100	13.5	standing
	Private Contr.	~3000 (60/mo)	5.4	standing
Meru	CD Meru	~250	9	standing
Muranga	WaterAid/ICA	~300	8	basket
Mutomo	Danida	288	78	ground
Tharaka	SIDA	10	20-40	standing
10 distr.	CARE	150	30	standing

Remarks: ESA is external support agency

Results of a questionnaire issued by the Catholic Diocese of Kitui, which is included as an example in Appendix VIII, indicated that 9 m^3 tanks promoted by them were used on average by 12 people providing 5 litres per day during the longest dry seasons. Savings for these groups in terms of daily walking for water were considerable, on average 6412 km per tank, or over 17 km per day.

Little data is available on the quality of water provided by water harvesting systems in Kenya. Rooftop catchment standing tanks with taps and groundtanks with handpumps are assumed to supply safe water. Those without sanitary extraction or without roofs and filters are assumed to supply poorer quality water as are tanks fed from surface catchments. Rock catchments and earth dams are open to various organic pollutants including faecal coliforms. However, they are considered safer than traditional surface water sources. Sub-surface dam water is thought to be the highest quality because it experiences slow-sand filtering.

Socio-economic impacts

A criticism of many water harvesting systems in Kenya are that they are inappropriate because they often run dry, providing water for only a few months following the rains. Women still have to walk long distances during parts of the year and families still drink water from contaminated traditional sources. Not all water harvesting systems are designed to provide a complete drinking water supply. Some are planned from the start as supplementary sources. A good example is the Sarisa water catchments. The six square metre plastic sack catchment can provide 4000 litres from 750 mm of rainfall assuming 90% runoff, roughly 60 litres per rain day. If the women using them have enough storage vessels, the collection of this runoff frees up sufficient time for planting, weeding, crafts and child care during the time of peak demand on their labour.

Given the large variation in annual rainfall in ASAL regions, there will usually be periods when water shortages occur as virtually all water points dry up before the next rainy season. For example at Mutomo in Kitui, the largest annual rainfall recorded is six times that of the smallest. Statistically, 80% of all water harvesting systems dry up at least every third year (Danida, 1987). With runoff farming systems, the UNDP/ IFAD report states that increasing direct infiltration will only produce secure crop yields in two out of three years, an increase from one in three years without the systems.

7.4 Intervention strategies

Technology selection

ESAs and government bodies have historically made technology selections and have preferred conventional and communal systems such as spring protection and groundwater exploitation. Several changes have taken place in the last decade that have resulted in a larger role for communities in technology selection and a wider range of technologies being selected. Firstly, ESAs have increasingly concentrated their efforts in areas where groundwater and spring sources are not available and where a number of partial supply sources as opposed to a single permanent source must be exploited. Secondly, the range of technology options has expanded following development and promotion of water harvesting systems. Thirdly, the Government of Kenya has instituted the District Focus Strategy, giving the communities a larger role in decision making, especially in terms of prioritizing developments and in selection of water sources. Requests for assistance are put to development committees and a community is assisted if it has a priority need and its proposal is economically and technically feasible.

Whilst small ESAs often select only one technology, larger integrated projects recognize the need in ASAL regions for multiple sources of supply. For example, from 1982-88, the Danida Mutomo project developed 288 groundtanks, 108 rock catchment dams, 25 sub-surface dams, 125 shallow wells, 11 tube wells, three spring protections and rehabilitated 15 earth dams. They help develop a range of technologies at household, group and community levels because:

- each raises the carrying capacity of the others by reducing the overall load on resources;
- larger, perennial systems provide back-up supplies;
- the hardship in terms of journey to water increases more slowly as the dry season continues;
- the population can always find an improved source rather than resort to unimproved traditional water points.

Recently, a review was carried out by FAO consultants of the various types of runoff farming used in Turkana and Baringo. They recommended that three systems should be considered for selection throughout Kenya for crop and rangeland improvement. These were the diamond micro-catchments for tree production, the semicircular bunds for fodder and shrub regeneration, and the trapezoidal bunds for crop production. Additionally, UNDP/IFAD (1988) found that only technologies involving little recurring need for labour and not requiring sedentary lifestyles should be selected for use by semi-nomadic pastoralist communities.

Community aspects

ESAs in Kenya are tending towards longer-term involvement with communities, establishing themselves in specific regions with bases and a network of extensions linked into and supporting the District Focus Strategy. Recent examples include the Plan International programmes in Embu and Meru and the SIDA Tharaka project which work in areas and at scales currently under-served by the Ministry of Water Development, providing coordinated, complementary activities. The District Water Engineers in Meru, Machakos and Kitui indicated that they were happy for ESAs such as the Catholic Diocese to work with households since this is below their scale of involvement and reduces the load on communal supplies they develop. Since the District Focus Strategy was implemented, there has been more coordination in decision making and the division of responsibilities between government and non-government sectors in a particular district. The subject of who to assist, when and how is decided by consensus since the communities, government and ESAs are all represented on the District Development Committee. The assisted generally include the 'rural disadvantaged' who are subsistence agro-pastoralist, especially female-headed and childless households, and have little monetary resources, insufficient labour to carry out daily tasks, no time for extra activities, live furthest from water sources, and are often in poor health.

Amongst the rural communities there is a strong tradition of self-help in agriculture, particularly amongst women members of the community, which makes both village level and household systems appropriate. Group members can relatively easily be organized to work together on communal systems and help each other with household systems in turn. Projects in Kenya usually require groups to make some demonstration of their willingness to participate. Mostly, this takes the form of preparing the site for construction, organizing manpower and delivering all locally available construction materials to the site.

It is generally agreed in Kenya that whilst developing water sources, ESAs should also aim at building up the capacity of communities to continue these developments. Critically, this includes strengthening community organization and technical skills training. The preferred approach to training is to take people who are based in the local community, preferably selected by the community themselves, and train them through on-the-job experience to become fundis. Usually graduates of the local polytechnics are selected because they are more likely to remain in the area if an ESA withdraws and continue as independent contractors. CARE, Catholic Diocese and Danida have all taken this approach. In particular the Catholic Diocese of Machakos have successfully created a sustained system of private builders who continue to build 60 tanks a month on an independent basis.

Many water harvesting systems involve quite a high management input either to maintain water quality or to ensure that water is rationed for key uses (like drinking, cooking and washing hands) so that it lasts out the dry season and has its full health impact. The approaches to operation and maintenance vary widely. For example, some projects such as the Catholic Diocese of Meru provide only verbal instructions, whilst Danida at Mutomo provides practical demonstrations coupled with subsequent monitoring and Plan International at Embu provides detailed written instructions on system use and a timetable of maintenance activities to users. The latter's clear and sensible instructions are included in Appendix IX as an illustration. However, projects providing written instructions and regular monitoring are in the minority.

Financing strategies

In Kenya, almost universally, groups are expected to provide at the minimum a self-help contribution of labour, local materials, and any subsequent operation and maintenance requirements. The labour and local materials generally constitute below 30% of the capital costs and do nothing to offset institutional costs. With structures such as earth or clay-plug dams, the contribution may be considerably higher since few commercial materials are required. Self-help labour is often discounted as a real cost and is excluded from cost details given by projects. However, it is important because time spent on system construction by self-help labourers cannot be used for agriculture, firewood and water collection, or in some cases, income generation.

There is an increasing move amongst ESAs towards the involvement of groups in the financing of schemes, especially those at the household scale. Experiences with loans and repayments have not been successful. The Diocese of Meru and Kitui suffered severe difficulties in recovering loans given to households as part of earlier revolving fund programmes. Householders have little collateral for loans and require flexible repayment schedules due to the insecurity of income generated under the variable environmental conditions, and many default on payments. In some cases loan schemes cannot get off the ground because householders are unwilling to take financial responsibility for improvements such as water supply projects feeling that it is the role of the government to do so. Additionally, they may have no land rights and are unwilling to improve their home and services because of their insecurity. Seed money is limited in amount and availability. Although the Ministry of Culture and Social Services and the Ministry of Planning and National Development have some experience of financing village level initiatives, there is currently only a limited infrastructure in Kenya for small-scale financing and few financial institutions geared up to the supply of thousands of seed investments.

There have been few genuine experiences of full cost-recovery in Kenya. It has usually been attempted only after periods of heavy subsidy and promotional costs for the ESA involved. Examples include the rooftop and tank projects of the Diocese of Kitui and Machakos. The former has moved from providing free and highly subsidized tanks to local households to a programme of only partial subsidy. The latter has switched to complete user-financing. The project originally offered three tank sizes at subsidized rates. They helped develop local finance mechanisms and raised awareness. The promotional phase involved:

- initially, each tank was subsidized 400 Ksh, with one 4 m^3 tank being given free to each group at a communal point they selected to encourage participation;
- the group was instructed in interdependent financing, for example, 50 members paid 50 Ksh per month raising money for two tanks, and so all 50 could be served in 25 months;

- group members were encouraged to collectively fetch materials and assist artisans on each others tanks, and more than one tank was constructed at a time so economies of scale could be utilized;
- an artisan was trained in each group and provided with access to formwork.

Once the promotional phase stopped, the financial management and technical skills provided to the community had created sustained tank demand and production. However, projects like this requiring a significant financial contribution often find that only the most able in the society can participate. This was clearly experienced by the Diocese of Machakos, Plan International Embu and Diocese of Kitui projects, the latter having found that 70% of its assisted tanks were being taken by families in which members had office jobs or owned businesses.

With runoff farming to improve direct infiltration, it has often proven necessary to pay farmers to build systems even though they are the direct beneficiaries. This is especially true where farmers have little history of undertaking self-improvements. Systems have been promoted in the northern areas of Kenya subject to periodic severe droughts and famine such as Turkana and Baringo. Food for work has been used to encourage semi-nomadic farmers to become involved and supply labour inputs. Whilst the systems have boosted participating farmers yields, food for work has caused others to be unwilling to build additional systems without it, and even to stop farming for fear that the flow of food would stop (UNDP/IFAD, 1988). In an Oxfam project in Turkana (Cullis, personal comment 1989), the success of small runoff harvesting gardens has overcome these problems as shown by the fact that the growth in participating farmers has not fallen even though the amount of grain offered as an incentive has been reduced dramatically. In southern Kenya, sedentary farmers were encouraged to construct fanya-jus by incentives such as a free plough per certain number of kilometres dug by a group, or the ownership of jembi's or other farm tools loaned to the group by the project staff. The same groups used to develop water projects were used in the crop improvement programme, in some cases, one development being used as an incentive for involvement in the other. A high level of cooperation was achieved.

7.5 Future perspectives

According to the UNDP, "over the last few years, experimentation has been conducted with small-scale runoff harvesting techniques to concentrate water for improved cropping, range intensification, stock and domestic water. Some of these techniques have achieved technical feasibility and some social acceptance. They have outgrown their pilot phase and enough is known about their parameters for wide scale implementation" (UNDP/IFAD, 1988). The government and ESAs have not yet taken full advantage of these technologies including sub-surface dams, ground (sub-surface) water tanks, roof catchment systems, small pans and dams, and groundwater recharge. These systems will become more important since in many areas, the large conventional water source potentials have now been fully exploited and a smaller scale approach will be required to cope with ever increasing demands into the 1990s. In view of this, in 1989, a new Ministry was formed in Kenya, the Ministry for the Reclamation and Development of Arid, Semi-Arid and Waste Lands. It has overall responsibility for planning and coordination of government activity in the development of the marginal areas, which have been given a priority basis. Draft guidelines for a plan of action for the arid regions for 1989-93 envisage that 25% of all water requirements can be satisfied by water harvesting technologies, 60% from rock catchment dams, 30% from sub-surface and sand-dams, 8% from surface catchments with ground tanks, and 2% from roof catchment tanks. The proposed target financing for all water harvesting investment for 1989-93 is US $50 m, $18 m for domestic and stock water systems, $25 m for crop improvement systems and $7 m for rangeland and agroforestry systems.

For runoff farming crop improvement systems, the target may not be reached by 1993 because the Ministry of Agriculture is not yet convinced that sufficient parameters are known. To promote runoff harvesting on a long-term basis, it feels it must first undertake pilot projects to identify the most effective forms of runoff harvesting for a given district context, and carry out demonstrations to farmers to show the increase in productivity that can be achieved (Mburu, personal comment 1989). On the other hand, it is likely that ferrocement rooftop catchment tanks will be developed more widely than the 2% envisaged now that ESAs accept that the technology has proven feasible for building by locally trained fundis and volunteer labour. KWAHO/WaterAid in particular hopes to widely promote their ground tank through a video and slide-sound show, a small manual and increased dialogue with other ESAs and the training of their fundis.

For drinking water supplies, there is no doubt that both communal and household systems need to be developed on a continuous basis otherwise a relatively constant supply of water will be sub-divided amongst an increasing population. As clearly explained by the Principal Community Development Officer in the Ministry of Culture and Social Services, an implicit assumption is that if small-scale water harvesting systems are adopted as a major development option, they must be replicated on a widespread and numerous basis. At present the sum total of water developments are not keeping up with the rise in population. Many water harvesting projects, because they provide finite storage, provide a static resource and only if they are replicated continuously will they make any sustained long-term impact in a given area.

8. *Mali Country Review*

8.1 Introduction

In Mali, water harvesting for drinking water purposes has received little official attention. The national drinking water policy has focused almost exclusively on the exploitation of groundwater resources through the installation of boreholes and handpumps. This will not succeed in all parts of the country due to the high costs and difficult hydrogeological conditions. In the Mopti region, for instance, groundwater is quite deep, between 40-75 metres and only around 7% of the population has access to a borehole (Rapport sur l'Approvisionement, 1988). The majority of the population still relies on traditional sources such as dug wells. During and immediately following the four-month rainy season, ponds, lakes and streams are commonly used. Some man-made depressions such as excavations for making mud bricks have been developed as traditional water harvesting points in the Mopti region by the lowland Dogon. These sources are used for drinking water even though waterborne diseases like dysentery and guinea worm are widespread and of concern to health authorities. Conditions are similar in other regions of Mali, particularly those in the north of the country.

There is a pressing and well recognized need in Mali to develop resources such as water harvesting for agricultural purposes. The government has national policies for increasing village self-reliance in food production and for fighting desertification. Over the last five years, natural depressions have become a focus of attention. "Aménagement de bas-fonds" programmes designed to increase their water holding potential for livestock watering, gardening and rice cultivation are being implemented through the building of dams and barrages. Little attention has been directed towards these depressions as a drinking water supply.

At a traditional level, water harvesting is practiced in several regions to improve direct infiltration into fields. The Dogon in particular have applied a range of effective, cheap, socially adapted and labour-intensive techniques of soil and water conservation to their farmlands. Some of these techniques have received attention from ESAs such as the World Bank, who in July 1989 organized a seminar on water harvesting in Mali to exchange experiences and discuss possible methodologies. These direct infiltration enhancements are a priority need in zones with less than 800 mm of rainfall.

8.2 Technology aspects

Rooftop catchments and tank systems

There is apparently no experience in Mali of externally supported efforts to develop rooftop harvesting systems by improvements in cistern construction. There are traditional examples of rooftop harvesting, but generally only in the urban areas by households with corrugated metal sheet roofing. Roof runoff is commonly collected in buckets and pots. Reasons given for rainwater collection include convenience, reduction in the need to buy water, and appreciation of water taste and softness. Water collected is generally used for drinking, cooking, laundry and bathing during the rainy season. Few year-round systems are developed, most probably because of the expense of constructing large storage volumes that can hold water for the eight month dry seasons. Water collection from mud roofs is rare, householders indicating that runoff is dirty and bad-tasting. Although runoff is not harvested, mud roofed houses do have gutters to prevent erosion of the house walls.

Surface catchments and reservoirs

There are both traditional surface catchment and reservoir systems and externally introduced systems in Mali. The latter are supported by government agencies such as the Ministry of Agriculture, the Directorate of Waterworks and Energy and the Compagnie Malienne pour le Développement de Textile (CMDT) who work closely with ESAs such as GTZ, UNDP, Peace Corps and Canadian bilateral NGOs.

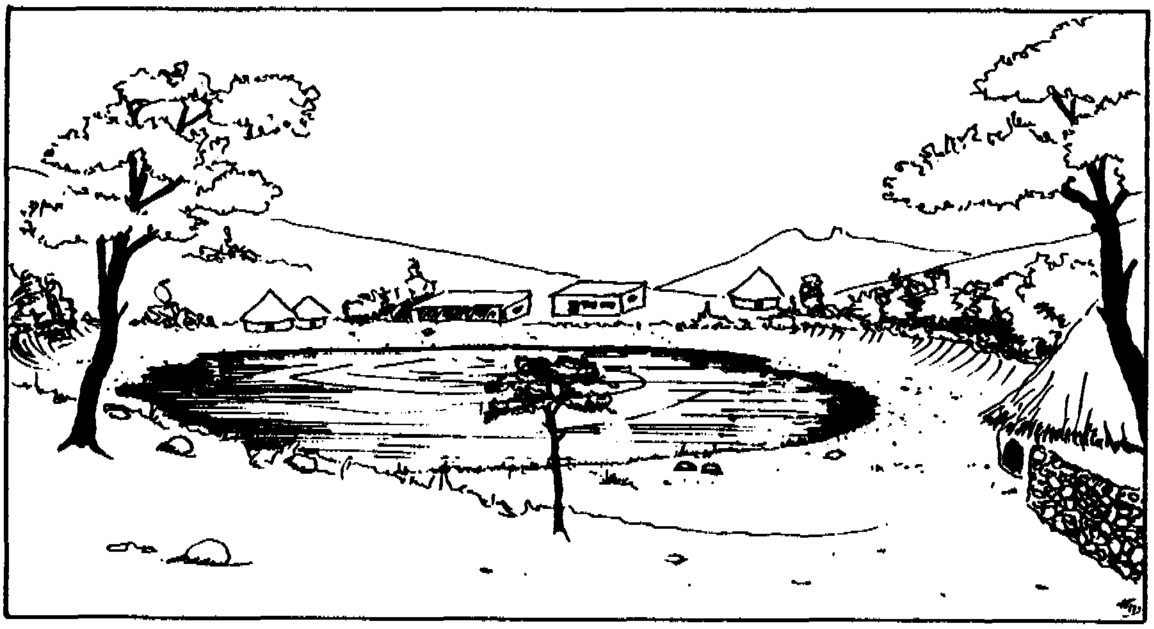

Figure 12: Banco-pit made into a bourogara water source.

A potential source found in most villages are banco pits from which mud is extracted for brick manufacture. Some villages use them as water storage reservoirs. In Dogon lowland villages they are called "bourogaras" and are well-maintained. Dimensions range from 20 to 40 m in diameter and 4 to 10 m in depth (Figure 12). The oldest pits are the best maintained, reinforced with rocks and kept covered with water plants. Villagers feel the plants protect the water against dust, slow evaporation and help purify the water although no studies have been made on their water quality. Some collect run-off from hill slopes and others from the village. Similar to bourogaras are the "jogodoji" which are roughly 30 m^3 tanks dug specifically to collect runoff.

There are three main kinds of improved systems:

- construction of single "micro barrages" across small valleys (water retention dams) of varying dimensions;
- deepening out of lakes and ponds for watering of livestock "surcreusement des mares". This takes place in the northern regions, where pastoralism is important;
- building a series of small dams in shallow depressions. These interventions are most recent and concentrated in the southern regions where rainfall is higher.

Many of the early barrages were simple earth dams. Recently, more complex dams have been introduced to try and prevent problems of dam breaching. An example is the Ntossoni dam in Sikasso region built with support of the CMDT, details of which are illustrated in Appendix IV. It has an excavated foundation and is made from local materials with additional reinforcement of concrete and gabions assembled on site. The core is laterite made from termite mounds and there is a facing of gabions and a flow dissipation basin. The dam is 80 m long, the reservoir 2.5 m deep and the peak storage is 80,000 m^3.

Runoff farming to increase direct infiltration

Many of the improved surface reservoir systems are used for irrigation. In addition, there are a number of systems adopted in Mali, particularly by the Dogon people, to directly increase infiltration, improve crop production and reduce soil loss. Construction is labour intensive and the systems are well adapted to the specific geographic circumstances of the Dogon: shortage of land, degrading soils, sloping fields, heavy run-off and erosion, and low annual rainfall (400-500 mm). They include:

- earth bund microcatchments ("bondes") of varying size (1 m^2 to 100 m^2) and shape depending on slope and soil qualities;
- permeable bunds (rocks, bundled stalks and/or branches) of varying length and orientation, in squares or in parallel lines, each designed to enhance infiltration;
- water collection pockets of 30-40 cm diameter and 10 cm depth, dug on almost flat land with degraded soils, and filled with manure and a few seeds (Figure 13).

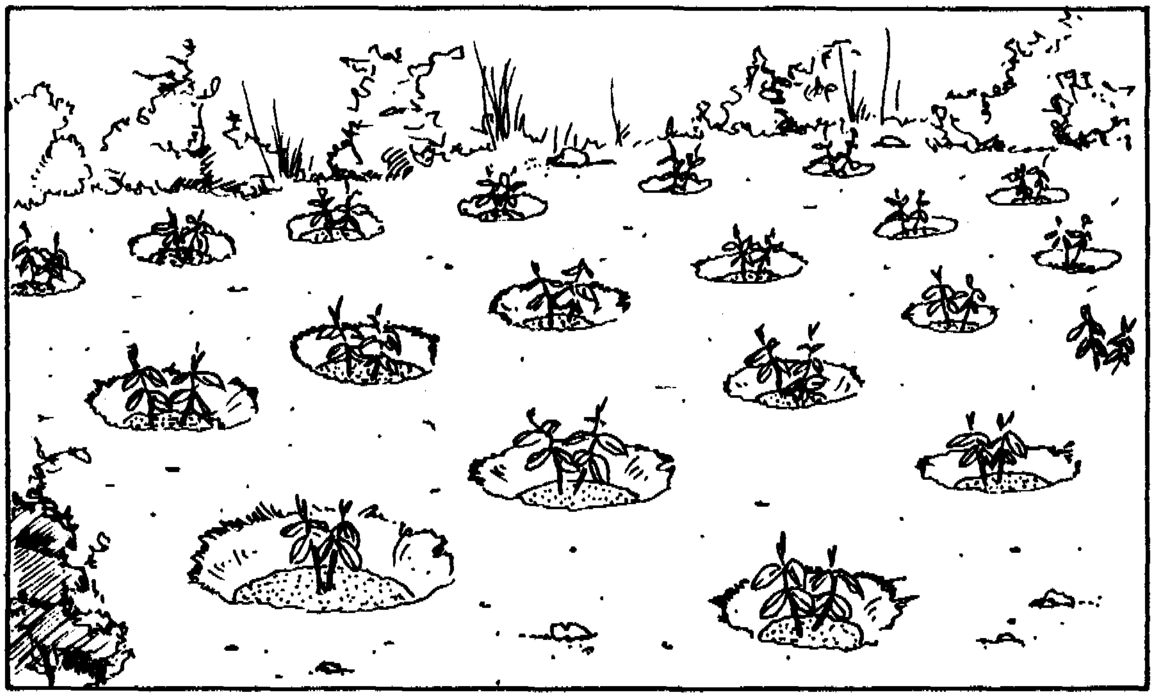

Figure 13: Water collection pockets.

Larger labour-intensive systems have also been built with external support. For instance, permeable rock barriers "digues filtrantes" are built across alluvial valleys. They are check barriers that do not arrest the flow of run-off, but slow it sufficiently to enhance infiltration and sedimentation, and to reduce the erosive force of flow (NEF, 1988). An example is the system of Janveli Maounde. The largest of three barriers is 90 m long, 2 m high and 5 m wide. The two smaller upstream barriers are 50 m long, 70 cm high and 4.5 m wide. Valley-side barriers "diguettes" are about 30 cm high. The first barrier is built in a 30 m wide ravine, the other two upstream where gullies have not yet developed. There are currently about 20 projects in Mali introducing runoff farming systems to different regions. Several are supported by the National Forest Service of the Ministry of Environment and Livestock and the CMDT, both working in combination with ESAs.

8.3 Social, economic and environmental considerations

Cost aspects

There are few accurate cost figures and details of manpower requirements available for the various surface reservoir systems and crop improvement structures developed in Mali. Since many have used self-help labour and local materials, the true costs have not been determined nor have efforts been made to establish a realistic cost-benefit assessment. Traditional systems for surface water collection (bourogaras) and direct infiltration (such as earth bund construction) are developed totally from local materials and labour and involve no commercial cost to the users. Labour input, however, is considerable. Maintenance of these reservoirs does not require as much labour as construction, and in the case of depressions requires an input of a few days, two or three times per year by a group of young men.

Large improved systems are not affordable without external inputs of capital and technical assistance. For instance, the large fortified earth dam at Ntossoni cost 5,441,515 CFA ($17,000) not including the consultants salary or administration costs of the project supporting it. It has an estimated storage capacity of 80,000 cubic metres and is assumed to have a working life-expectancy of 10 years. About 3,000 labourer days were used in construction. The capital cost per cubic metre of water stored is roughly $0.21. Assuming recurrent costs in maintenance of $2,600 (UNDP/IFAD, 1988) the unit cost per cubic metre of water is $0.05. However, not all is available to the villagers due to seepage and evaporation, perhaps of more than 60%. With village labour alone valued at $7,390, it is not conclusive that the dam project was worthwhile. A programme of shallow well construction or smaller water harvesting systems might have provided water for gardens and livestock more cheaply and conveniently.

As an example of check barrier costs, at Janveli Maounde the cost of the 90 m barrier was estimated at $812.5 which includes 480 person days of labour and transport of rock material and excludes tools, donkey carts and project staff (NEF, 1989). Since this barrage directly benefits 1.8 hectares of fields upstream by helping retain soil water, the cost per hectare of improved farmland works out at $450, although there are wider effects related to the prevention of erosion over a larger area. In comparison, the cost of constructing earth bunds would be roughly $100-$400 per hectare based on figures from Kenya.

System use

Water from traditional depression sources is used for household supply, watering animals and gardening whereas the improved versions are promoted for the last two and for fish-farming. With bourogaras used by lowland Dogon, use is regulated so that the water is kept clean and provides a supplementary supply during six months of the year. The smaller jogodojis are used for household water supply or sometimes water is sold to herders passing with their cattle. It is clear that traditional water sources such as the banco pits can make an important contribution to domestic supply although only as a supplementary source. For example, Janvelli Maounde has seven bourogaras. Assuming their dimensions average at 30 m x 30 m x 7 m, the total storage available (not allowing for seepage or evaporation) for the village of 1,200 inhabitants is 44,100 cubic metres. Water lasts for roughly six months per year and is used for animals, gardening, and all domestic purposes including bathing, drinking and cooking. The village also has two wells for additional drinking supply.

Dams constructed for livestock and irrigation water also provide water for only part of the year due to high evaporation and seepage. At Ntossoni, the dam provides water for eight months and so cattle still rely on traditional sources. In principle with these dams, the majority of the village population can profit from this improvement, since most people own cattle. However, it is clear that large cattle owners are the major beneficiaries.

Socio-economic impacts

In the opinion of government authorities, the main problems facing the rural areas of Mali are land degradation and the inability to produce sufficient food for a growing population or for cash-crop export. Introduced water harvesting projects have mostly been aimed at providing water for livestock and crops and stabilizing and preserving soil and water conditions on farmers fields. Traditional systems have had the added aim of providing more convenient and reliable sources of household water. Data to assess the impacts of these various systems in terms of improved yields per hectare and the proportion of the farming population benefiting from the development, however, are not yet known. Many systems are introduced on the assumption that they are beneficial and that they will have a significant impact on food production and land degradation. Little monitoring of results has been carried out. It is suggested by ESAs and widely believed by villagers that dam construction has a positive influence on regional groundwater levels, causing aquifer recharge and improved well yield. However, because of the small-scale and number of developments this is not likely except at a very local scale, for instance immediately adjacent to or downstream of a dam. No evidence is available to support these claims although the UNDP plans to establish a research project to assess any possible relationship.

For Mali as a whole, no information is available on the number of families practicing traditional water harvesting for crop improvement, or over what area. However, it seems to be used on only a small number of fields. Farmers interviewed were convinced of the positive impact on yields, but said they were hampered by lack of time and labour to undertake construction.

Some introduced systems have had negative rather than positive impacts due to unforeseen conflicts and land-use complications, and others have failed shortly after construction. Most dams built in the Koutiala Cercle have exhibited technical problems. A study in 1988 showed that of 14 dams constructed since 1984, five were not able to retain any water, four were damaged but could still hold some water, three were in good state but were repaired and only two needed no repair since construction. To help combat this, the UNDP are planning a research and training program for technicians of government institutions active in implementation of dam projects (UNDP, 1988).

Added examples of negative impacts include the Ntossoni dam which has given rise to a number of conflicts of interest as only a small proportion of the village population benefited from it although all members contributed to its construction. The fact it is 4 km away from the village is a major source of dissatisfaction. The check barrier at Janveli Maounde was washed away in 1989 following construction in 1988 and this has given rise to considerable feelings of frustration amongst the villagers. Up until then, the farmers had pointed out that the millet and the trees on the fields above the last barrier were greener than those below showing the positive impacts. However, only twenty per cent of the population that contributed labour would have benefited due to field ownership patterns.

The use of many dams for gardening, both through flooding and hand-irrigation, causes conflict for several reasons including the need to allocate the flooded land amongst villagers, competition for the best land, competition over the water as the dam level falls, competition between gardeners and livestock owners for water and access across gardening land, and disputes over gardens damaged by cattle. At Ntossoni, women used to practice rice-growing in the valley. They now experience the downstream conflicts of dam construction as their source of padi-field irrigation water has been seriously reduced by the damming of the valley at an upstream location. They cannot carry out their traditional farming. There are also inter-village disputes as those downstream complain that their source of water has been cut-off.

These observations are interesting because development workers often assume women to be major beneficiaries of water harvesting activities, although they generally do not participate in decision making, planning and construction. However, using the example of Mopti, out of the three systems used, women only directly benefit from the bourogaras which provide a more convenient source of domestic water and free up time. The rock barriers were planned, built and managed by men, and structures to improve infiltration are usually only applied on men's fields. The effects of some dams have been negative for women as shown.

The example of Ntossoni dam is like many such projects, focused mostly on the construction of a dam. The plan for the dam was not based on a thorough analysis of the existing situation: land rights and land use patterns, livestock watering and grazing patterns, users needs, market analysis for garden produce, and wider implications. The benefits from gardening are seriously constrained by the lack of marketing possibilities for vegetables. The benefits for livestock are limited by the fact that the dam location is far from the grazing grounds and that concentrating cattle around a reservoir is a major cause of accelerated degradation. With provision of water for cattle being a major objective of most Malienne dams, many areas are under strong ecological pressure from livestock. This results in a lack of fodder, over-grazing and environmental degradation. However, with careful planning, these negative pressures could be avoided since a wider network of reservoirs would prevent this concentration whilst supplying more water.

8.4 Intervention strategies

Only a small proportion of the rural population practice traditional systems and little information is available on the growth or transfer of these technologies within the country. External interventions have focused primarily on the introduction of larger scale water harvesting systems for the improvement of crop production, the support of livestock and the prevention of serious land degradation. Little attention has been addressed towards domestic water needs which are satisfied either by conventional water systems developed through the national drinking water policy or left to traditional sources. Rooftop harvesting has not been promoted.

Technology selection

Few projects have built on traditional knowledge or practices. The dominant strategy adopted by externally supported projects has been to design new systems of improving surface water supply or improvement of direct infiltration for individual villages and in return expect significant inputs of labour from the complete population. Traditional systems have often been by-passed. Adoption of these large scale interventions without adequate community involvement in planning and maintenance has enhanced the risk of conflicts developing between users and the lack of upkeep or penetration of these technologies.

For example, the Dogon people of Duentza Cercle are aware of the shortage of cultivable land and increasing degradation of soils. Traditionally, they try to ameliorate this by digging collection pockets and constructing small bunds. The Near East Foundation developed a project to build larger rock check barriers to rehabilitate eroding alluvial farmland. Having suggested building a number of mid-sized barriers at distances along the valley requiring considerable village labour input, the villagers decided that if they were to work collectively, they wanted a single large barrier where the erosion was deepest. A compromise was reached in which the villagers built first a large barrier and later smaller ones upstream. Building a large barrier proved a mistake as it was washed away the year after. Without external support the village would not have attempted such a reclamation, preferring to work on their individual lands where traditional practices are suitable. Whilst check-dams are a suitable technology, they were not used in appropriate circumstances.

Community aspects

Many traditional systems have operated with a level of community organization at the family or intra-community level. For instance, in the Mopti region, most runoff farming systems for infiltration enhancement are practiced on the individual farmers fields. Domestic water supplies such as the bourogaras or dug wells are organized at a section level, with several distinct groups operating within a single village. The group is well-organized. Each section Chief mobilizes young men from his section to clean and maintain the reservoirs a few times a year. Users obey instructions not to use soap or do laundry and bathe in the source. Externally supported projects, however, have often worked at a new level. They have adopted village, or multi-village systems, using the community members primarily as a free-labour force, without looking into aspects of local organization. Selecting large, labour-intensive projects places a considerable burden on many communities requiring male labour during the slack periods in the agricultural calendar. It is traditional for men to leave the area during this time to earn additional income as temporary migrants elsewhere. Whilst there may be nothing wrong with the hardware aspects of the systems which may well exploit an under-utilized resource, they do not fit in comfortably with the existing social context. The Ntossoni dam project experienced significant difficulties in the organization of a work programme due to village differences of opinion and the experience post-construction is that no local groups have taken responsibility for annual maintenance and the repair of flood damage. There have also been conflicts over water and land use. For the sustained and successful functioning of these new systems, projects in future require a greater amount of attention to be addressed to community issues other than the organization of mass labour contributions.

Financing strategies

The financing of water harvesting technologies has not been used as an intervention strategy in itself, but as a means of enforcing a particular technology selection. ESAs have rarely provided funds to communities to facilitate them to more widely adopt their traditional techniques of improving domestic water supply or increasing infiltration. Instead the ESAs have provided capital and technical expertise to construct large-scale, pre-determined technologies. They rely on the perceived improvements, the gratitude of the recipients and their desire to conform with government policy as the incentive for community acceptance and the supply of the labour inputs from the village. Whilst the communities provide a sizeable physical input of self-help labour and materials, the skilled labour is usually supplied from outside the village, paid for by the external agency associated with the project. Not all systems require these external inputs however. Some rural dams in Mali are financed by Local Development Committees and built by Malienne private contractors using taxes collected from the local population. Nevertheless, manual labour tends to be the biggest component of the true cost of these systems. A study of the experiences of the locally managed projects has not been undertaken.

8.5 Future perspectives

Despite high investments, only around 20% of Mali's total population has access to a borehole and handpump. In some areas, groundwater resources are inaccessible or too costly too exploit, and in others there has been intensive mining of ground water resources (RIM, 1980). Water harvesting will therefore have a significant role to play as both a supplementary and, in some cases, year-round household water supply source. Currently it is used mostly as the former. The importance of developing water harvesting in Mali was recognized by most people interviewed during the review. Although their preference was groundwater due to the assumed poor quality of surface water supplies, they concluded that in many circumstances, water harvesting is the most feasible option to adopt. Roof catchment systems appear to have least potential due to the predominance of mud roofs and long dry periods of up to eight months.

The storage required to bridge this supply gap is too expensive for most households to contemplate. Larger, communal surface catchment systems show a great promise and can be used for the complete range of water needs if well managed.

With runoff farming to improve direct infiltration, experience in Mali has shown the introduction of systems to be a slow process. Their labour-intensive nature is a major constraint, especially for communities who have a high seasonal out-migration and therefore a shortage of labour for construction. This conclusion also applies to labour-intensive dam and barrier construction. A cash income from seasonal migration is valued more highly than an improved water source. It also has priority over improved crop yields because of the poor marketing prospects for extra produce. Clearly, chosen techniques must be as labour-efficient as possible and small scale. ESAs such as the Near East Foundation now realize that it is difficult to mobilize whole communities, especially if construction takes a long time and only a minority benefits. Reij has come to a similar conclusion elsewhere in West Africa and states that farmers often seem to favour a family rather than a collective approach (Reij et al, 1988).

9. *Tanzania Country Review*

9.1 Introduction

In Tanzania, water harvesting for drinking water purposes has only recently begun to receive serious attention from the government and ESAs. It is now being recognized as one of the potential sources to help meet the national objective to take clean and safe water within 400 metres from every home by 2001, so that each household member can use an average of 20-30 litres per day.

The rural population in Tanzania is growing rapidly and lives in over 8,000 villages (Thirkildson, 1988) most of which are not suited to the development of sustainable pumped and piped water supplies, except at very high cost. Furthermore, the availability of groundwater sources is not evenly distributed or of sufficiently high quality and surface water sources are often highly seasonal. Traditional water sources include springs, water holes, hand-dug wells and pits in river beds. They are often of low quality, seasonal and shared with animals. Access to safe water is below 20% and is particularly difficult in the regions of Shinyanga, Arusha, Mara, Tabora, Dodoma, Singida, Lindi and Mtwara (GOT, 1988). The climate is such that there is a maximum dry season of five to six months, with one long or two separate rainy seasons with high annual variability. Many of these areas receive less than 600 mm of rainfall and hence coupled with the poor water situation, rain fed agriculture is at best marginal and subject to periodic failure promoting low food security levels for the mostly subsistence farmers.

9.2 Technology aspects

Rooftop catchments and tank systems

Rudimentary rooftop catchment harvesting is practiced as a traditional supplementary supply by many householders in Tanzania, even those with thatch or mud roofs. During a rainstorm, pots, pans and calabashes are positioned beneath the eaves of the houses to catch some of the runoff. Sometimes, oil drums or lined dug pits are used for storage. This reduces the need to walk for water from other sources, including stand-pipes, for a short period after. On the Makonde plateau in Mtwara region, the regional water engineer estimates that 80% of the households practice some form of rudimentary harvesting.

Some improved rooftop harvesting systems have been built on a piecemeal basis in Tanzania often with the help of ESAs. Based on a UNICEF/Kenya design, several hemispherical, roofed, subsurface ferrocement groundtanks were constructed in Mtwara region (stages in construction are illustrated in Appendix I). They have a volume of either 55 or 100 m^3, and seven have been built at hospitals and dispensaries, and one at a school. Technicians were trained at the Danida project in Mutomo, Kenya. Experiments have also been carried out in the area with assembling tanks from pre-fabricated 1.5 m^3 concrete rings, based on a design from Thailand. Also in Mtwara region and neighbouring Lindi region, the Community Development Trust Fund (CDTF) have supported the construction of 100 m^3 groundtanks for use with village grain stores ("godowns"), offices and workshops that they had previously built for communities.

Also based on a UNICEF design, smaller cement jars were promoted in Tanzania by the Tanganyika Christian Refugee Services (CRS) both as rooftop catchment tanks and general water storage jars (Figure 14). Sizes ranging from 0.25 to 1 m^3 were built by householders using a small Kiswahili instruction manual issued by the CRS. They are no longer promoted by the organization since they only had a limited impact on water availability during the dry season due to their small storage capacity. The CRS now concentrate on conventional systems such as drilled wells and handpumps.

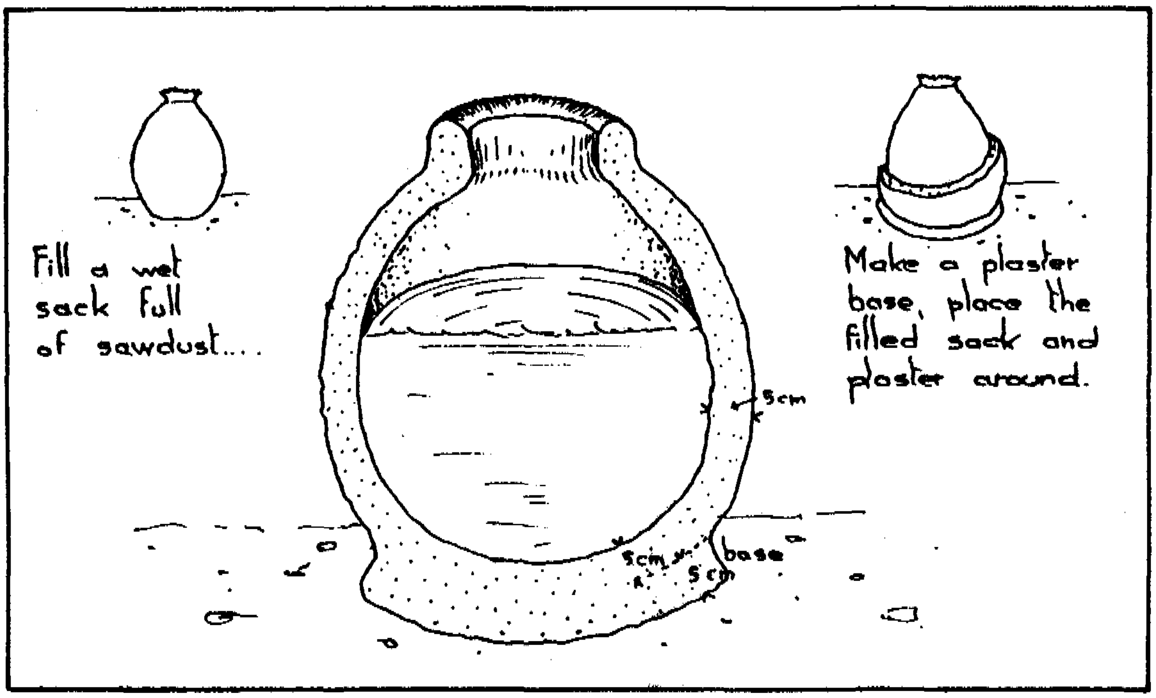

Figure 14: Cement water jar.

In Dodoma region, the Ministry of Water, in cooperation with WaterAid, has built a number of 20 m^3 ferrocement cylindrical standing tanks for the Diocese of Central Tanganyika at a Blind School. They are built in multiple sets, for example four to a building, using wooden formwork made in 12 sections. The original design has been modified to allow the roof to be built onto the tank and for the formwork to be collapsed and taken out through the roof man-hole. The reinforcement is mainly fencing mesh which is easier and cheaper to buy in Tanzania than weld-mesh and chicken-wire used for similar sized tanks in Kenya. The HESAWA project in Karagwe District of Kagera Region recently helped to build 21 ten m^3 ferrocement standing tanks for private households (McEnery, personal comment, 1990). They have trained 10 government and 10 village artisans in construction and are currently contemplating an expansion of construction activities in 1990/91.

At various locations around the country, missionaries have commonly constructed rooftop catchment systems for their homes, churches, community halls, hospitals and schools. They can be found in the Dodoma, Shinyanga, and Lindi regions as well as in the Bagamoyo district. Where there are alternative water supplies the rooftop systems are still used as supplementary or back-up supplies.

A relevant technology for rooftop harvesting is also being constructed in Dodoma region. The Low Cost Housing Unit is manufacturing handmade sisal cement roof tiles, sheets and gutters. A lattice of 200g of sisal fibres placed in two layers at right-angles is made on a layer of cement-mortar (1:2) smoothed in a frame over a plastic sheet and board. The fibres are then covered by more mortar, smoothed and manually compacted. The tile is cured by submerging in water vats for seven days. They are fixed to the roof by nails as with hurricane tiles. There are splash guards/deflectors fastened by an eye hook to the edge of the roof, onto which the gutters are hung suspended by wire cradles. The Tanzanian Building Research Unit has shown that the sisal cement tiles can last 15 years or more. An improved rooftop surface is a pre-requisite for the wider development of improved water harvesting systems capable of supplying clean water.

Surface catchments and reservoirs

There are a few examples of traditional surface catchment and reservoir systems in Tanzania. On the Makonde Plateau in Mtwara region, pits are often dug to catch runoff from the compacted ground around houses. The cement lined pits are usually 2 to 3 m^3 but can be as large as 8 m^3. Pits are also used in the Serengeti. At Robanda village, they are dug by hand and fill with both surface runoff and shallow groundwater (Kiwasila, personal comment 1989). No attempt appears to have been made to improve these systems by building more and larger stores with increased quality protection measures.

A number of earth dams have been built in Tanzania, designed by engineers using standard criteria and constructed with earth-moving machinery. Few records exist of dam locations and specifications although the Ministry of Water does have a small dams handbook used in planning which is in the process of being up-dated. The manual is based on guidelines developed over 20 years ago and many dams built in Tanzania are older than this. Most of these are silted up due to lack of catchment protection, site erosion by livestock and minimal maintenance. There are plans by ILO to encourage an increase in construction of earth dams of the Charco design (Figure 15) using labour intensive construction methods (Stanislawski, 1989). There is potential for the development of sub-surface dams to exploit shallow groundwater in seasonal rivers but, as yet, little current experience of this surface catchment technology exists in Tanzania. A few sub-surface dams were built in Dodoma Region in the 1920s and more recently in the 1950s and 1960s at Bihawana mission 15 km from Dodoma (Nilsson, 1988). Late in 1989, CARE Kenya sent a technical advisor to the Dodoma region on a brief evaluation mission to determine whether CARE should support this technology development. The results of this evaluation are not known.

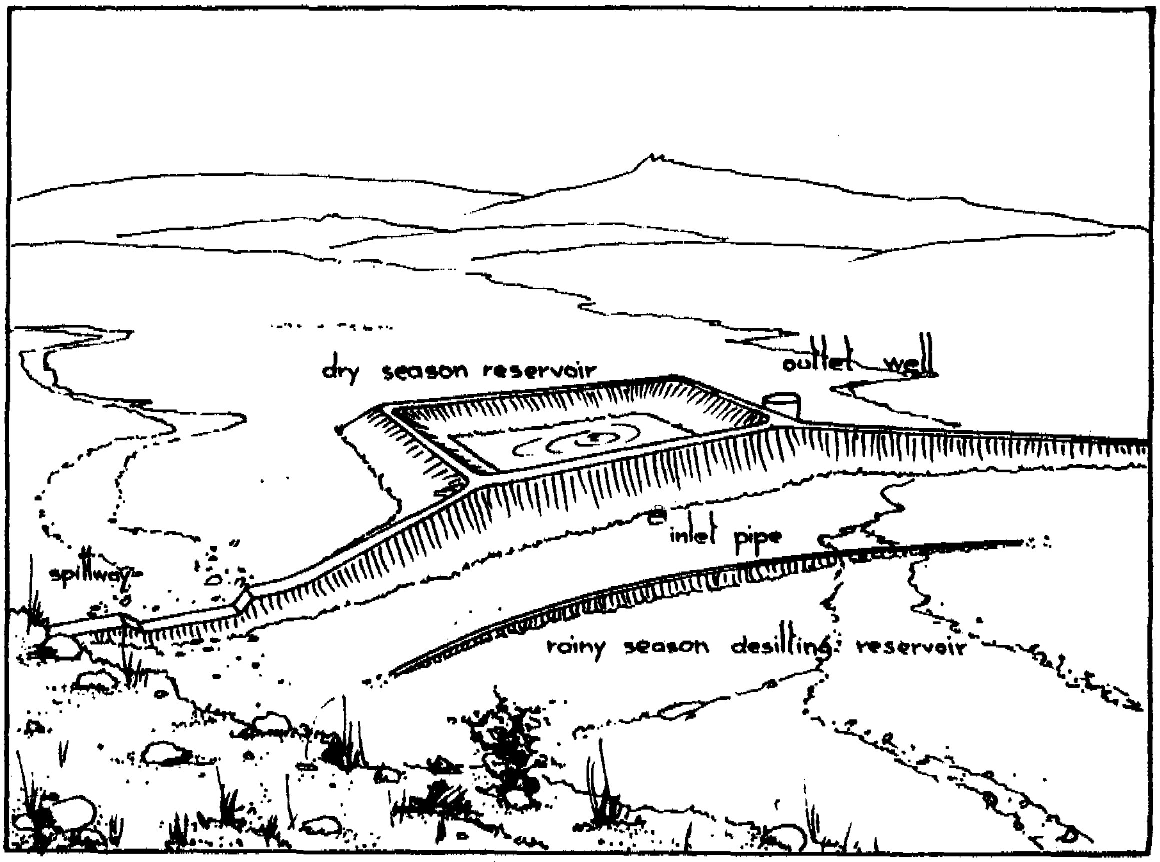

Figure 15: Small Charco earth dam built with manual labour.

Runoff farming to increase direct infiltration

Tanzania has not significantly used runoff farming techniques to increase direct infiltration even though valuable improvements in the agricultural productivity of the more marginal areas could be achieved through their adoption. Contour ridging by manual labour was enforced by colonial authorities for the production of cassava up until the 1950s. Heavy rains destroyed the banks leading to concentrated gully formation and contributing to high erosion rates in areas like Dodoma Region of 10 mm per annum (Christiansson, 1986). After independence, these types of runoff farming soil and water conservation practices were rejected until the 1970s when piecemeal attempts to re-introduce contour ridging and contour ploughing were made. The Dodoma Region Soil Conservation Project began in 1973 involving the manual construction of contour bunds and check dams. However, investment has been limited and only 11,000 hectares were ridged in the first ten years. The government has tried to promote terraces and contour ploughing in Arusha Region (Christiansson, 1986). Danida are beginning a soil conservation programme in Iringa, but their primary focus is on preventing soil erosion rather than water management (Enhard, personal comment, 1989).

9.3 Social, economic and environmental considerations

Cost aspects

Only a limited number of cost details exist for Tanzania from which to make estimates concerning the relative costs of water harvesting and conventional water supply systems. Some comparative figures are available for 1986. At this time, the construction cost of a CDTF 100 m^3 groundtank was estimated as being 40000 Tsh (Smet et al, 1986). The construction costs per capita for a range of conventional systems built by the government were calculated by the Ministry of Water and exclude institutional, running and maintenance costs (Njau, personal communication 1989). They are listed in Table 12.

Table 12: Water system construction costs per capita (1986)

	Tsh/cap	US $/cap
shallow well and handpumped	282	5.6
surface gravity-fed	582	11.6
surface and diesel pumped	1056	21.1
borehole and diesel pumped	1232	24.6
groundtank (CDTF)	1425	28.5

Source: Ministry of Water, Government of Tanzania

The cost of the groundtank (based on provision of the same service level of about 20 litres per day) is the same order as the diesel-pumped borehole but considerably more expensive than handpump supply. However, since water harvesting involves lower operation and maintenance costs, the relative costs per litre over the lifetime of the supply system will reduce making the system more attractive in cost terms.

In October 1989, the cost of 20 m^3 standing ferrocement tanks built by WaterAid in Dodoma region was 120,000 Tsh exclusive of labour, institutional costs and local materials. The formwork cost 350,000 Tsh and can be used for 20 to 25 tanks. The cost per tank inclusive of formwork is therefore approximately $925. Although the tanks are used for schools as a supplementary supply, they could also be used to support a family of six people throughout the year assuming the tank fills twice and that each person uses roughly 20 litres per day. In this case, the construction cost of the tank per person excluding local inputs is roughly $150.

Other 1989 cost figures identified include estimates made recently of the likely construction costs of a range of surface catchment systems planned in Dodoma region in central Tanzania (ILO, 1989). They appear to be high in comparison to costs recorded in other countries (for example, groundtanks in Kenya and medium earth dams in Mali are much cheaper). The reliability of these figures are not known but they are listed in Table 13 to show their orders of magnitude.

Table 13: Estimated 1990 costs of surface catchment systems

	Tsh	US $
Groundtank (110 m^3)	1100000	7566
Charco dam (8000 m^3)	2800820	19316
Small earth dam (30000 m^3)	8368800	57716
Medium earth dam (60000 m^3)	18164000	125269
Rubber seal reservoir (1500 m^3)	33000000	22759
Sub-surface dam (assume 3500 m^3)	2000000	13793

Source: cost estimates for 1990 by ILO

The sisal-cement roofing tiles produced in Dodoma can be included to give a realistic cost estimate of providing an upgraded rooftop and tank system in Tanzania. Sheet tiles cost 200 Tsh per unit or 334 Tsh (\$2.3) per m^2 of roof area. Gutters cost 350 Tsh (\$2.4) per metre complete with hangers, and deflector.

System use

Depending on the volume of storage used by the households or communities, traditional systems can provide a valuable contribution to local water supply. With household pits dug on the Makonde plateau, water is usually rationed, being used for specific purposes only and it can last several months. The main objective is to provide more convenient local water, preventing the need to go to distant, more unsanitary supply points. Up to 80% of households are estimated to use some form of rooftop harvesting as a supplementary supply. In Mtwara region, the water shortage is so critical that households with larger leak-proof pits, or organizations with large rooftop tanks, can sell water to other villagers.

Large surface catchment systems such as earth dams built in Tanzania can provide water year-round to a community but are often distant from settlements and are likely to be contaminated since many are shared by households and animals with little source protection. Smaller communal systems built in Tanzania have had only a limited impact, providing at best a few weeks of supplementary supply before users resort to their traditional water points. The real needs of the users have either not been addressed or resources have been too limited for a larger construction programme to be implemented. For example, in Mtwara and Lindi regions, the CDTF built water tanks to accompany improved grain stores and other community buildings, introduce larger water harvesting systems to the community and help relieve women of the burden of having to walk long distances for water. However, a single 100 m^3 groundtank built in a village like Newala can only supply about 135 litres per villager during the dry season, enough for one or two weeks.

Little data is available on the quality of water supplied by the various traditional and introduced water harvesting systems. It is generally assumed by the government and ESAs that runoff from thatch and ground surfaces is unhealthy or unpalatable but that runoff from man-made surfaces such as metal or cement is clean. However, it seems that quality is a lower priority issue in Tanzania than quantity and availability. The Head of Preventive Services in the Ministry of Health indicated that the current primary aim is to improve daily water accessibility. Once this is successful then quality can be considered.

Socio-economic impacts

The case of the CDTF groundtanks has indicated the danger of raising unrealistic expectations amongst communities concerning the benefits and potential of water harvesting. Providing a single 100 m^3 tank for a whole village cannot hope to provide more than several days domestic supply. It has, in fact, been the cause of considerable friction and disagreement within the villages. The expectation of the villagers at each godown site was generally that there would be an equable distribution of water for domestic purposes since the godown was communal property. But some women complained that there were unfair distribution practices (Smet et al, 1986). At some villages, village leaders were allocated far more water, and at others, the water was used for other purposes such as a workshop construction. The main water carriers, the local women, felt little impact on their daily lives. They felt they had no control in planning and deciding on priorities for use of the water provided and over water distribution. The presence of improved water supply is no guarantee that women will have easy access to the water or that walking distances will be reduced.

9.4 Intervention strategies

Technology selection

Technology selection in Tanzania has generally been carried out by donor advisory teams working with the Ministry of Water or with their own teams of project technicians. Water Master Plans have been prepared for most regions by foreign consultants and have primarily focused on conventional water supply systems such as boreholes, gravity systems, stand-pipes and handpumps.

Whilst there has only been a very limited experience of water harvesting system development, a new initiative by the ILO and the Prime Ministers Office plans to adopt a sensible approach to technology selection given this history. In a project to develop water harvesting in Dodoma region, prime focus will be on earth dams but prior to implementing any construction, the planning team will make a full feasibility study including:

- collection of meteorological and hydrologic data;
- collection of topographic, geological and land-use information;
- estimation of monthly evaporation;
- identify possible construction sites and their catchment areas;
- meet community leaders and find out, current water supply problems, preferred water supply systems, possible contributions of labour and materials, appropriate management strategies, local knowledge about sites;
- inspections of catchment areas;
- inspections of sites for structures;
- choice of most promising sites;
- survey of most promising sites.

By taking this approach, ILO will seek to avoid problems with community acceptance and sustainability as well as choosing the most appropriate technical design. Their goal is:

- to collect water over the short time when it is available in excess;
- to minimize evaporation losses during several months of dry season storage;
- to make this water available throughout the year; especially at the end of the dry season (Stanislawski, 1989).

Community aspects

Some traditional systems have been the focus of considerable community organization and cooperation. For example, in the Serengeti, village groups combine to dig and use water collection pits, growing lilies to prevent evaporation, leaving shade trees and preparing fences to help keep the water sanitary. There are pit attendants, generally women. Management is voluntary.

In contrast, there is little experience in Tanzania with successful community-based schemes using water harvesting systems. Most experiences have been limited to single technology interventions, with projects providing a standard system to institutions. The Rural Water Engineer in Mtwara has built tanks mostly for health centres and schools in areas isolated from other alternative water sources. SIDA have started building some tanks for institutions in Kagera and Mwanza regions, WaterAid with the Ministry of Water have built tanks at a school in Dodoma region and UNICEF have supported construction of two tanks for health centres in Hai District. No attempt has been made to develop any sustained local capacity with the further development of communal or individual household storage capacity for surface catchments or other large roofed areas. In general, skilled contractors have been brought in. Only the HESAWA project seems to have instigated local training courses. In Mwanza courses in tank building have been run at Misungwe Technical College since 1987 with financial help from SIDA. In Karagwe, Kagera District, HESAWA, in cooperation with the Ministries, have trained 10 government employees and 10 village artisans for a future pilot tank building project in three villages.

In similar fashion, many earth dams built up until now, have not been directly linked to any user group. Since there has been no responsible group, little attention has been given to management or maintenance. Many water points have subsequently deteriorated. A large proportion are completely silted or have been breached and require extensive, costly rehabilitation.

Financing strategies

Up until now, the Government of Tanzania has assumed responsibility for the finance of water supply development as a basic and free service. Over 60% of the cost has been financed by ESAs and many communities are totally reliant on the activities and financial support of donors. However, even with these donor contributions, investment has been insufficient to reach a large enough proportion of the population to date. It is increasingly being recognized in official circles that communities must contribute to and even take over the financing of basic services such as water. Now, Village Water Committees are expected to institute a village water fund which in the long run should be capable at the least of supporting the operation and maintenance costs of projects.

9.5 Future perspectives

The Government of the Republic of Tanzania has formulated a new guiding Water Policy which has been submitted for ratification to the party system. It states that a major aim of the government will be to insist on the construction of dams and rain water catchments and to strengthen the collection of rainfall data so that informed calculations can be made on potential resources. The government wishes to encourage the construction of big and small dams in the dry areas to preserve the rainwater which is otherwise uselessly lost. It states that rainwater can also be caught from household roofs and catchments built on the ground and that the water, if well preserved, is clean and safe for all domestic needs. The government plans to encourage individual people, institutions, corporations and industries to construct rooftop catchments and storage tanks.

There are a number of obstacles to be overcome before the government can achieve some of these aims. Ministry of Water planners in Dar es Salaam have noted very little literature on water harvesting experiences in Tanzania in their searches over the last three years. They are aware of the successful use of rooftop harvesting in South East Asia and in other African countries. To help its adoption as a mainstream technology option they feel they must first carry out a period of research and evaluation of the actual feasibility of introducing it for household supply in peri-urban and rural areas. Additionally, the UNICEF Water and Environmental Sanitation team were not confident about the development of household water harvesting systems such as rooftop catchments and tanks, observing that:

- there are low iron sheet roofing percentages, perhaps 10%;
- there are limited financial resources for household capital investment;
- they are not as yet a mainstream technical option and hence have little or no institutional support;
- rainfall levels are too low and dry seasons too long requiring large, expensive storage;
- rains are not strong enough to wash the roof clean;
- water quality will not be high enough and will need treatment;
- it is too difficult an option for Tanzania which still needs to develop the required community-based skills and is not ready for mass household system development;
- it can only provide a supplementary not primary supply;
- it requires too much of a regional, manpower intensive approach.

Although there is under-utilised potential for sub-surface dam construction and the wider use of shallow groundwater in sand-rivers for household water supply throughout the country, the main focus for surface catchment development seems to be on earth dams. Earth dam construction will rely either on intensive use of labour or heavy earth-moving machinery. There is only limited experience in community-based labour intensive projects in Tanzania, especially in the water sector. Currently, many large dam construction units are grounded due to non-functioning machinery or lack of funding. For example, five out of six earth-moving teams in Dodoma were out of commission in 1989 due to equipment failure from lack of maintenance and spare parts.

Little mention was made by any parties in Tanzania of the use of or potential for runoff farming to improve direct infiltration into farmers' fields and promote increased yields and annual food security. However, with the majority of rural households operating at a subsistence level and reliant on rain fed crops under highly variable and marginal climatic conditions, the benefits of soil and water conservation techniques will be considerable and deserve serious consideration. Many of the marginal arid and semi-arid areas of Tanzania have similar land-use characteristics as Kenya, with increasing soil erosion and uncertain crop yields due to seasonal climatic variation. Experience there has shown that the use of fanya-ju terraces, micro-catchments and earth bunds can increase yields from sorghum in marginal seasons by up to three times, although in the wetter seasons there is little improvement.

10. Togo Country Review

10.1 Introduction

Water harvesting in Togo is used mainly to supply drinking water in the rural areas where permanent surface water is not available and there is no exploitable groundwater. In Togo, the preferred technology has been drilled wells with handpumps and up to 1989 a total number of 2960 groundwater supply points had been created. However, because of maintenance problems, up to 50% of handpumps do not function and the unsuitable hydrogeology gives rise to unsuccessful drilling rates of 30 to 40%. Between 15 and 20% of targeted villages cannot be provided with a reliable water supply this way. In these areas, water shortages are critical near the end of the dry season and women must travel up to 15 km to bathe and wash clothes, or must buy water at high prices.

Conditions for water harvesting are relatively good in Togo. Annual average rainfall is quite high and in some areas the dry season is short, around three months. However, in other areas, it can be higher at five months. For example, Savanna region is the most northern region of Togo and has an average rainfall of 1000 mm per year (with a minimum of 871 mm in the 1970-1985 period) and a dry season of about 170 days in the period from October to May. Plateaux region in the south has an average rainfall of 1200 mm with a minimum of 1033 mm during the 1970-1985 period and an average dry season of 110 days. Areas with traditions of water harvesting include the "biseau sec" (dry zone) in Maritime region and the eastern part of Plateaux region.

Since 1985, water harvesting systems have been developed by two projects and are being promoted by one research centre in Togo. The "Programme de Développement Socio-Sanitaire" has been executed by the government and USAID (Lindblad, 1986. Roark et al, 1988). Its "Campagne Citernes" was begun in 1985 to serve villages in Savanna and Plateaux regions which had no groundwater option. The "Projet de Ressources Hydrauliques Villageoises", was begun in 1984 and executed by CUSO and the government. This project developed a surface catchment system in two villages of Maritime region where drilled wells were not feasible (CUSO, 1985). Several other organizations have been experimenting with water harvesting systems for drinking water, in particular the Peace Corps, World Neighbours and the Direction Générale des Affaires Sociales. Their experiments are being done at Kara in cooperation with the Centre de la Technologie Appropriée whose main objective is to develop and promote alternative and sustainable development technologies. In the field of water harvesting, they have been:

- establishing a permanent exhibition of prototypes and a library at Kara;
- running training seminars for masons and craftsmen;
- starting pilot projects with governmental and non-governmental organizations.

10.2 Technology aspects

Rooftop catchments and tank systems

Perhaps 60% of the roofs in many rural villages are now made of corrugated iron sheets. The majority of these households use them for runoff collection into jars and buckets, usually without gutters. Some families have privately constructed rainwater harvesting systems with storage capacity up to 10 m^3 by digging underground cisterns, lining them with cement and covering them with iron sheets.

Figure 16: Cement stave cisterns and hangar roof catchment (photo: de Vries, 1989).

New water harvesting systems (Figure 16) have been constructed by the Campagne Citernes for extended families of up to 12 members (GOT, 1987), and consist of:

- an 80 m^2 roof catchment area called a "hangar" comprised of six reinforced concrete pillars and a roof of corrugated iron sheets with gutters;
- four 6 m^3 storage capacity cement stave cisterns fitted with a water tap, an overflow and an automatic device which diverts the first runoff to avoid dirt from the roof entering the cistern (the first flush-device is illustrated along with some others from Africa in Appendix VII).

However, following a two-year programme, the systems were evaluated to be time consuming, complicated and relatively expensive to construct. A simpler, 40% cheaper, 6000 litre cistern design has recently been developed using rounded hollow concrete blocks with bevelled edges rather than cement staves. It eliminates the need for expensive wooden forms, specially skilled masons and some imported materials. As yet only three have been built in Savanna region.

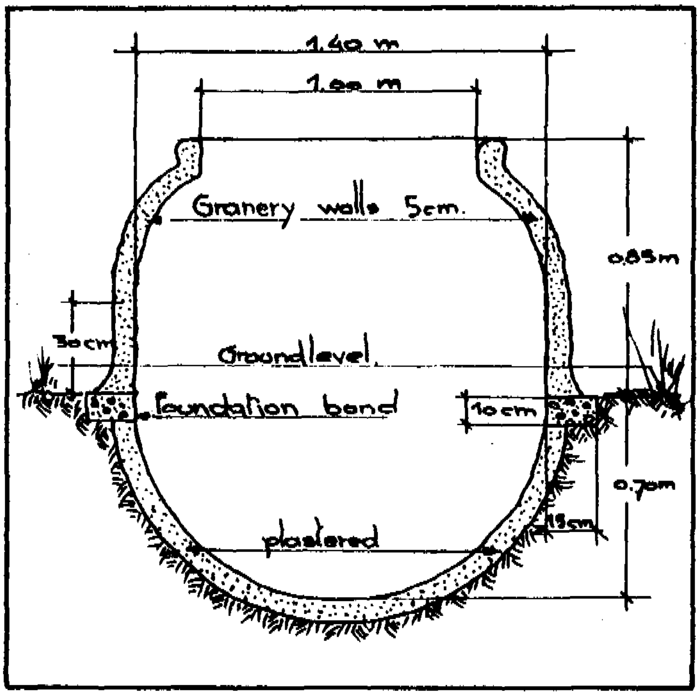

Figure 17: Granary cistern built at the Kara centre.

Experiments with other cheaper technologies based on more traditional structures have started at the Centre de la Technologie Appropriée in Kara. The round hut cistern is a traditional round hut made of earthen bricks, but built on a concrete foundation reinforced with iron bars, lined with ferrocement and covered with an iron sheet lid. The prototype is 3.5 m^3 capacity but it can be constructed up to 10 m^3 capacity. The granary cistern is a traditional granary store which can be constructed by a village mason. Some are constructed partly underground. The interior of the granary is lined with a soil-cement mix and ferrocement. They range in size from 1.5 m^3 to 10 m^3. A 1.5 m^3 prototype at Kara is illustrated in Figure 17. The small granary cistern is similar to a 1 m^3 design recently introduced in the Notse area by Ghanaian masons.

Rooftop harvesting is also used to supply drinking water at rural schools throughout Togo, benefiting from the large iron sheet roofs. A multitude of cistern types and sizes have been built, both standing and sub-surface, and cylinder and rectangular. In almost all cases they have been made from concrete reinforced with iron bars or of cement bricks.

Surface catchments and reservoirs

Some villagers in Togo dig pits adjacent to their houses to collect surface runoff. There is little data on their capacity or numbers. Catchments are usually areas of compacted earth, unprotected by fences and therefore easily contaminated.

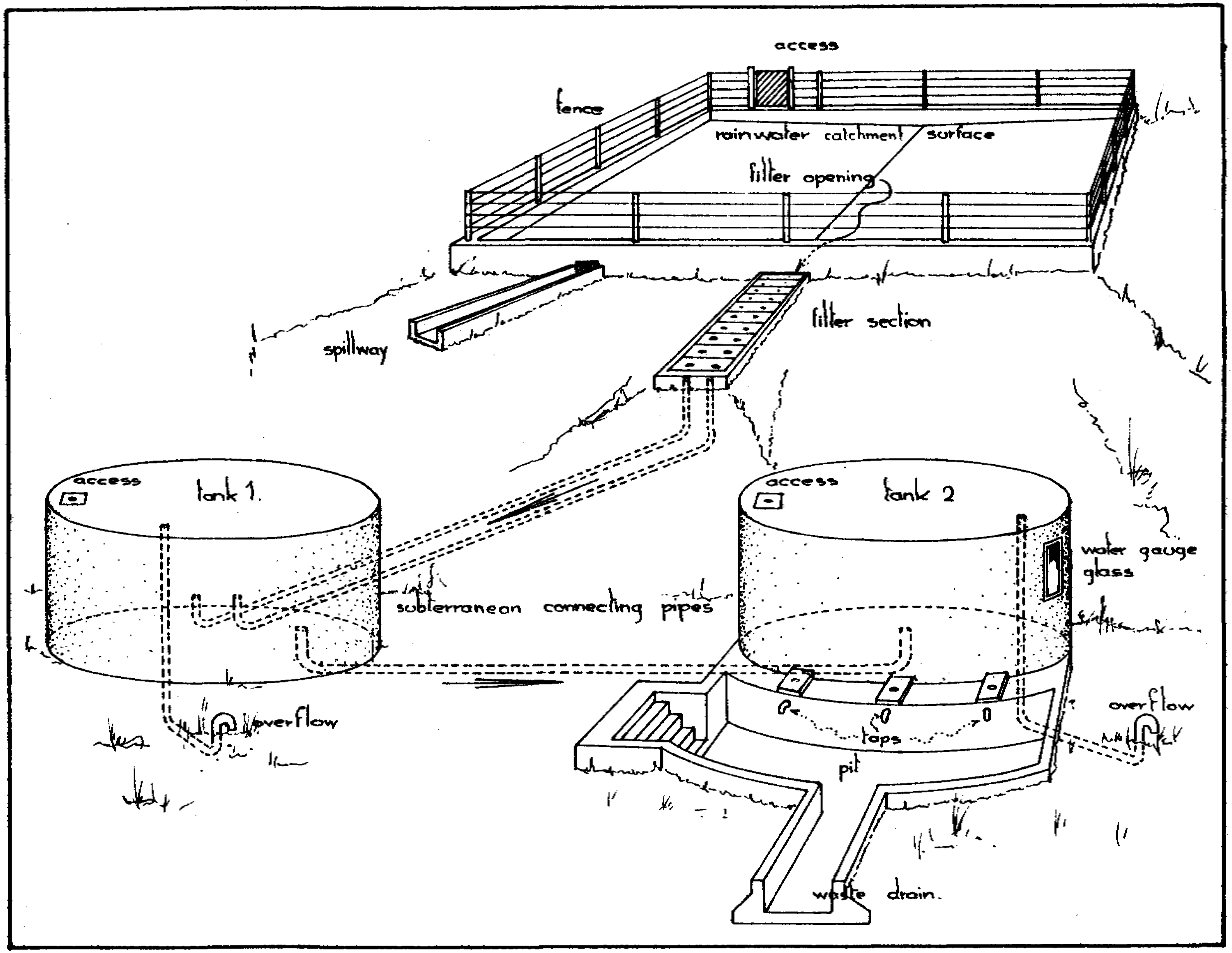

Figure 18: Concrete catchment and cistern system (after CUSO, 1987).

Larger, communal surface catchment systems have been developed for household drinking water supply. The Projet Villageoises constructed water harvesting systems that consist of a 1.5% sloping concrete covered collecting surface of 1400 m^2 coupled with two partly sub-surface cisterns linked by underground pipes. The cisterns are made of reinforced concrete and have a volume of 163 and 131 m^3 (Edgar, 1985, 1986). The catchment surface is surrounded by a wall and a fence of barbed wire. Rainwater runs off into the sedimentation unit where it first passes through a sieve. The water remains at least 15 minutes in the sedimentation unit which has a capacity of 20 m^3, and is then funnelled through a filter and underground pipes towards the first cistern. The cisterns have a contents gauge and an overflow. The system is illustrated in Figure 18. Three water taps have been installed below the second cistern in the water-distribution area which has an outlet for spilled water. It has been calculated that the system can collect about 80% of the rain from the catchment surface in the cisterns. Rains of an intensity of more than 60 mm per hour and which last more than 20 minutes cannot be entirely collected and will be partially diverted through an overflow canal. With this technology, regular maintenance and cleaning of the catchment surface, sedimentation tanks, filters and the cisterns is essential:

- the entry sieve and the surface must be cleaned and erosion damage around the system repaired after each rain;
- erosion control, repairs to the fence and to cracks in the concrete catchment surface, and the pulling of weeds from the surface must be carried out each month;
- the catchment surface must be cleaned, and the sedimentation tanks, filters and cisterns must be drained and cleaned every year before the rains start (CUSO, 1987).

Runoff farming to improve direct infiltration

No examples of runoff farming to improve direct infiltration for crop production were identified in Togo. This is probably due to the fact that the rainfall regime is quite favourable for rain fed agriculture in most of the country and there is little call for techniques to boost infiltration into the soil. Annual average rainfall varies from 1600 mm in Plateaux region to 1000 mm in Savanna region, with a dry season of three months.

10.3 Social, economic and environmental considerations

Cost aspects

Although no information is available on the cost of materials and self-help labour used to construct the larger traditional rooftop or surface catchment systems, detailed cost data does exist for systems promoted by the ESAs. The construction costs of different systems and the annual equivalent cost (AEC) per m^3 of water supplied are presented in Table 14 assuming that cisterns are filled twice each year, that they have a lifespan of 30 years and that recurring costs are negligible.

Table 14: The cost of various catchment tank systems in Togo

Cistern	Volume m^3	Cost fcfa	Cost US $	AEC $\$/m^3$
Small Water Jar (Ghana masons)	1	8000	25	0.42
Campagne Citernes	6	60000	187	0.52
(inclusive of catchment)		135000	421	1.16
(inclusive of village input)		200800	627	1.74
(inclusive of project costs)		769000	2400	6.66
Granary Cistern (Kara)	10	60000	167	0.28
Round Hut Cistern (Kara)	10	80000	222	0.37
Projet Villageoises (inclusive of catchment)	294	12392000	35811	2.00

Remarks: The AEC is annual equivalent cost

Table 14 shows a wide range of construction costs for introduced and experimental systems in Togo. The cheapest systems are those built at Kara and designed to be constructed by local craftsmen using a larger proportion of locally available materials (materials and labour are both included in the costs). The most expensive systems are those promoted by the ESAs which have been built using more complex technologies and specialist technicians.

An assessment of the costs of the Campagne Citernes and the Project Villageoises indicate some of the wider cost considerations related to catchment construction and ESA costs. With both, the cost of constructing a catchment area for the storage cisterns was greater than the cost of cisterns themselves. The material and skilled labour for one Campagne Citernes cistern cost $187.5 whereas one quarter of the hangar cost $234.4. Added to this must be the village contribution of 75 worker-days, gravel and sand which was estimated at $205.6 per cistern and quarter hangar and additional project costs.

The material and skilled labour costs for the Projet Villageoises surface catchment system totalled $23,311 but added to this must be the cost of equipment, technical supervision and the village contribution of 1,500 worker-days, estimated by officials to be $12,500. Even without the added costs, the system is twice as expensive as supplying the village with a drilled well equipped with a handpump if that option had been environmentally feasible. The actual costs and labour needs were considerably more than planned. In 1985, costs were estimated at only fcfa 4,097,000 per system ($11,380 at current exchange rates). At that time, this was over fcfa 450,000 (12%) higher than the estimated cost of equipping the village to the same service level using individual family rooftop catchment systems. The village labour component required for each was estimated at 822 and 2,368 man-days respectively. The cheaper possibility of using existing roofs and upgrading traditional cisterns was rejected due to the increased logistical requirements of organizing this village labour and a sufficient amount of skilled workers.

System use

The actual service levels provided by the introduced systems in terms of amount of water provided per person per day is determined by the people in charge of the communal storage. These are either the family head (usually male) or the village leader. With the Campagne Citernes cisterns, water is distributed to wives and relatives by the eldest man in the family. The 6 m^3 stored at the end of the rains is capable of providing roughly 5 litres of water per day during a typical dry season. However, the cisterns are not used during the whole year for several reasons:

- during the rainy season many families prefer not to use the cisterns until they are full and instead use rainwater collected from their own roofs in pots and pans, or water from nearby traditional water sources;
- the quantity of water stored in the cistern is not always sufficient to cover the drinking water needs during the entire dry season, mainly because the number of users per cistern has grown above the design target;
- cistern water is often used for all the family water needs until it is exhausted, which may be two months before the end of the dry season meaning that women must once again trek to distant sources.

The Campagne Citernes extension agents had stressed the importance of rationing cistern water for drinking use only but this advice was not generally heeded according to a recent follow-up assessment by O'Brien (1990).

During the four years and three dry seasons the Projet Villageoises systems have functioned, villagers have received a minimum water supply of 5 litres per day which rises up to 10 litres per day during the rainy season. This is because of the strict system of water distribution according to family size. Originally, the systems were designed to guarantee a minimum of 11 litres per person per day of good drinking water during the dry season and up to 19 litres during the rainy season. However, populations have increased dramatically from under 300 to 500, reducing the per capita supply accordingly. Additionally, cracking of the catchment in one village was not repaired and the cisterns fail to fill completely.

Socio-economic impacts

It is not known how many traditional water harvesting systems exist or what cumulative capacity they provide. As yet, it seems that only a small proportion of families have privately expanded their storage facilities by developing large pits or purchasing lower-cost tanks such as those exhibited at Kara. A growing number of households are purchasing small tanks from Ghanaian masons, but they are too small to make a significant impact on satisfying household dry season water needs. Where external support has been given to develop larger systems, the impact of new water harvesting systems has been mixed. Only a limited number of families (350) and villages (17) have been assisted. With the Campagne Citernes only 17% of the project targets were reached during the two years resulting in the construction of 59 hangars and 256 cisterns with a capacity of 6 m^3 each. Of the 114 villages with dry boreholes only 15 received cisterns, 9 in Plateaux region and 6 in Savanna region.

Technically, the systems introduced by the Campagne Citernes and the Projet Villageoises have succeeded in providing a regular supply of good quality drinking water to participating groups but they are both expensive, have not been introduced on a widespread basis, and have not been replicated. On their own they satisfy a declining percentage of the drinking water needs of the village as the population increases by natural growth and immigration. The water harvesting systems are static and unable to respond to the dynamics of each particular village. In addition, since the systems were each designed to provide drinking water only, it means that villagers are still dependant on other water sources such as permanent surface water sources (rivers, lakes) at large distances from the village (4-15 kilometres). Whilst women are released from the chore of fetching drinking water, their burden is only partly reduced because they must still trek to distant alternative water sources to satisfy non-drinking water needs.

According to Campagne Citernes staff, the health benefits from providing a cleaner source of water in comparison with unprotected traditional sources has been strengthened by combining each construction with an intensive health education programme amongst the communities. However, as found by O'Brien (1990), failure to ration cistern water for drinking only means that for part of the year, the unsafe traditional sources are still used for drinking by many tank owners. According to villagers, several water-borne diseases, in particular guinea worm, have been eradicated from villages because of system construction, but independent and reliable information on this subject does not exist.

10.4 Intervention strategies

Technology selection

Technologies have been selected by the external agents in each of the Togolese projects introducing new water harvesting systems. The communities have played little part in selection or planning although they are usually expected to contribute considerable amounts of labour and pay for the system upkeep. The consequence of selecting alien technologies such as the cement stave construction or reinforced concrete techniques has been that outside labour and materials have been used, considerably increasing costs and reducing the potential for village-level replication. By choosing this method of technology selection, little trust or comprehension existed that the cisterns could contribute to resolving the drinking water problems in some villages and participation in construction activities was sometimes very slow. The exceptions are the small, low-cost water jars which are increasingly being constructed for Togolese households by Ghanaian masons. A growing number of householders are selecting these jars out of their own free choice and without any external support.

Community aspects

Traditional water harvesting systems tend to be organized at the household scale in Togo. Activities at the community level were established by ESA projects through the formation of a Village Development Council (VDC) and involvement of the community in project implementation. The VDCs were made up of a roughly even mix of men and women (for example five to four) and acted as the counterpart organization in the village. Contracts were signed between the VDCs, the project management and the Togolese government regulating the obligations of each party in system construction and maintenance. As part of their obligation, the Campagne Citernes provided training for VDCs, skilled masons, construction materials, equipment and logistical support, and field agents for health education and monitoring. Similarly, the Projet Villageoises carried out a programme of awareness-raising and preparation for system takeover by the community. Village artisans were trained to carry out simple repairs and the committee responsible for the system shown how to maintain and clean the system (CUSO, 1987).

In the Projet Villageoises, a single village-scale system was used by up to 500 people, each happily taking a fair share of water based on a system of quotas. A set of markers are used corresponding to the number of buckets which can be distributed daily. Each family is assigned a certain number of markers according to its size. These markers hang in the left one of two identical metal boxes fixed on the wall at the water outlet (Figure 19) at the beginning of each day. When a member of a family takes water, one of their markers is removed from the left to the right box. Every family has a fixed place for its markers in the box. A family can take water during the day until all its markers are in the right-hand box. At the end of the day all markers are placed back in the left box. No water quota can be accumulated. Every one or two years the water quotas of each family is revised according to changes in size.

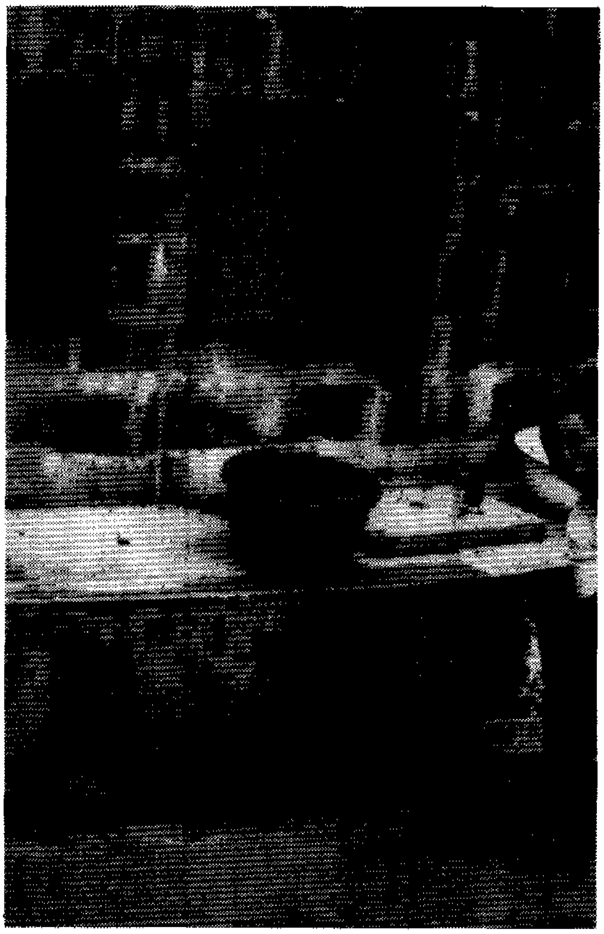

Figure 19: Village water quota system markers at water outlet (photo: de Vries, 1989).

By encouraging community cooperation, the Campagne Citernes was sufficiently flexible to be responsive to social problems experienced during implementation. When project management found that the original strategy of linking the four cisterns fed from each hangar by PVC pipes and providing one tap for 50 people was creating social tension, the system was adapted so that each cistern was given its own tap and each cistern given to one family unit of seven to 12 people. However, although the Campagne Citernes took a sensible approach to community involvement, its targets were not reached largely because of social issues. There was a lower than expected village participation due to lack of conviction about the system's usefulness, the complicated construction technique, the slow pace of construction and the lack of labour availability during the agricultural season. The choice of an alien technology caused problems for resident village masons who found the specialist skills needed beyond their abilities and special trained technicians were required.

The elected VDCs coordinated village activities during the construction phase and now supervise any maintenance of the system. Other than that, their role has now ceased. Whilst still formed, they have not been used to coordinate any subsequent necessary village developments such as sanitation or produce marketing and income generation. Additionally, although the VDCs contain women members, the role of women in system management has been limited. All key functions, except that of treasurer, are held by men, the keys of the taps are held by men and the quotas decided and managed by men.

Financing strategies

The Togolese government has relied on ESAs in funding water harvesting projects. The "Programme de Développement Socio-Sanitaire" was funded by four international donors: USAID, Fond d'Aide et de Cooperation, European Development Fund and Peace Corps. The "Projet de Ressources Hydrauliques Villageoises" was funded by the ICDA. The overhead costs of the ESAs have been considerable. For example, the Campagne spent 197 million fcfa, an average cost of 769,000 fcfa ($2,400) per 6 m^3 cistern.

Villages' participation in financing was limited to providing labourers and locally available materials such as sand and gravel. With the Campagne Citernes, this was roughly 20% of the true cost of the systems. In addition, each family group had to deposit 5,000 fcfa ($15.6) with the VDC fund to be used for the maintenance. They make the same contribution annually to pay for repairs. Since maintenance costs have been low during the last four years, most VDCs have accumulated considerable amounts up to $1,000 per village. Systems built in 1985 and 1986 have required little maintenance and major repairs up to now but the committees responsible have continued to collect funds from the water users on a regular basis. This has lead to an unproductive hoarding of large sums of money and a declining motivation of the beneficiaries to contribute to these funds or work on communal fields to raise money. However, the funds are not used for other purposes due to the fear of repair costs should, for instance, a hangar roof be damaged by a hurricane.

10.5 Future perspectives

The potential for the development of water harvesting in Togo is being shown by an increasing spread of improved traditional rooftop harvesting systems mainly using semi-underground cisterns constructed in local materials but reinforced with cement. To produce a year-round supply, further improved technologies, incorporating a large storage component need to be developed based on skills within the reach of local masons and craftsmen. Cheaper and simpler experimental designs are being piloted by the appropriate technology centre at Kara. Trials are taking place concerning the appropriateness and the life-expectancy of these cisterns and their comparative costs. However, because Kara has no effective outreach programme for the promotion of these systems, a replicable programme of application will require the support of government field agents and the ESAs.

All of the relevant government agencies (Hydraulics, Sanitation, Social Affairs) and ESAs (UNICEF, USAID, World Neighbours, CUSO) consider water harvesting as a valuable element in a mix of technologies which should be applied to improve the water supply of rural villages. Nevertheless, it is mainly considered as a last resort technology in situations where all other technologies are not feasible (spring capping, wells, handpumps, piped water systems) and for special cases like schools. This attitude has developed primarily because of a bias in perceptions created by the experiences of the Campagne Citernes and the Projet Villageoises. Both introduced high cost systems and experienced significant cost over-runs. Both systems provided only a limited quantity of water (for example, 5 litres per person per day) and needed continuous management such as cleaning to prevent contamination.

The Campagne Citernes and the Project Villageoises both adopted highly technical approaches outside the scale of village capabilities. The past approaches have been too sophisticated with construction remaining dependent on materials and skilled labour provided by ESAs. They have not been replicated and clearly form a static supply and diminishing service. The views of the government and ESAs will need to change if water harvesting is to achieve a significant impact in the areas where it has greatest potential.

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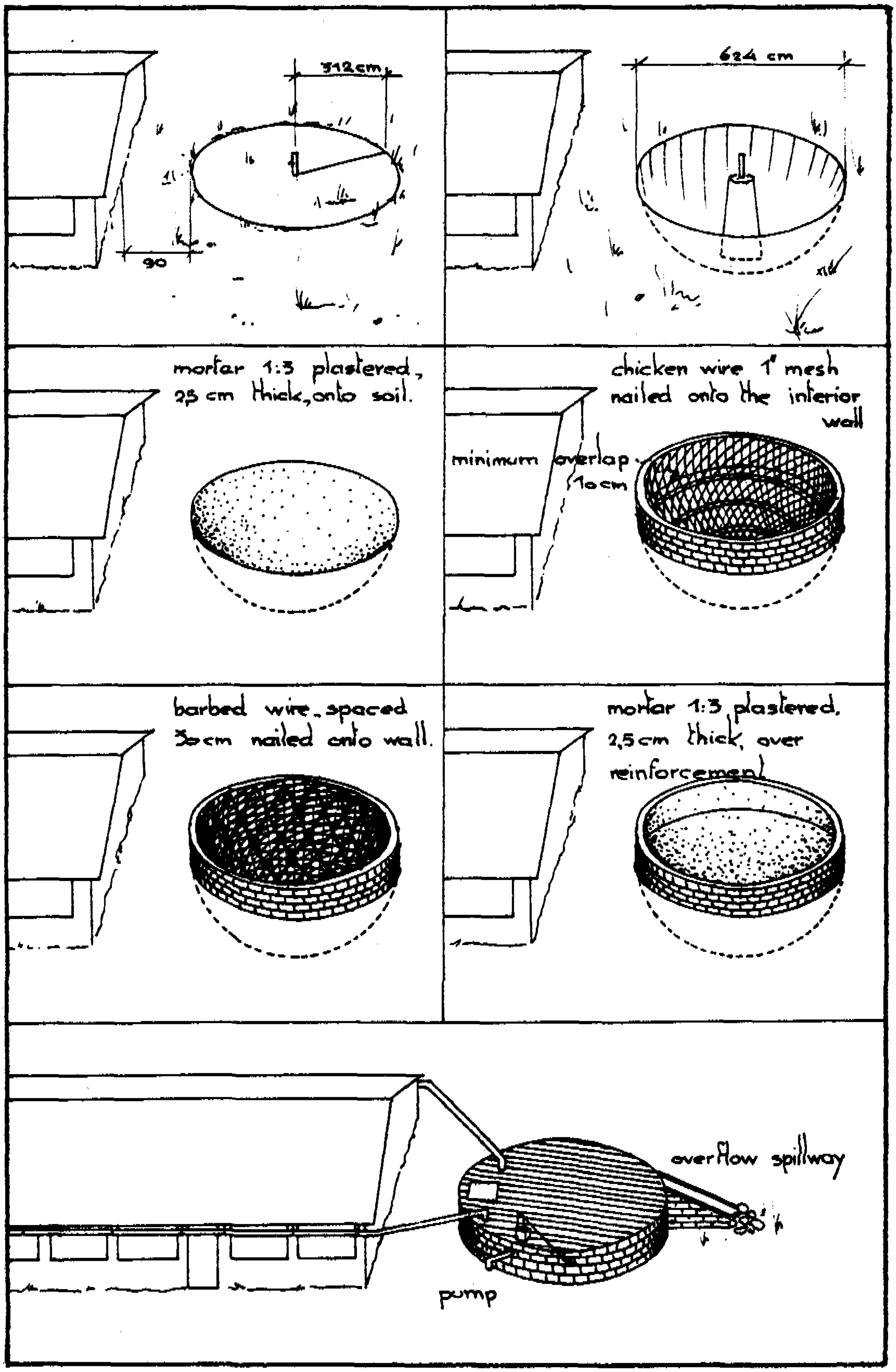
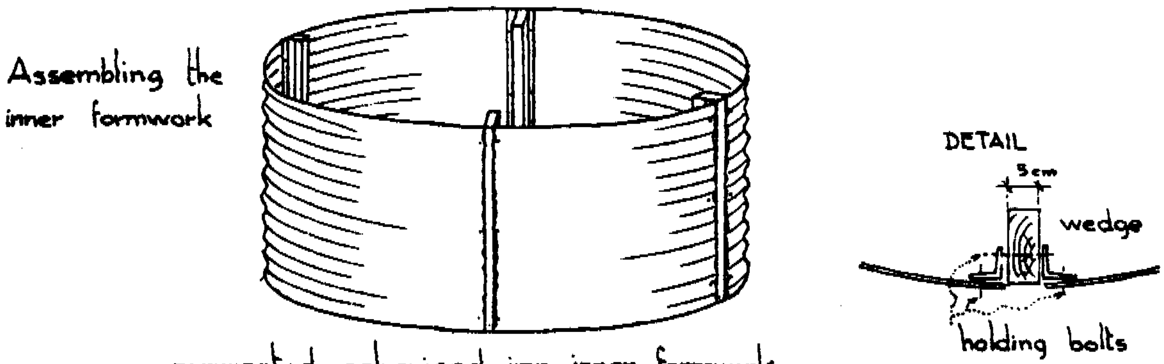
Appendix I: Stages in the construction of a 78 m^3 ferrocement groundtank (Lee and Nissen-Petersen, 1989)

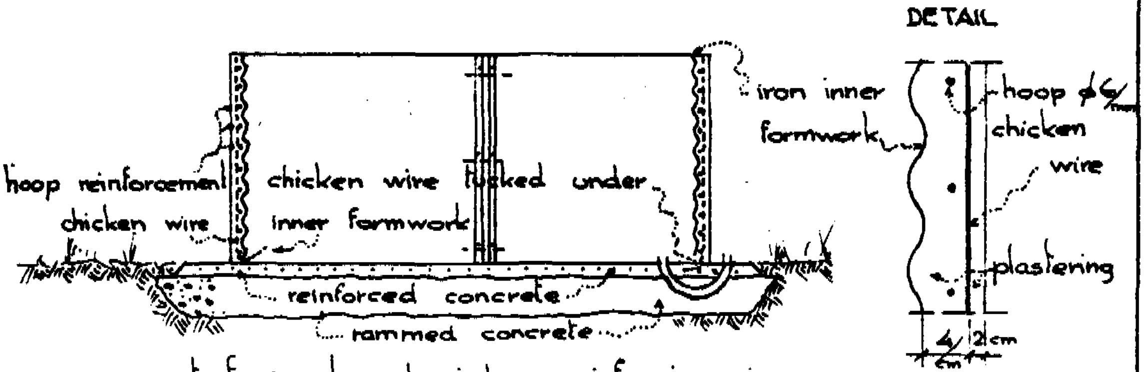


Appendix II: Ferrocement standing tank construction

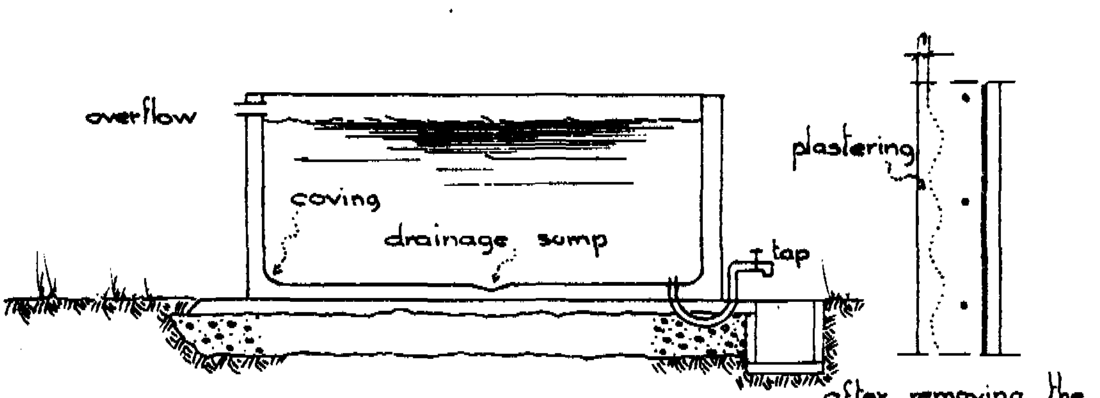
Appendix II.a Principles of construction of small ferrocement standing tanks (Watt, 1978).



corrugated galvanised iron inner formwork.



erect formwork and wind-on reinforcing wire.

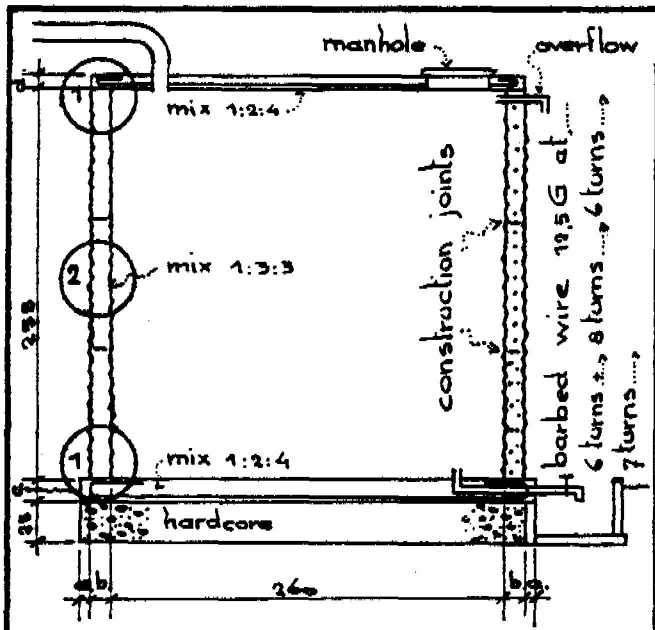


the completed tank.

after removing the inner formwork plaster bottom and wall.

Appendix II.b The Diocese of Machakos, 13.5 m^3 tank, Kenya (de Vrees, 1987)

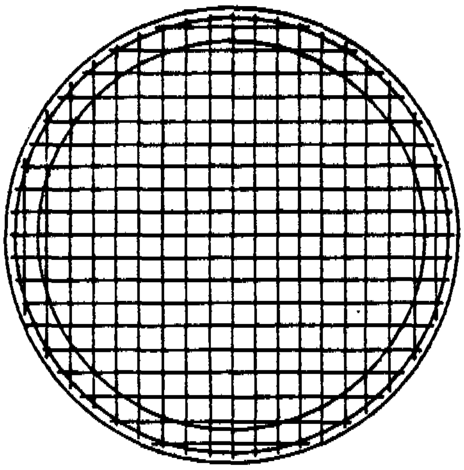
Technical drawings



a=7,5. b=12,5. c=15. d=10

BILL OF QUANTITIES

cement	28 bags
sand	5 tons
aggregate (½")	5 tons
hardcore	3 tons
R.B. ϕ 6 21	lengths
waterproof cement	3 kg
outlet pipes	-
fittings ¾"	1 set
timber 6"x1"	40 m'
timber 3"x2"	20 m'
shuttering poles 2,6m;	8 nos
nails 2" and 3"	3 kg
barbed wire 12,5 G;	200 m'



bar plan for roof and floor slabs with ϕ6. 150 mm (dimensions in centimeters)

NOTES

1. the wall reinforcement shall not be joined to roof and floor reinforcement
2. plaster inside in 3 coats;
   1st coat mix. 1 : 3;
   2nd coat mix 1:2 with waterproofcement;
3. 3rd coat of nil;
3. incase black cotton soil, floor slab should have extra reinforcement in top layer.

0 1.00 200

Building instructions

Tank size: 13,500 Litres

Dig a circular hole 0.3 m deep and diameter 3 m. Fill this hole with the hardcore. The owner can do this.

Day 1: Sprinkle water over the hardcore. Put a concrete cover on top with a thickness of 2.5 cm and a diameter of 3 m. Use cement-sand-aggregate (volume proportion) 1:2:4. Sieve the sand. Place the round bars on top of the floor, according to the drawing (space between the bars is 15 cm). Use bailing wire to connect the bars. Put the outlet pipe in place (nipple - elbow - 2 ft G.I. pipe - socket - tap). Pour concrete mixture 1:2:4 on top of the reinforcement, up to a level of 12.5 cm above the reinforcement so the total thickness of the floor is 15 cm. Make sure that the floor is level by using the timber and spirit level. Labour: 35 worker-hours. Use three bags of cement.

Day 2: Install the mould on top of the floor. The inside diameter is 2.6 m.
Put in the first turn of round bar. Fill the space between the mould with concrete-mixture 1:3:3 up to 7.5 cm from the bottom. Put in the first turn of barbed wire. Don't cut the wire. Fill the space again with concrete up to another 7.5 cm. Put in round bar again and continue this process up to the end of the mould (six turns round bar, six turns barbed wire 12 1/2 G). Labour: eight worker hours. Use three bags of cement.

Day 3: Remove the mould from the first ring and install it on top. Put in one turn of round bar. Fill up with concrete mixture 1:3:3 up to 7.5 cm. Use barbed wire (eight turns) up to the top of the mould. Labour: eight worker hours. Use three bags of cement.

Day 4: Remove the mould from the second ring and install it on top. For the third ring, make six turns with the barbed wire (every 15 cm one turn). Labour: eight worker hours. Use three bags of cement.

Day 5: Remove the mould. Make a hole at the top of the wall for the overflow. Make the inside of the tank wet. Plaster the inside of the tank roughly with cement - sand mixture 1:3. Labour: 20 worker hours. Use two bags of cement.

Day 6: Plaster inside of the tank with cement/water proof - sand mixture 1:2. Make a final coating with pure cement and water. Labour: 15 worker hours. Use three bags of cement.

Day 7: Fix the shuttering for the roof. Place the round bars (distance 15 cm). Connect them with bailing wire. Keep a place open for man-hole-cover and inlet for drain pipe. Labour: 20 worker hours.

Day 8: Make the roof slab out of a mixture of 1:2:4. The roof should be 10 cm thick. Make a concrete man-hole cover (slightly bigger than the gap in the roof 0.6 m x 0.6 m) using reinforcement. Labour: 20 worker hours. Use four bags of cement.

Day 9: Plaster outside of the tank with a mixture of 1:4 cement - sand. Construct a water point around the tap. Labour: 20 worker hours. Use five bags of cement.

Day 10-23 Pour water on inside and outside of the tank at least three times a day (responsibility of the owner) for proper curing.

Day 16: Remove the roof shuttering and clean the tank. Connect the gutters from the roof with the tank inlet.

Cost details

Costing and bill of quantities for 13.5 m^3 (3,000 gallons) storage tank as per design Machakos Diocese.

			Ksh.
Cement	30 bags	@ 102.30	3,069.00
Aggregates	7 tons	@ 250.00	1,750.00
Sand	7 tons	@ 150.00	1,050.00
Hardcore	5 tons	@ 250.00	1,250.00
R.I. Bars Ø 6 mm	25 length	@ 45.00	1,125.00
Barbed wire 12, 5 G	1 role	@ 546.00	546.00
Waterproof cement	3 kg	@ 65.00	195.00
Lordex	3 kg	@ 50.00	150.00
Timber 6" x 1"	120 rft	@ 3.00	360.00
Timber 3" x 2"	200 rft	@ 3.00	600.00
Binding wire	2 kg	@ 30.00	30.00
Nails	2 kg	@ 15.80	31.60
Manhole cover	1	@ 400.00	400.00
Piping and fittings			320.00
	Total materials		10,876.60
	Transport		800.00
	Labour		1,600.00
	Contingencies		540.00
		Ksh.	13,816.60

NB: The cost estimate is valid for 1990 after which the storage tank might cost more due to yearly increases from inflation.

Appendix III: Upgraded ALDEP household water harvesting systems from Botswana (ALDEP, 1989b)

Specifications for the ALDEP Roof Catchment and Storage

Roof Area - 40 m^2
Roof Dimensions - 8 m x 5 m
Shed Frame Dimensions - 6 m x 3 m
Shed Height - front 3 m, rear 2.5 m
Tank Capacity - 7000 litres
Tank Dimensions - 0.1 m high, 3.0 m diameter

Materials required

6 Treated posts, 100 mm diam x 3.9 m long
4 Wooden beams, 115 mm x 50 mm x 4.2 m long
4 Wooden beams, 114 mm x 50 mm x 5.0 m long
18 Galvanized corrugated roofing iron sheets, 4.0 m x 0.7 m
3.5 m Galvanized guttering, 75 mm x 100 mm
3 m Galvanized down pipe, 75 mm x 100 mm
10 Gutter brackets
Hand pump and tube
Polyethylene tank, 7000 lt
1 kg of 60 inch Wood nails
1 kg Roofing nails
6 Treated posts for tank cover: 3 x 3 m x 100 mm, 3 x 2 m x 200 mm
Galvanized sheet metal tank cover, 9 m^2

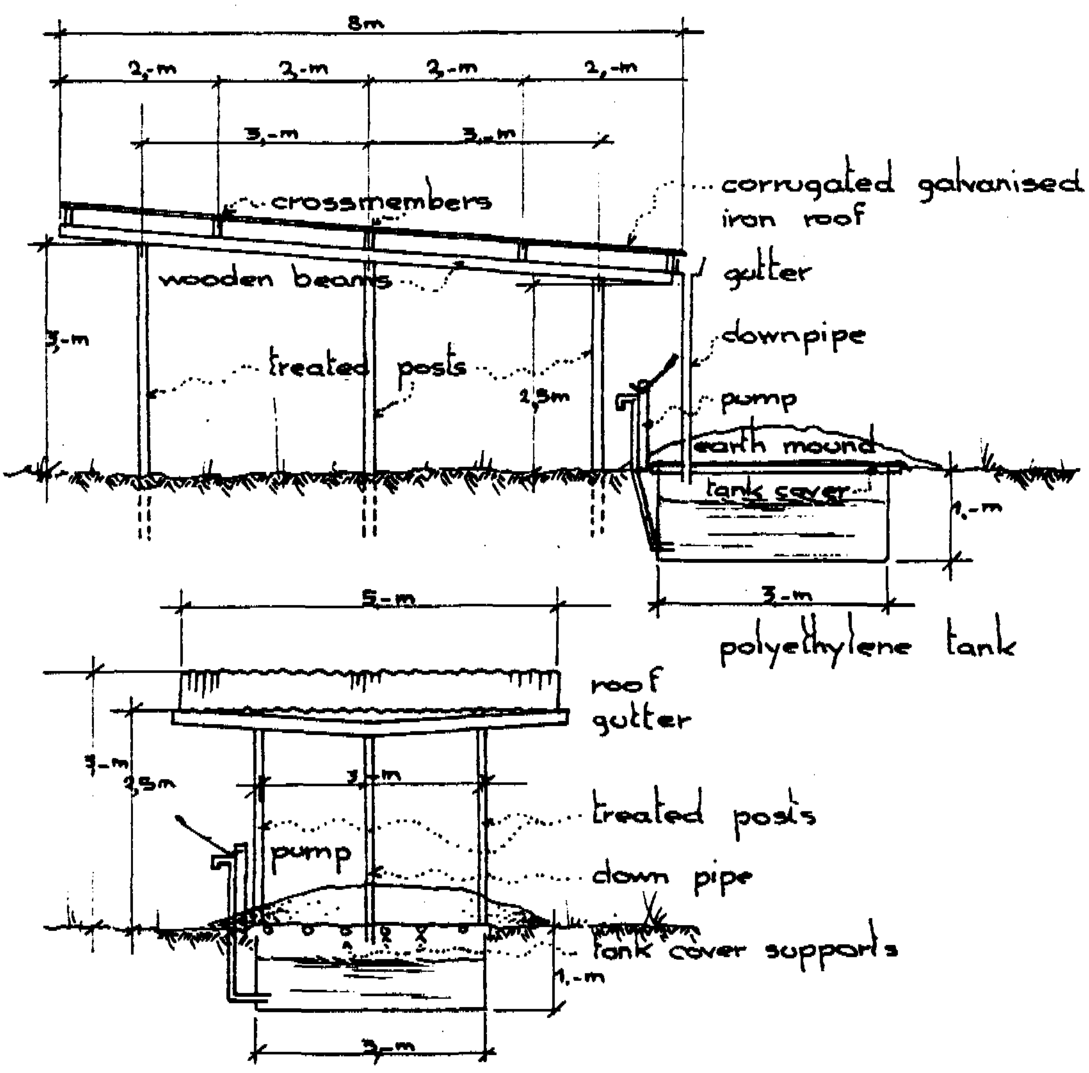
Building guidelines

1. The structure should be built on flat ground, away from trees.
2. The holes for the poles should be exactly 90 cm deep. The correct spacing between the holes is 3 metres.
3. It is not necessary to cut anything from the length of the two poles at the high end of the shed. The two middle poles should be cut to a length of 3.65 metres and the two poles for the lowest end should be cut to 3.40 metres. It is very important to get the depth of the holes and the length of the poles exactly correct. Before putting the poles in the ground, a cut measuring 12 cm x 10 cm should be made in the top to make a position for the wooden beams. When the poles are put in the ground, they should be in line with the others and standing straight up from the ground.
4. The 4.2 m wooden beams should be nailed lengthways onto the post first. Then, the 5 m wooden beams are nailed across the lengthways beams. It is very important that straight beams are purchased.

5. The galvanized sheets are laid first on the lower side of the structure. The overlap at the lower end should be about 5 cm past the end cross-support beam.
6. Very little slope is required for the gutter, and any slope should be in the direction of required water flow.

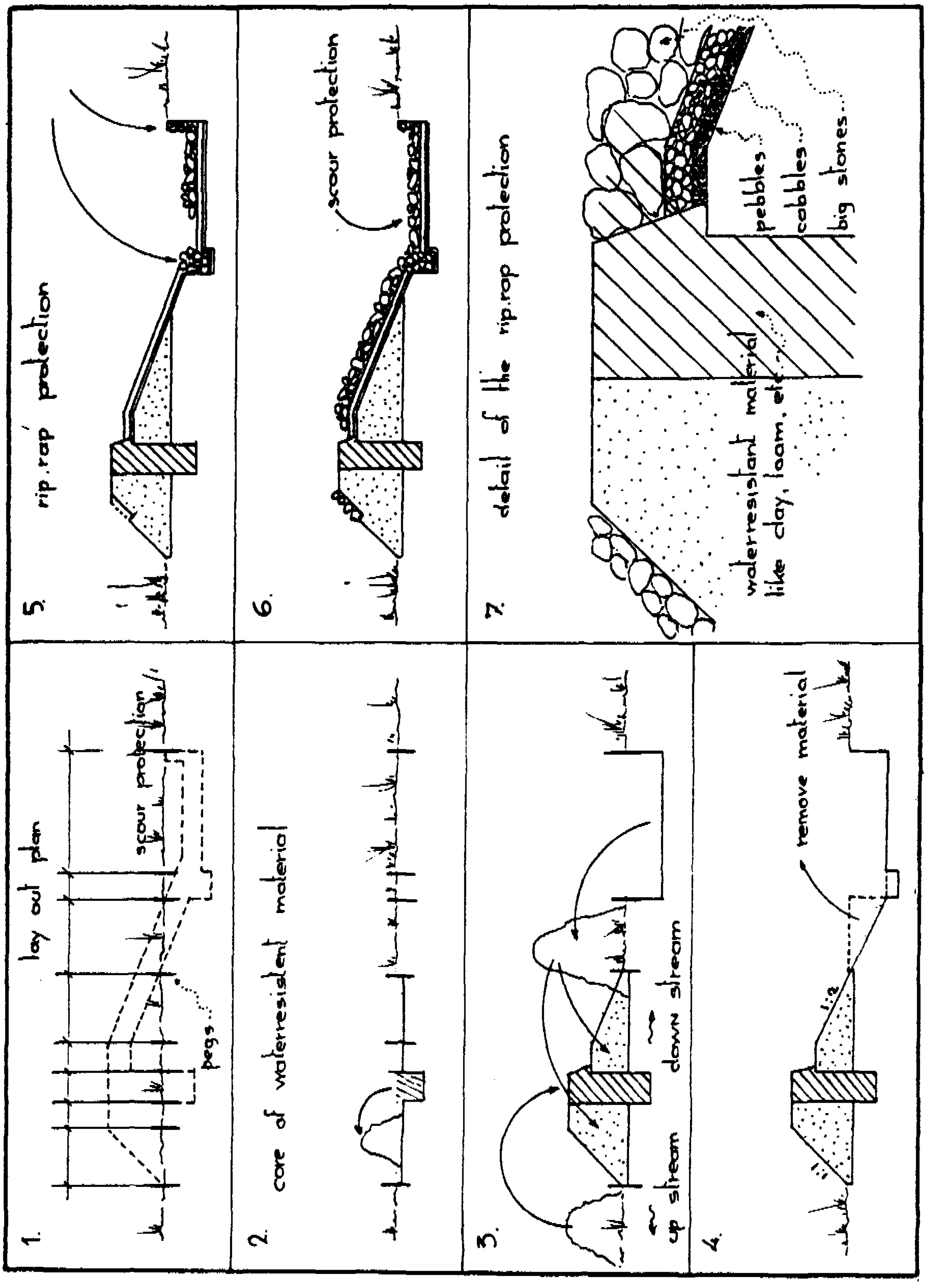
Estimated Total Cost: Pula 1500.00 (approximately US $750)

Sketch of ALDEP system



Appendix IV: Technical details and costs of Ntossoni earth dam, Mali

Technical drawings



Construction materials for the Ntossoni dam

Peg no.	Clay VR(m^3)	Compaction VD(m^3)	VD-VR(m^3)	Termite Mound (m^3)	Chippings (m^3)	Gravel (m^3)	Stones (m^3)
6- 7	5.1	13.8	8.7	4.9	1.4	2.8	7.2
7- 8	4.3	25.6	21.3	4.7	2.3	4.5	11.9
8- 9	8.8	25.6	16.8	5.5	2.5	5.0	13.0
10-11	19.8	25.9	6.1	7.9	2.9	5.7	14.8
11-12	29.5	26.7	- 1.9	10.2	3.2	6.5	16.7
12-13	49.3	29.0	-20.3	11.2	3.6	7.2	18.6
13-14	71.8	sand	-71.8	18.6	3.8	7.5	19.3 *
14-15	43.4	29.0	-14.4	12.9	3.5	7.0	18.1
15-16	34.4	26.3	- 8.1	10.8	3.4	6.7	17.3
16-17	29.2	22.4	- 6.8	9.4	3.1	6.2	16.1
17-18	18.1	25.9	7.8	7.6	2.8	5.6	14.6
18-19	8.1	25.6	17.5	5.2	2.5	4.9	12.8
19-20	7.0	25.6	18.6	5.3	2.5	3.0	7.7
Total	328.8	302.3	-26.5	114.2	36.5	72.6	197.1

* + 9 m^3 (gabions)

Summary of Material Volume Requirements

I	Compacted Clay	Volume excavation	=	302.3 m^3
		Volume earth fill	=	382.0 m^3
II	Termite Mounds	Volume	=	114.2 m^3
III	Stone	Volume chippings	=	36.5 m^3
		Volume gravel	=	72.5 m^3
		Volume stones	=	197.1 m^3
IV	Water	Volume	=	150.0-200.0 m^3
V	Other materials	Cement	=	30-35 sacks
		Sand	=	5.0 m^3

TOTAL VOLUME OF DAM STUCTURE = 802.4 M^3

Source: Hassing 1988

Costs of the Ntossoni dam

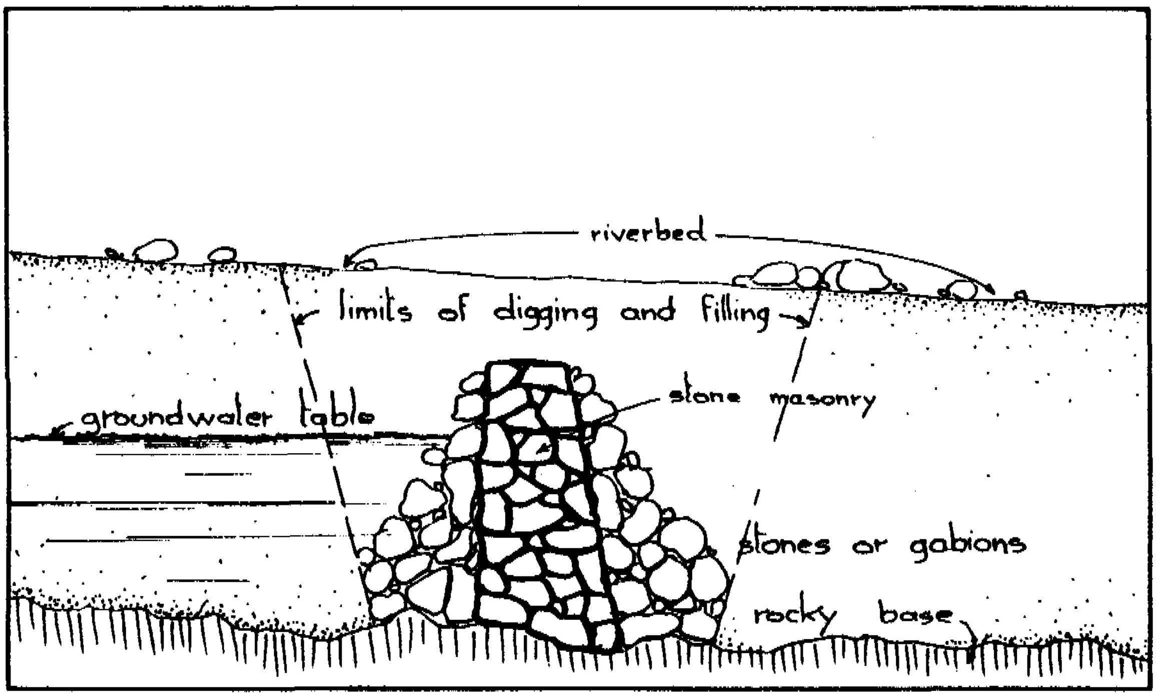
Specifications:

		COST	No.	Value	Sub-total
I	Tools				
	Wheelbarrows	20,000	8	80,000	
	Picks	3,870	25	19,350	
	Shovels	2,000	25	17,500	
	Rammers	14,500	5	14,500	
	Rammers	16,865	5	16,865	
	Sticks	2,500	20	20,000	
					168,215 CFA
II	Materials				
	Iron mesh	50,000	4 m	12,000	
	Gabions	4,000	20 m	80,000	
	Iron wire	5,000		1,500	
	Cement	3,000	35 sacks	105,000	
					198,500 CFA
III	Transport				
	Lorry 6T	20,000	28 days	560,000	
					560,000 CFA
					926,715
IV	Village participation (estimate)				
	Manual Labour	2,686	x 800 CFA/d	2,148,800	
	Carters	200	x 500 CFA/d	100,000	
	Scrapers made by villagers			20,000	
	Blacksmiths	100	x 800 CFA/d	80,000	
	Masons	24	x 1,500 CFA/d	36,000	
	Others			40,000	
					2,424,800 CFA
V	Technical Assistance (estimate)				
	daily allowances: 60 days, three persons			360,000	
	transport 5,000 km x 150 CFA/km			750,000	
	Equipment: photography, surveying equipment, etc.			500,000	
	salaries: three months (technician, driver)			480,000	
					2,090,000 CFA
				TOTAL CFA	5,441,515

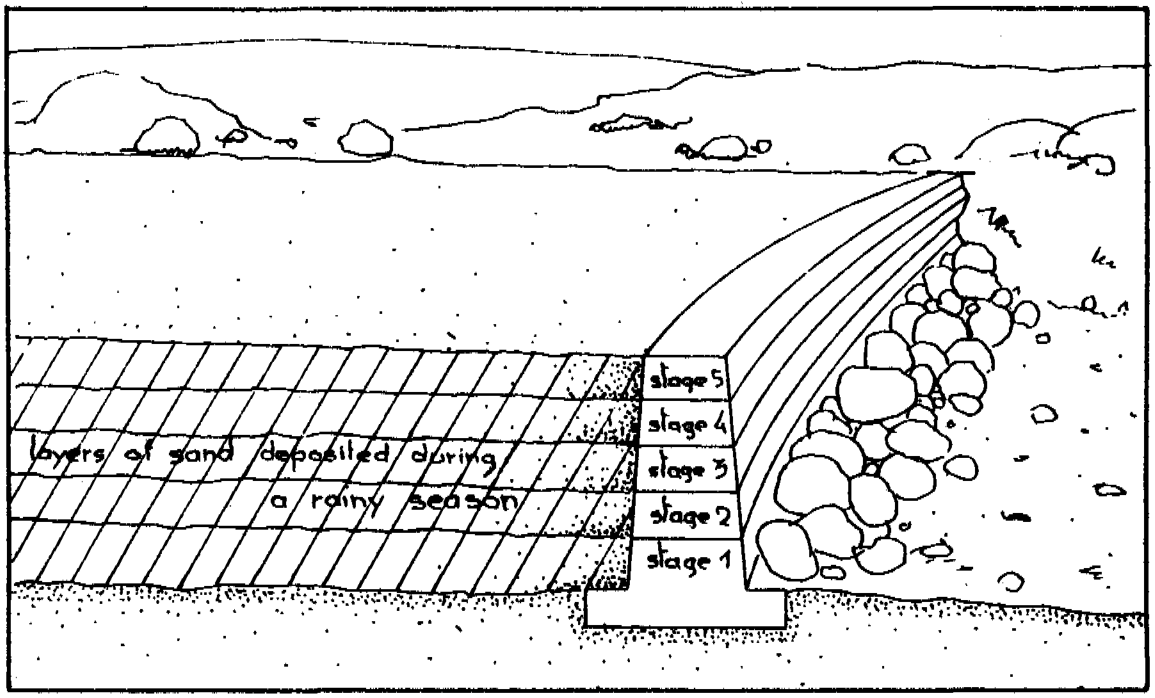
320 CFA = 1 US dollar

Source: Hassing 1988

Appendix V: Principles of sub-surface and sand-dam construction (Nilsson, 1988)

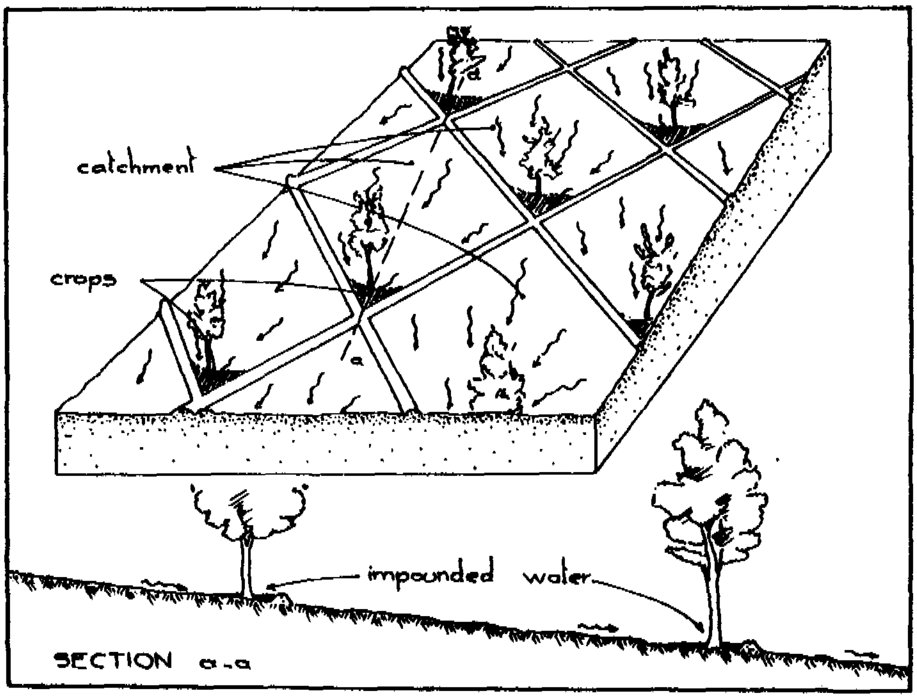


Masonry sub-surface dam construction (after Nilsson, 1988).

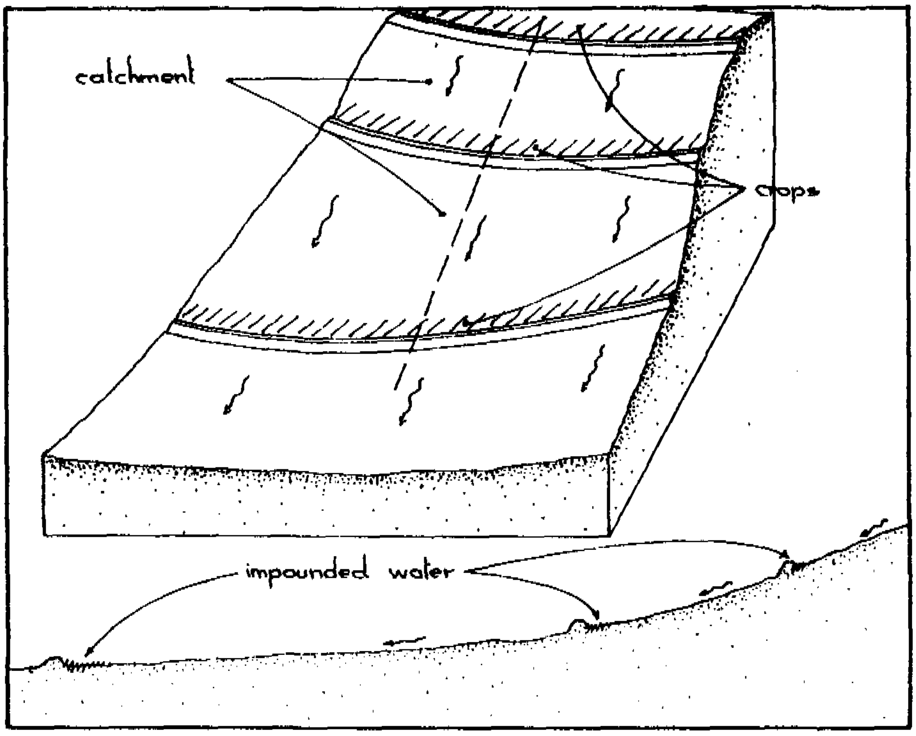


Sand-dam construction principles (after Nilsson, 1988).

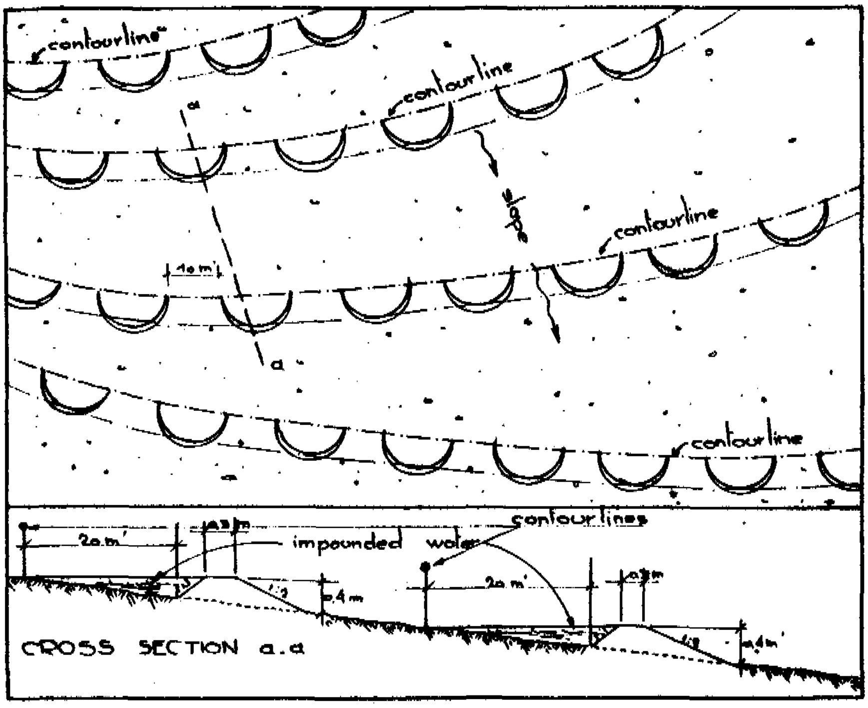
Appendix VI: Layout and construction of runoff farming systems



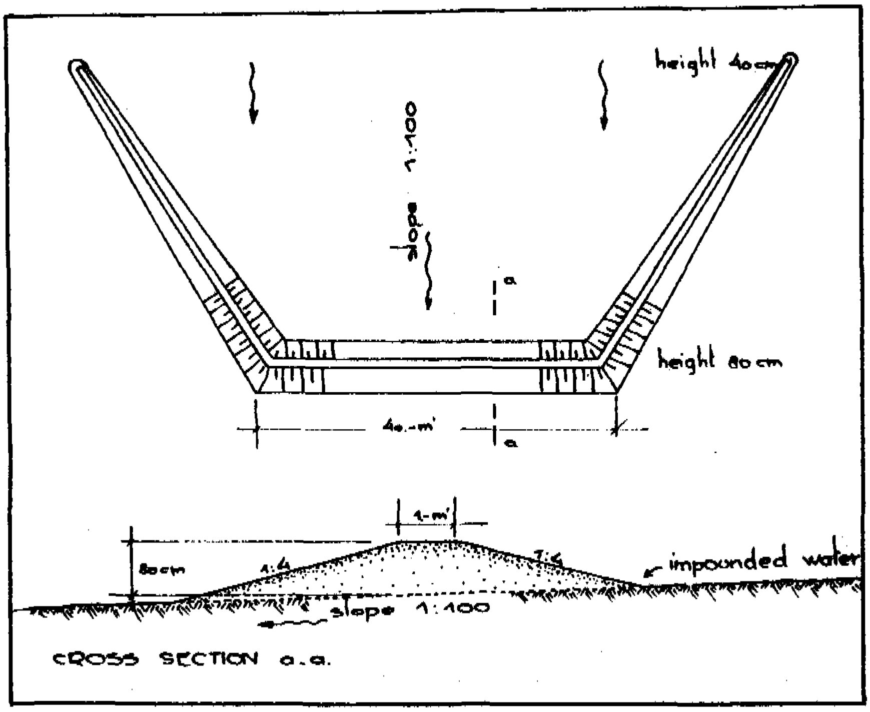
Micro-catchment layout (after Pacey and Cullis, 1986).



Contour bund layout (after Pacey and Cullis, 1986).

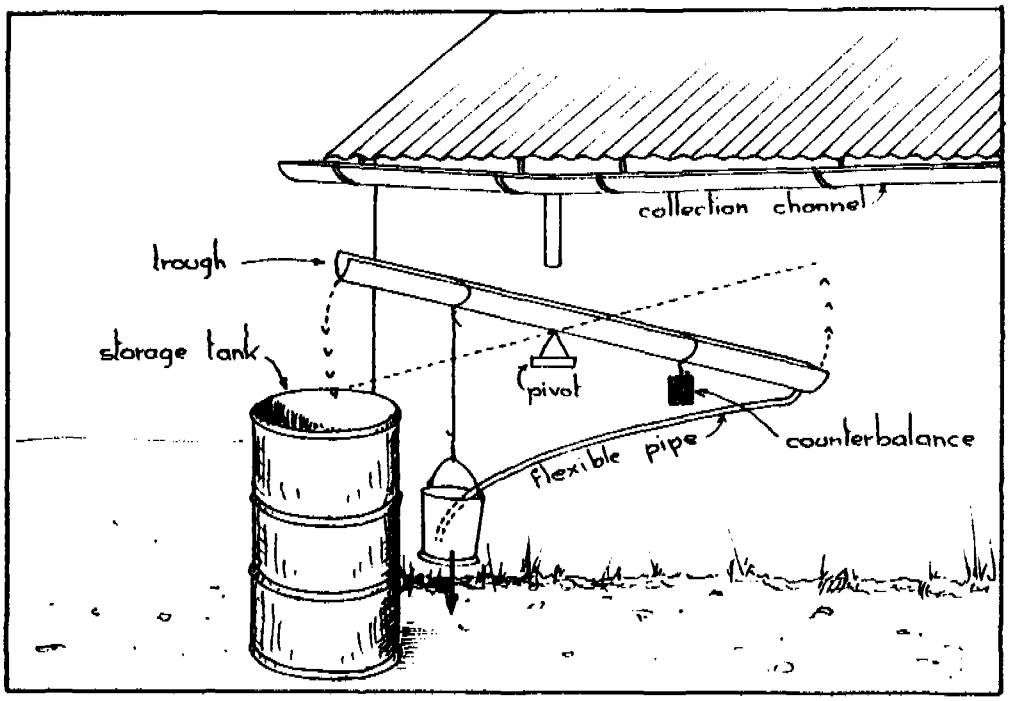


Semi-circular bunds in Turkana, Kenya (after Finkel, 1984).

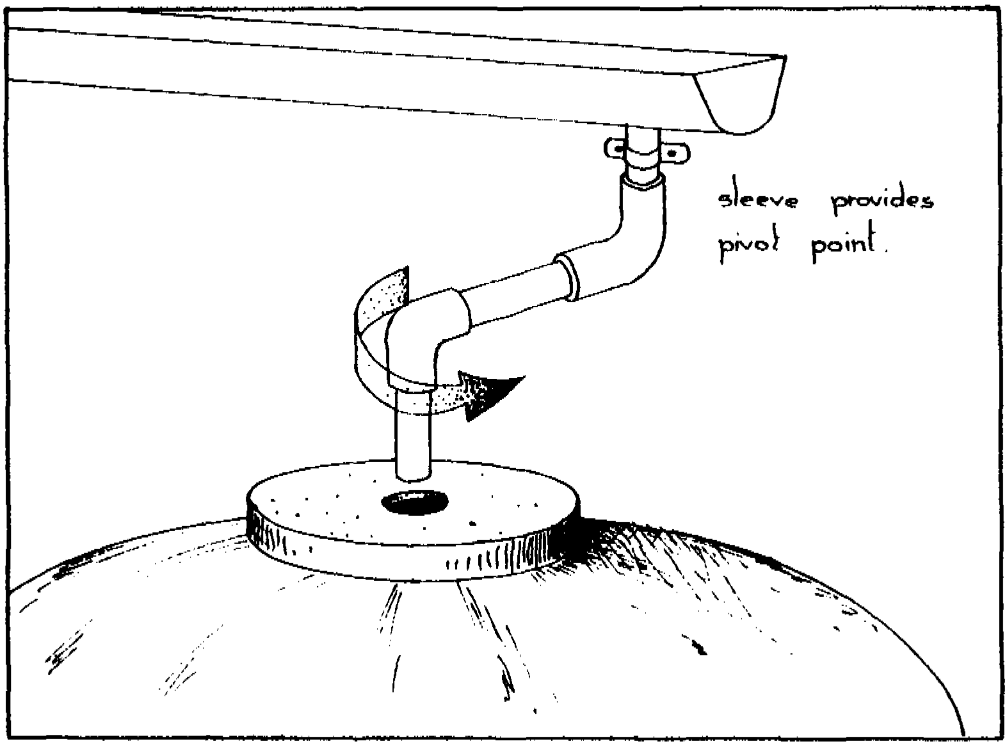


Trapezoidal bund in Turkana, Kenya (after Critchley, 1987).

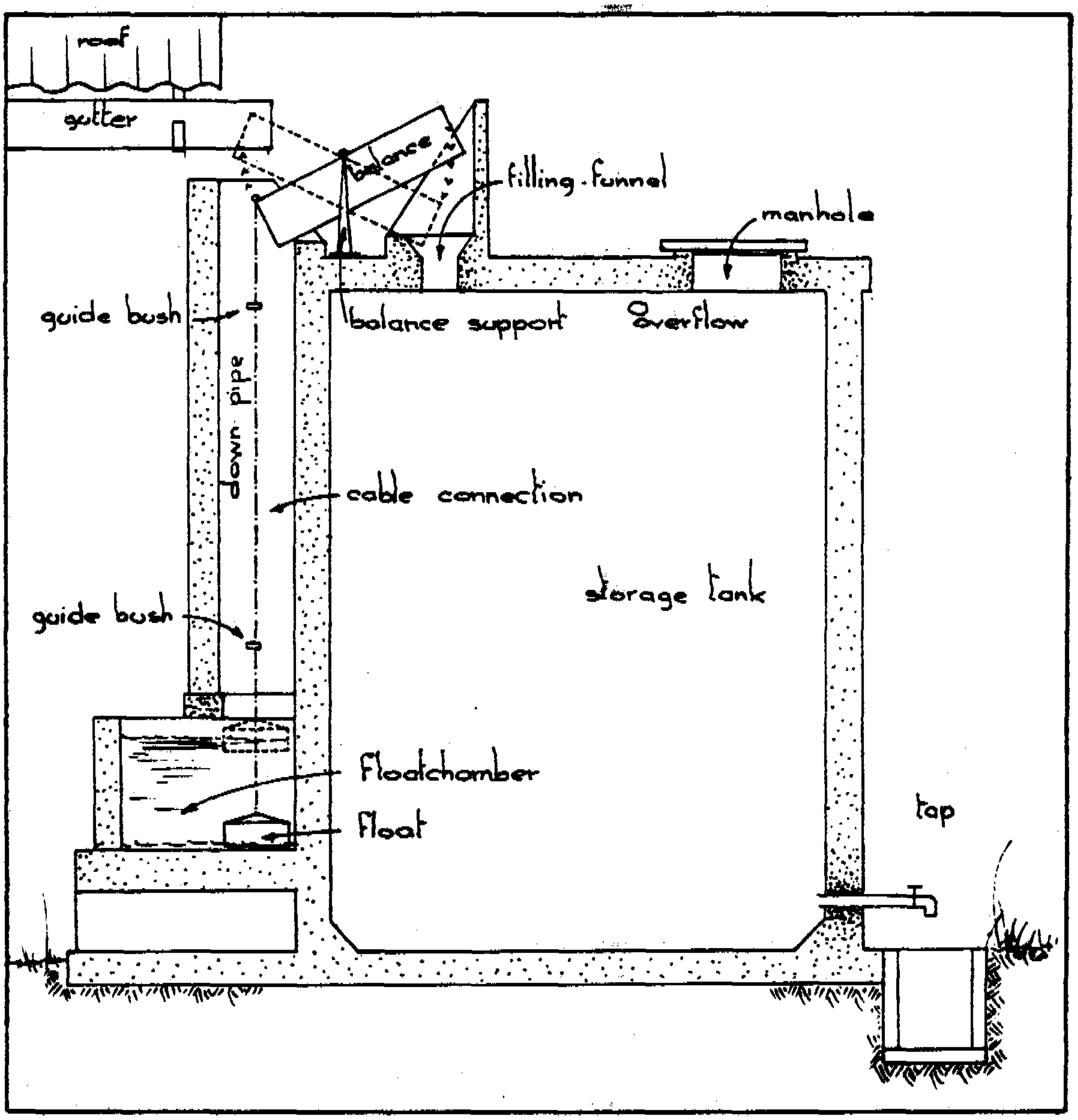
Appendix VII: Devices to protect water quality and divert the first foul flush of water from rooftops



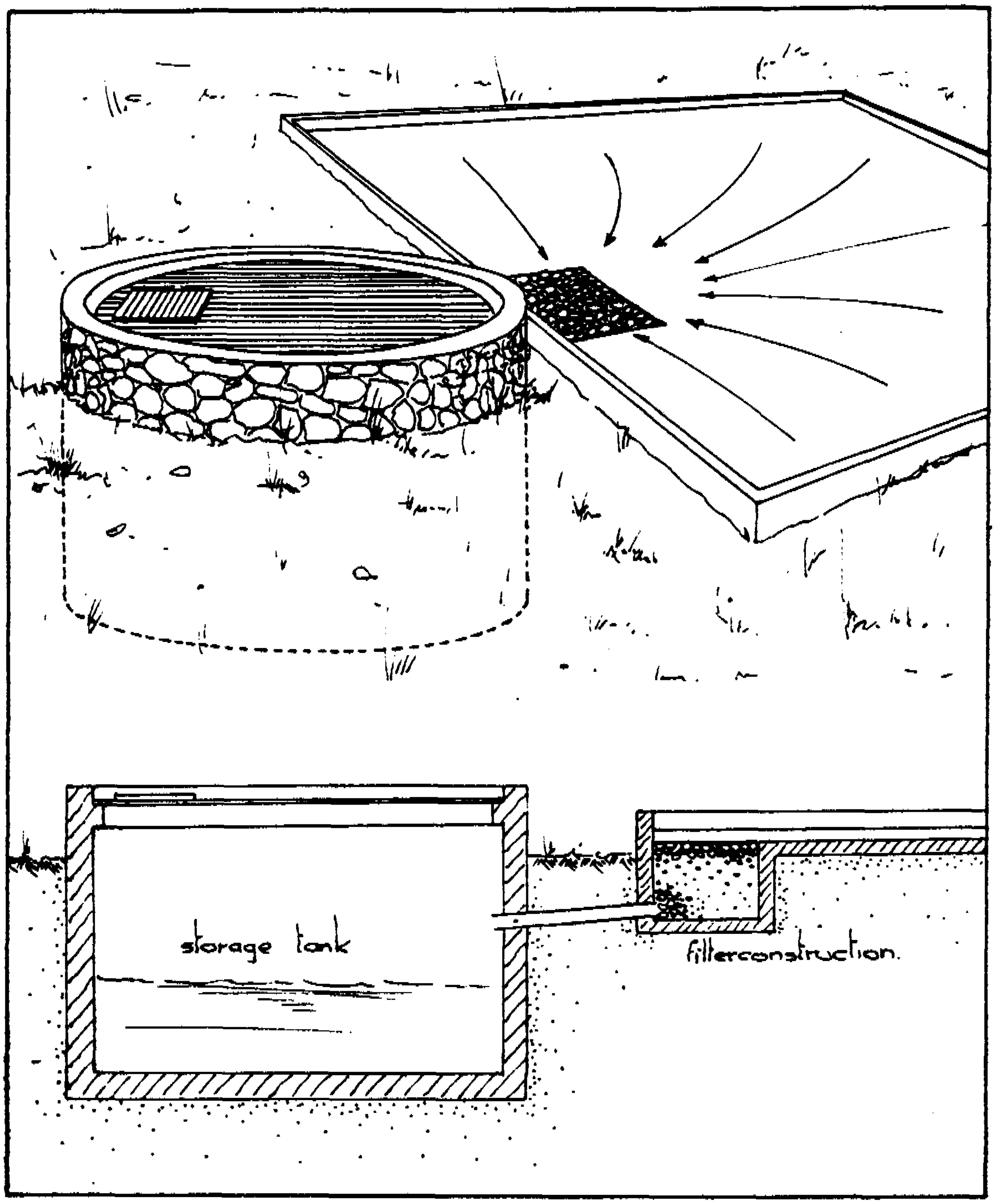
Simple pivot system seen in Kenya (after Omwenga, 1984).



Adjustable downpipe fitting (after ITDG, 1984).



First flush device for Campagne Citernes cistern, Togo (after Government of Togo, 1987).



Filter system for ALDEP groundtank, Botswana (after ALDEP, 1982).

Appendix VIII: Background to and details of the rooftop catchment tank user questionnaire, Diocese of Kitui, Kenya (Schriever J., 1989 personal communication)

Summary

Because of questions concerning how to further develop an effective tank programme, a questionnaire was arranged.

Kitui District is a dry area. To catch rainwater from rooftops can be seen as one of the most important methods of rainwater harvesting for domestic use.

The most important conclusions from the questionnaire:

- five litres of water per person per day are available in a dry period of 150 days for a family of 12 people (adults and children) using a Diocese of Kitui tank;
- savings in walking for water by owning a tank are 6412 km or 1280 hours/year;
- time gained/saved was used amongst other things for improved child care and supervision;
- people with tanks are also aware of the necessity of pit latrines;
- in a follow-up programme people are willing to pay for labour and material costs of a 9000 litre tank;
- the current programme found that the poorest people were not reached.

History

In 1987 the water-section of the Diocese of Kitui started a water tank project funded by the Irish Government.
A 9000 litre ferro-cement water tank design was chosen based on that of S.B. Watt (1978). With available resources, 40 tanks could be built in each of the 16 parishes, a total number of 640 tanks.

The total cost of a tank was approximately Ksh 5000 (estimate June 1988). The contribution of the Diocese was approximately Ksh 3000 (estimate June 1988). The contribution by the recipient was:

- cash Ksh 750;
- local materials like sand, cocoto, hardcore;
- food and accommodation for the artisan;
- manual labour (one or two casuals) to help the artisan.

Calculated in monetary terms this makes a total of approximately Ksh 2000 (estimate June 1988).

The tanks were divided, in principle, amongst the parish community groups by the parish council, a committee of chairman of church station councils all over each parish. This was necessary because of the limited number of tanks to be built in this project and the high demand by parishioners due to the heavy subsidy offered.

To make it easier for the staff of the water section to arrange transport, it was preferred to have a minimum of five tanks for a group to be built at one time. However, due to the distribution of tanks, individuals had to be accepted so increasing transport costs. The maximum number of tanks to be built for one group was 10, to guarantee a fair division over the parish.

Questionnaire

The Diocese of Kitui arranged a questionnaire, because they had questions concerning how best to continue a tank programme in the future. They were concerned particularly with:

- the user contribution;
- the installation of gutters (this had been poor previously);
- the linking of water supply improvement to sanitation;
- what kind of people were being reached.

The questionnaire was made by the staff of the water section of the Diocese of Kitui. The questions were modified where necessary by a psychologist.
As a trial each of the six area coordinators of the water section questioned one tank owner and filled in the questionnaire-form. They could not discover any appreciable difficulties or shortcomings. They arranged the following procedure: for every parish, 6 tank owners would be asked, so with 16 parishes this would produce a total of 96 respondents for the whole of Kitui District (15% sample). In each parish, every 10th, 15th, 20th, 25th, 30th and 35th tank owner on the implementation list would be questioned. All the forms were filled in between the 18th of April and the 11th of May 1989.

Rainfall and Tanks

There is a larger rainy season in November and December and a smaller one from the second half of March up to the end of April. The total rainfall in March and April prior to the questionnaire survey was normal, below half of the yearly total. The average annual rainfall for Central Kitui District is 750-1000mm and for North, East and South Kitui is 500-750mm.

Results

The questionnaire listed in the following pages is filled in with the observed results. The figures apply to the 96 (15% sample) respondents.

QUESTIONNAIRE

DIOCESE OF KITUI - Water Tank Project Evaluation

Name: . . . .
Group: . . . . Parish: . . . .
Date: . . . . Date finishing tank: . . . .

The existing tank programme is almost finished. We would like to have some information to help adjust the future programme.

1.	How did you come to know about tanks?			
	Through Parish Priest	19.8%		
	Through Parish council	45.8%		
	Through other groups			
	Through Mwethya group	29.2%		
	Through sub-chiefs	1.0%		
	Through SALU group			
	Through friends			
	Others	4.2% (station council)		
2.	How was the family selected for a tank?			
	By parish council	8.3%		
	By Mwethya group	75.0%		
	By parish priest	9.4%		
	By others	7.3%	3.1% just by paying 4.2% station council	
			YES	NO
3.	Was the family chosen through ballot vote?		77.1%	22.9%
4.	Was the family chosen as a result of there being nobody else with a mabati (metal) roofed house?		3.1%	96.9%
5.	Was the family chosen in the Merry-go-round system?		Cancelled!	
6.	Was the family given the tank by another member who did not want it?		3.1%	96.9%
7.	Has the family another tank?		4.2%	95.8%

8.	How many people of your family use the water of the tank? (daily use)	4.45 Adults 7.9 Children		
9.	Where is the husband working?	81.2% in Kitui District 14.6% in Nairobi 4.2% in another place		
10.	What kind of work has the husband/wife?		Husband	Wife
			YES	YES
	a) an office job		46.9%	14.6%
	b) own business		21.9%	2.1%
	c) depends on shamba work		24.0%	83.3%
	d) others		5.2%	
	e) no husband/wife		2.1%	

11. To whom did you pay the Ksh 750 for the tank?

parish priest	85.4%
parish secretary	7.3%
Kitui development office	7.3%
Others	-
Do please give us your receipt number	70% could, 30% could not

12. Had family paid full amount before construction? 94.8% Yes 5.2% No

13. Would you pay Ksh 3,000 for the same tank next year? 88.5% Yes 10.4% No 1% Don't know
(most people said yes, if possible to pay in instalments)

14. Were all materials on site when Fundi arrived? 100% Yes 0% No

15. How many members worked with the Fundi to construct the tank? (in %)

members	1	2	3	4	5	more
Day 1:	9.4	28.1	22.9	5.2	17.7	16.7
Day 2:	11.5	33.3	27.1	9.4	15.6	3.1
Day 3:	11.5	36.5	25.0	8.3	15.6	3.1
Day 4:	13.5	28.1	16.7	5.2	17.7	18.8
Day 5:	14.5	34.4	21.9	8.3	17.7	3.1
Day 6:	12.5	38.5	21.9	7.3	16.7	3.1
Day 7:	15.6	21.9	22.9	7.3	21.9	10.4
Day 8:	12.5	34.4	21.9	6.2	16.7	8.3
Day 9:	16.7	21.9	17.7	7.3	15.6	6.3

16. Was the fundi cooperative? 100% Yes

Yes, because .... (reasons given included: hard working, responsible, sociable, punctual, not selective with food, happy, active, willing to work, knows how to organize group members, good in supervision, kind, peaceful)

17. Did family keep water in tank after construction? 100% Yes

18. Are there any cracks in the tank? 19.8% Yes 80.2% No

19. Is the family happy with the tank? 100% Yes

Yes, because .... (main reasons given included: water is near - 62.5%, water is clean - 42.7%, + others: time saved, extra time for child care, enough time for other important activities, water problem solved, no more heavy carrying for long distances, etc.)

No, because . . . .
. . . .

20. Is the area close to the tank clean? 100% Yes

21. Does the family have a pit latrine? 80.2% Yes 19.8% No

22. How far is the pit latrine from the tank?

Less than 5 ft.	1.1%
Less than 10 ft.	1.1%
Less than 25 ft.	2.2%
Less than 30 ft.	5.4%
More than 30 ft.	90.2%

23. Is the house built of:

clay bricks	68.8%
stone	2.1%
cement blocks	21.9%
sticks and murram	7.3%

24. (a) have gutters been placed? 94.8% Yes 5.2% No

(b) By whom?

yourself	39.3%
your family	5.6%
a Fundi	55.1%

(c) Are gutters made of?

local materials e.g. sisal	5.0%
proper gutters	66.7%
mabati (iron-sheet)	28.3%

(d) Why are they not placed?

too expensive	60% (3 of 5)
construction problems	20% (1 of 5)
materials not available	0%
illness	20% (1 of 5)

25. How close is the nearest water source?

less than 2 km	15.6%
less than 5 km	29.2%
above 5 km	55.2%

26. What is the roof size in m^2?

south	69.4		
east	46.2		
central	40.8		
central north	45.7		
north	53.2		
far north	35.8	total average	48.5

27. What is the water-level in the tank?

empty	2.1%
1/2 full	10.4%
1/2 full	16.7%
3/4 full	19.8%
full	51.0%

Appendix IX: Guidelines issued for Plan International Embu to rooftop catchment tank owners, Kenya (1989)

1. Use

1.1 The roof surface and the gutters must be kept free from the excreta of birds and animals, dust and leaves. This is to safeguard the quality of the rainwater entering from the roof surface.

1.2 The gutters and inflow pipe must be regularly cleaned of leaves and other rubbish which may collect in them. This prevents clogging of the inflow pipe with washed off materials which would prevent water from entering the storage tank.

1.3 If there has been no rain for two or more days, the inflow pipe should be placed so that it is not leading into the reservoir but hanging beside it. Five to 10 minutes after rains begin, the inflow pipe can be connected to the reservoir again.

1.4 The mosquito *protection screen* over the overflow pipe must be checked regularly and if necessary should be repaired.

1.5 To keep the water consumption (for drinking and feeding only) under control the tap should be closed with a padlock.

1.6 The water level in the tank should be measured and noted once a week using the same measuring stick (which is not to be used for any other purpose).

1.7 A drop of 1 cm in the tank water level corresponds to approximately 20 litres (one jerry can) consumption. Storage capacity of 12000 gallons supplies 5 litres per person for a period of 125 days for a family of eight persons (two jerry cans/day), and 900 gallons can supply 4 litres per day (one and half jerry cans). During dry periods, the drop in water level should correspond approximately with consumption. If this is not the case, the reservoir is leaking and wet spots will be visible.

1.8 To prevent the place becoming a breeding place for mosquitoes, the *drain pit* should remain clean and dry.

1.9 Keep the drain to the seepage pit open and avoid blocking to prevent mosquitoes and insects breeding.

The water must be boiled before drinking.

2. Annual Maintenance

2.1 Annual maintenance is carried out at the end of the dry period, when the reservoir is "almost" empty.

2.2 Any leaks that have been noticed during the preceding wet season must be repaired. Wet spots on the wall are treated on the inside with a cement/water mixture (proportions 1:2 parts by volume). If a leakage is evident but no wet patches have been discovered in the walls of the reservoir, the floor of the reservoir must be treated with a cement/water mixture and finished off with a layer of plaster (portions 1:2 sand: cement by volume).

2.3 The interior of the reservoir is cleaned by removing deposits from the bottom and scrubbing the bottom and walls with clean water. The water used is discharged through the drain.

2.4 The roof surface, suspending hooks and the inflow pipe are checked and if necessary, repaired.

2.5 The gutter lining should be checked and sags and leakages repaired.