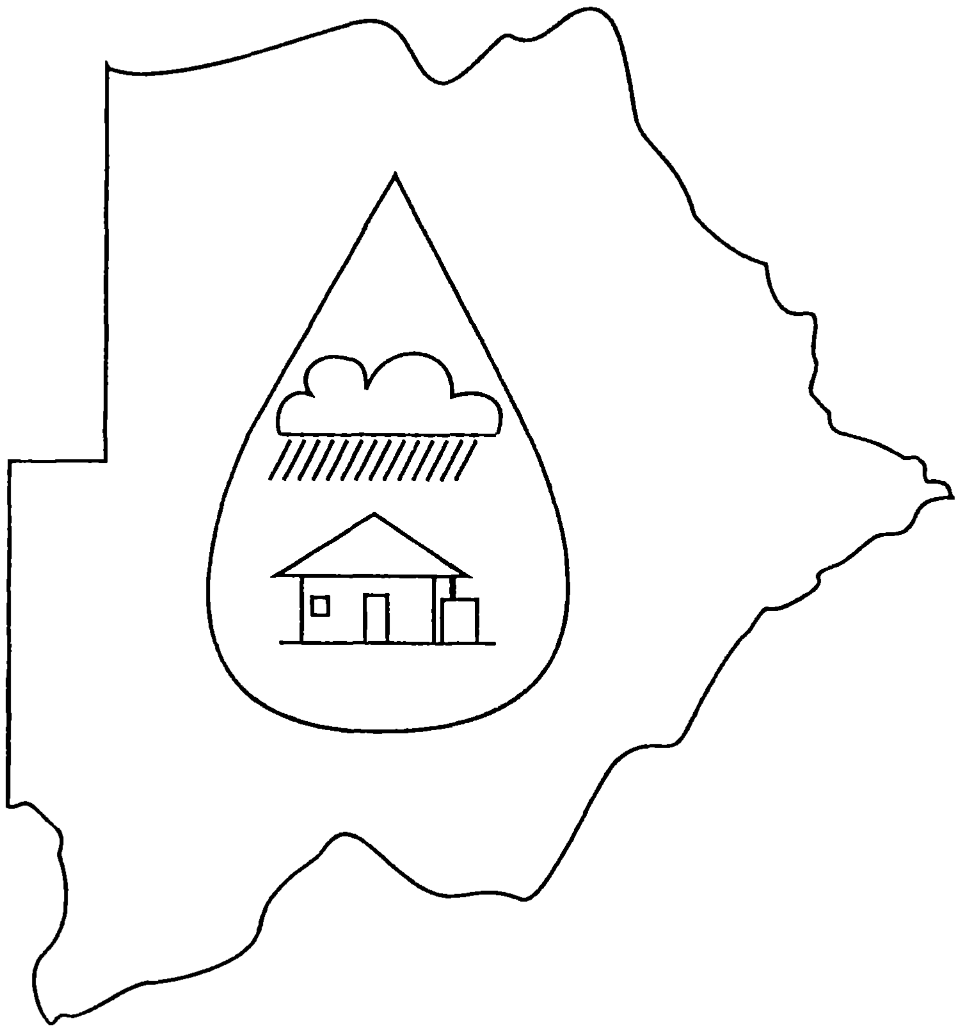
RAINWATER CATCHMENT SYSTEMS APPLICATION AND TECHNOLOGY WORKSHOP

1st - 3rd MARCH 1993



GABORONE / KANYE

BOTSWANA

Sponsored by BTC, SIDA, RIIC, DWA and NIR, and organised in conjunction with International Rainwater Catchment Systems Association (IRCSA)

Rain Water Catchment Systems
Application and Technology
Workshop Proceedings

1st - 3rd March 1993

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PREAMBLE

BACKGROUND

The art of Rainwater collection has been practiced for several thousand years both for domestic water supply and agriculture. Although rainwater catchment systems were in decline early this century the last two decades has witnessed a renaissance of this technology. In some rural areas of Africa and Asia growth of the technology has been spectacular for example in Thailand where around 12 million large ferro cement rainwater jars have been constructed in the last decade. In Africa Kenya has lead the way in the implementation of roof, ground and rock catchment systems. A large number of projects are currently underway including a programme constructing 46 cu m ferro cement roof catchment rainwater tanks at hundreds of primary schools in Kitui district. In Botswana despite a long standing interest in rainwater collection, as evidenced by the common sight of roof catchment tanks particularly in rural areas, enormous potential remains untapped. It is the goal of this workshop and the forthcoming international rainwater catchment systems conference in Kenya in August 1993 to promote rainwater collection and to address some of the obstacles both technical and socio-economic which impede the wider use of this technology.

ACKNOWLEDGEMENTS

The prime movers of this workshop are The Botswana Technology Centre, The Department of Water Affairs and the The Rural Industries Innovation Centre mobilised resources both financial and staff time inputs to make the workshop possible. The Swedish International Development Agency made a significant funding contribution making it possible to involve a wide spectrum of local and regional delegates.

The Other sponsors and support has come from
National Institute of Research, Botswana Polytechnic, University of Botswana, Ministry of Agriculture, Ministry of Local Government Lands and Housing, and the International Rainwater Catchment Systems Association.

ORGANISING COMMITTEE

An organising committee was set up to oversee the day to day running of the workshop and was responsible for the all decisions leading up to the workshop.

Kribanandan Gurusamy Naidu, Botswana Technology Centre (Chairman)
John E. Gould, University of Botswana (Co-Chair)
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OPENING ADDRESS

Mr. B.Khupe
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Water is a very scarce resource in Botswana. This is due mainly to the fact that rainfall is low, seasonal and erratic; ranging from less than 250mm in the southwest corner of Botswana to just over 650mm in the extreme north. Perennial rivers and good dam sites are few and far between and groundwater availability, accessibility, quality, yield and recharge are problematic. It is thus not surprising that water is considered one of the most precious resources in Botswana, and in some localities where periodic or chronic shortages exist it is especially valued. The scarcity of both surface and groundwater resources in particular in rural areas and in the western part of the country forces us to look to other alternatives like rainwater harvesting and waste water reuse. That is why the collection and storage of rainwater is widespread and practised to some degree throughout the country.

Rainwater catchment is not a new idea in Botswana. It used to be practiced in the pre-independence years where most government officers houses had metal tanks to collect rain. In rural areas people used to dig shallow pits near their homes to collect runoff. The disadvantage with the latter is that most of the collected water was left to infiltrate into the soil or evaporate into the air. The most common forms of rainwater catchment systems currently found in Botswana are those built at remote homesteads under A.L.D.E.P. and those built at schools in almost every village in the country by district councils. The brigades and private home owners have, however, also been responsible for the construction of many rainwater tanks.

Until now the Government has not concerned itself directly with the provision of water to smaller and remoter settlements. However, the Department of Water Affairs has recently completed the National Water Master Plan which investigated water resource demand and development in Botswana over the next three decades. Through this plan the Department of Water Affairs recognizes the need to serve all sectors of society. This includes the 450,000 people currently not catered for by the present the present urban and village water supply systems, of whom about two-thirds still lack access to improved water supplies. Many of those staying in the lands areas collect water from up to 4km from where they live, often from contaminated traditional sources.

In response to this urgent need for improved water supplies for small and remote settlements, a Lands Area Water Supply Study is ongoing and nearing completion. A wide range of different appropriate technologies will be required and rainwater catchment systems will certainly have an important role to play. The provision of improved water supplies to remote and isolated homesteads can be extremely expensive and it is especially in such situations that roof catchment systems are of greatest utility. Rainwater tanks can provide a convenient improved water source, and an extremely welcome one for the women and children who still walk long distances to collect water.

Rainwater catchment systems can also play an important role in helping to conserve water in larger towns and settlements. In small villages too, rainwater catchment systems can provide an invaluable supplementary or back-up supply which could be used at times when the main water supply systems are not functioning due to breakdowns, maintenance work or in severe droughts when boreholes sometimes dry up. These could help to reduce the reliance on very expensive water bowsers, which currently supply villages with emergency supplies.

By bringing together experts and practitioners in the fields of engineering, hydrology, architecture, building, agriculture, management and research this workshop will aim to share knowledge and experience in the field of rainwater catchment systems technology. Hopefully through these deliberations some useful ideas, realistic strategies and implementable recommendations will emerge. It is particularly useful to have with us experts from neighbouring countries with whom experiences and ideas regarding the development of rainwater catchment technologies can be shared.

This workshop focusing on the application of different rainwater catchment systems in Botswana is thus very timely. The findings and deliberations of this workshop will not only help those agencies charged with water supply provision in Botswana, but will also tie in well with the 6th International Rainwater Catchment Systems Conference scheduled to take place in Nairobi in August this year.

AN OVERVIEW OF RAINWATER CATCHMENT SYSTEMS IN BOTSWANA

Baraedi Jay[3] and John E. Gould[4]

ABSTRACT

Botswana is a semi-arid country with limited water resources particularly in the rural areas. This paper reviews the development of rainwater catchment systems in the country and considers its future potential particularly in the context of the forthcoming Lands Area Water Supply Project and the continuing Arable Lands Development Programme Water Tank Scheme. The increased use of rainwater as a supplementary supply at primary schools, clinics and private households through out Botswana is proposed, especially in localities experiencing periodic water shortages. Data on rainwater quality for roof tanks are presented and some of the limitations and advantages of using rainwater catchment systems discussed.

INTRODUCTION

Botswana has a semi-arid climate with mean annual rainfall varying from less than 250mm in the extreme southwest of the country to more than 650mm in the extreme north (Figure 1a and 1b). The rainfall is erratic and mainly concentrated in a rainy season lasting from October until April. Evaporation on the contrary is predictable and rates exceed 2000mm/annum in most areas. Due to Botswana's flat topography and sandy pervious soils surface water sources are limited.

Permanent surface water is rare in Botswana and although a few ephemeral rivers have been dammed to create reservoirs for serving major settlements and industry, the lack of suitable rivers and dam-sites mean that surface water supplies are not generally appropriate for providing rural water supplies.

Good quality groundwater is available in many areas of Botswana and over 15000 boreholes have been sunk throughout the country to access this supply. In some areas, however, the groundwater is either too deep, too unreliable or too saline to provide an acceptable supply for domestic purposes (Figure 1c and 1d). In these areas alternative water sources have to be found or water has to be trucked in by bowser from considerable distances and at great expense. In such locations, rainwater collection is frequently the most cost effective option. It is also often preferable to long pipelines for supplying water to small scattered communities in remote areas.

The National Water Master Plan has highlighted the need to provide water to all sectors of society. In response to this a major Lands Area Water Supply Project is currently being investigated to provided improved water supplies for the 300,000 people in remote rural areas who presently lack access to any form of conveniently located improved water supply. Rainwater catchment systems, especially in the form of individual roof catchment tanks are likely to play an important role in this project, especially for serving remoter isolated homesteads.

In rapidly growing urban centres such as Gaborone, rainwater catchment systems offer the potential for reducing demand for mains water and there-by buying more time for finding alternative sources of supply. Rainwater catchment systems can

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also be used in villages with existing reticulated borehole supplies to act as a supplementary back-up supply at times when the main system is not functioning. Villages suffering periodic water shortages and currently supplied by costly water bowsers in these instances, and remoter settlements where it can take many days before breakdowns are rectified should be targeted as the first in which to increase rainwater catchment capacity. The rainwater tanks could even be used to store borehole water in times of drought in anticipation of future breaks in supply.

HISTORY OF RAINWATER CATCHMENT SYSTEMS IN BOTSWANA

Although the evidence is limited, traditionally people have collected rainwater running off ground surfaces in excavated pits and from the eaves of thatched roofs in pots and other small containers for centuries. In fact, to a degree this practice continues to the present day.

The use of more formalized rainwater catchment systems such as roof catchment tanks probably dates back to the turn of the century. While there are occasional passing references to rainwater collection in the literature from the colonial period, the first major study on rainwater collection in Botswana was published by ITDG (1969). This outlined a project to install excavated ground catchment tanks at 12 Primary schools in eastern Botswana for storing water for irrigating school gardens. Follow up reports by ITDG (1971), Farrar and Pacey (1974), Gould (1985), and Pacey and Cullis (1987) concluded that although the project failed, partly as a result of the very high labour requirements involved, it may have sown the seeds for the nationwide Arable Lands Development Programme (ALDEP) tank programme which took root a decade later.

Many older buildings had rainwater tanks included in their original design, in Nata the primary school still uses tanks built in the 1940's and even in Gaborone many of the BHC high cost houses built in the 1960's have corrugated iron tanks. In the 1980's the Botswana Technology Centre encouraged the implementation of ferrocement rainwater tanks using the design advocated by Watt(1978) involving the use of corrugated iron moulds. Around 150 tanks of this type were constructed ranging in volume from 10 to 30 cubic metres, however as a result of poor workmanship and inadequate training and supervision, there were a variety of problems with these tanks and only a minority have stood the test of time, Gurusamy (1991).

CURRENT STATE OF THE ART

The single biggest scheme responsible for rainwater tank construction in Botswana has been the Arable Lands Development Programme administered by the Ministry of Agriculture. Through their water tank package which has provided a substantial subsidy to small farmers more than 700 sub-surface ferrocement ground tanks were built between 1979-1991. Most of these used traditional threshing floors or compacted surfaces as catchment aprons (Figure 2a). Since the beginning of 1991 more than 200 7m^3 polyethylene surface tanks connected to roof catchment systems have been installed (Figure 2b), bringing the total number of tanks built under the scheme to something approaching 1000.

Ground Catchment Tanks

Although the ALDEP tanks were originally designed to provide water for draught animals in the lands areas to allow early ploughing at the start of the rainy season, invariably people used the water for domestic purposes including drinking, (Ainley 1984). These ground catchment systems used traditional mud/dung threshing floors as catchment areas and as with most ground catchment systems the quality of the water was very poor due to contamination of the catchment area by excrement from small children and animals. It was in response to this problem that the Ministry of Agriculture developed the new design involving a raised corrugated 40m2 iron sheet catchment area and a $7m^3$ plastic polyethylene tank, (Visscher and Lee 1991). While the bacteriological quality of rainwater collected from ground catchments is invariably poor, that from properly maintained roof catchment systems with a cover and tap is generally suitable for drinking.

This problem has been addressed in a number of ways:

- replacing ground catchment systems with the new ALDEP roof catchment system design

- discouraging the use of water from ground catchment tanks for drinking

- erecting fences around tanks (and sometimes catchment areas)

Farmers throughout Botswana owning fewer than 40 head of cattle can participate in the ALDEP catchment tank scheme and they receive an 85% subsidy from the government towards the P2500 roof/tank system, Figure 2b. Despite this generous assistance some farmers find the 15% down-payment averaging around P350 prohibitive and the project remains under-subscribed.

Roof Catchment Tanks

Roof catchment tanks are a common sight at primary schools in villages throughout Botswana. Surveys conducted by the Botswana Technology Centre have revealed that about half the 800+ primary schools in the country possess tanks, most of them being of the corrugated iron variety. Since these have an average life expectancy of only about 5 years many schools have leaking tanks. Despite having average roof areas of around $1300m^2$, the average number of roof tanks per school is just over 2. The average volume of the tanks totalling just $12m^3$. This is only around a tenth of the volume required to ensure that most of the rainwater available is captured. Despite the poor performance of roof catchment tanks at schools the majority of schools in Botswana are keen to have more tanks.

Rainwater tanks are also found at clinics and other government buildings in many villages and it is the district councils who are charged with the construction and maintenance of these. Some councils eg. Central District Council have been constructing brick tanks at schools, but these have also been subject to cracking problems due to a design fault.

Many private households have also invested in roof catchment tanks especially in rural Botswana where the trend towards replacing thatched roofs with impervious tiled or corrugated iron ones has the fortuitous advantage of benefitting rainwater collection.

Most of the ferrocement roof catchment tanks built in Botswana have either been constructed by private contractors or the Brigades. Problems with the design, lack of training, poor materials and water and bad workmanship have resulted in a generally disappointing long term performance of many of these tanks, Gurusamy and Gould (1992). This is unfortunate as experience with ferrocement tanks in other parts of the world, eg. Thailand, Philippines and Kenya has been extremely promising, Gould (1991).

The issue of water quality is frequently raised in relation to rainwater catchment systems. While water from ground catchments is certainly not suitable for consumption without first being boiled or chlorinated, water from clean well maintained roof catchment systems is generally potable. While not always reaching WHO standards it is nevertheless generally safe and if in doubt it can be simply treated by exposing it to sunlight for a few hours in a glass or transparent plastic bottle to allow the ultra-violet light to kill off any pathogens. The results of bacteriological analysis of the water quality of 10 covered roof catchment tanks are given in table 1. While all but one of the samples are within even the WHO standards for total and faecal coliform counts the presence of significant numbers of faecal streptococci in half the samples is indicative of contamination by birds, plant matter or lower animals. Although not a serious health hazard it could potentially expose the consumer to the risk of contracting a rare form of salmonella. This contamination probably indicates that insufficient effort had been made to ensure both the roof and the tank were reasonably clean at the time of collection.

Table 1.

Results of Bacteriological Analysis of Stored Rainwater in Covered Roof Catchment Tanks in Botswana.

Location of Tank	Total* Coliforms	Faecal* Coliforms	Faecal* Streptococci
Tutume	**0**	**0**	**0**
Nata	**0**	**0**	**0**
Francistown	**0**	**0**	**0**
Francistown	**0**	**0**	**0**
Unknown**	**1**	**0**	**1**
..	**0**	**0**	**44**
..	**0**	**0**	**75**
..	**0**	**0**	**90**
Tlokweng	**0**	**0**	**46**
Morwa	**0**	**0**	**165**
Max. Recommended **Concentration** (WHO)	<10	<1	<1
Local guidelines (Remote rural supplies)	<100	<10	<10

* Per 100ml calculated from 5ml and 50ml samples.
** Source of data - Stenstrom and de Jong (1983)

Source: Gould (1985)

Other Rainwater Catchment Systems

Among other rainwater catchment technologies which have been developed in Botswana are a few isolated examples of rock catchment systems, for example at the weavers in Oodi. There is certainly considerable potential for exploiting this technique much more widely as is currently being done in several semi-arid regions in Kenya.

One interesting innovative technique currently being developed by the Rural Industries Innovation Centre (RIIC) is the collection of rainwater from pans. A pilot project is currently ongoing at Zushwa in western Kgalagadi District.

ADVANTAGES AND LIMITATIONS OF THE TECHNOLOGY IN BOTSWANA

The main advantages of rainwater catchment systems are that they can be used almost anywhere and can potentially provide a very convenient high quality water source.

Limitations of the technology lie in its high cost per unit volume supplied and the fact that the quantity of water available is restricted by the size o the catchment, the volume of the tank and the nature of the rainfall. In drought periods rainwater catchment systems yield very little water.

POTENTIAL FUTURE DEVELOPMENTS

One major advantage regarding the possible future expansion of rainwater catchment systems in Botswana is that major programmes already exist through which this technology can be funded. The ALDEP water tank package, the councils water development programme and the Lands Area Water Supply Project.

Nevertheless, there are a number of areas where new development could be encouraged, these include:

- the construction of large ferrocement roof catchment tanks with volumes of up to 50m3, at schools and clinics in rural areas, similar to those currently being constructed in Kenya.

- the inclusion of roof tanks in the designs of all future low cost BHC and SHAA housing projects.

- the introduction of rainwater catchment systems at large institutional buildings at urban centres to encourage water conservation

- major rehabilitation of existing systems.

DISCUSSION AND CONCLUSIONS

Rainwater catchment systems can potentially provide a convenient, clean if somewhat limited water supply in any part of Botswana where a suitable catchment area is available. While the technology cannot effectively compete with other forms of supply where abundant high quality ground and surface water sources are available, it does offer a useful alternative in areas with water problems and for supplying remote isolated households. Rainwater catchment systems also provide an excellent supplementary or backup supply in villages suffering periodic water shortages.

Batswana in general seem to appreciate the cool sweet taste of rainwater and in rural areas are keen to embrace this technology. Considerable potential exists to substantially expand the use of this technology to help to fill gaps and improve the overall national coverage of improved water supply both temporally and spatially.

The use of large ferrocement rainwater tank designs developed in semi-arid parts of Kenya, Nissen-Petersen (1990) may hold the key to the most appropriate way for developing rainwater catchment systems in Botswana during the rest of the 1990's. Substantial investment in training and adapting the design for Botswana conditions would, however, be a vital pre-requisite to ensure the success of backing this approach.

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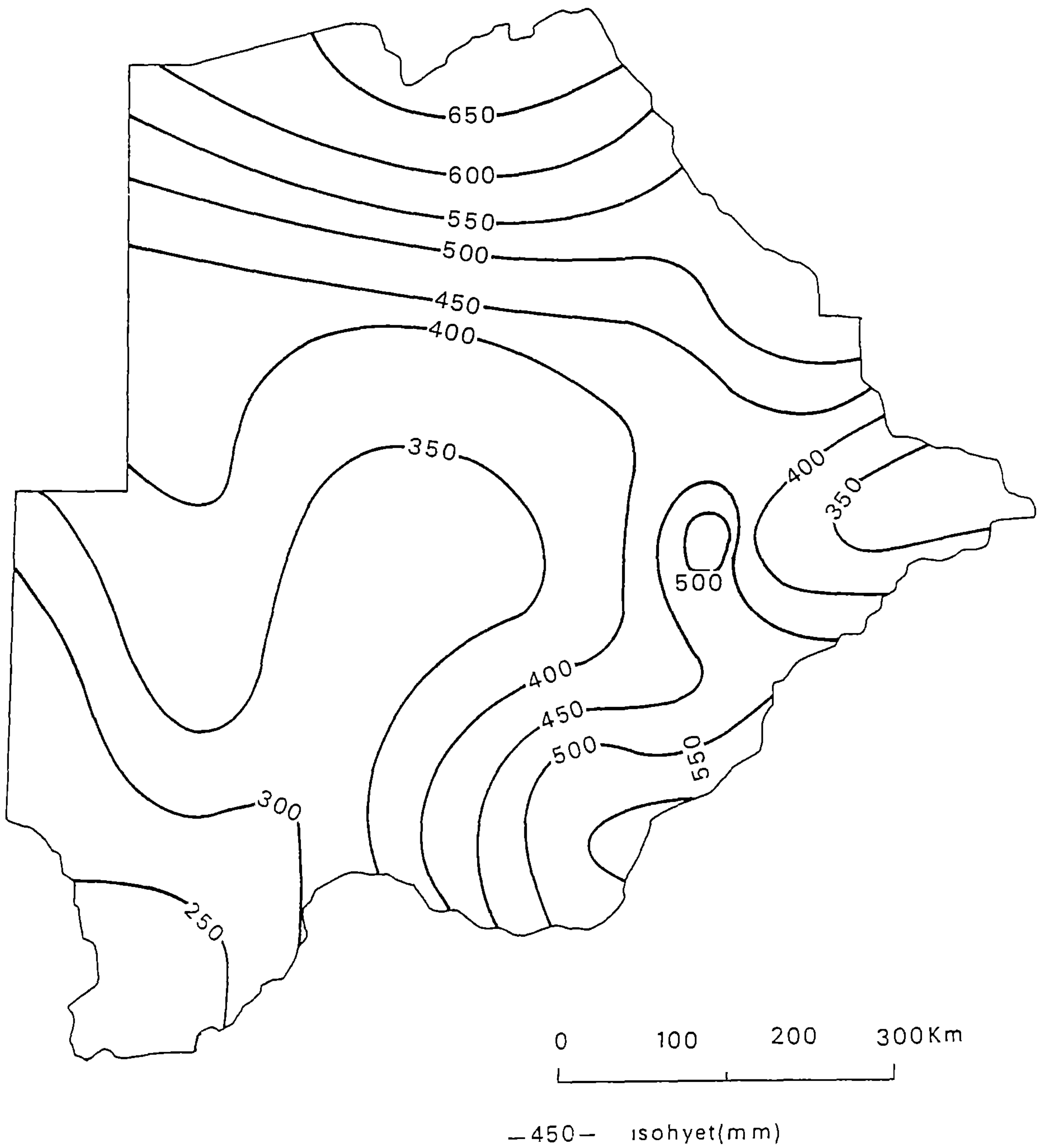

Figure 1(a) Mean Annual Rainfall over Botswana (mm)

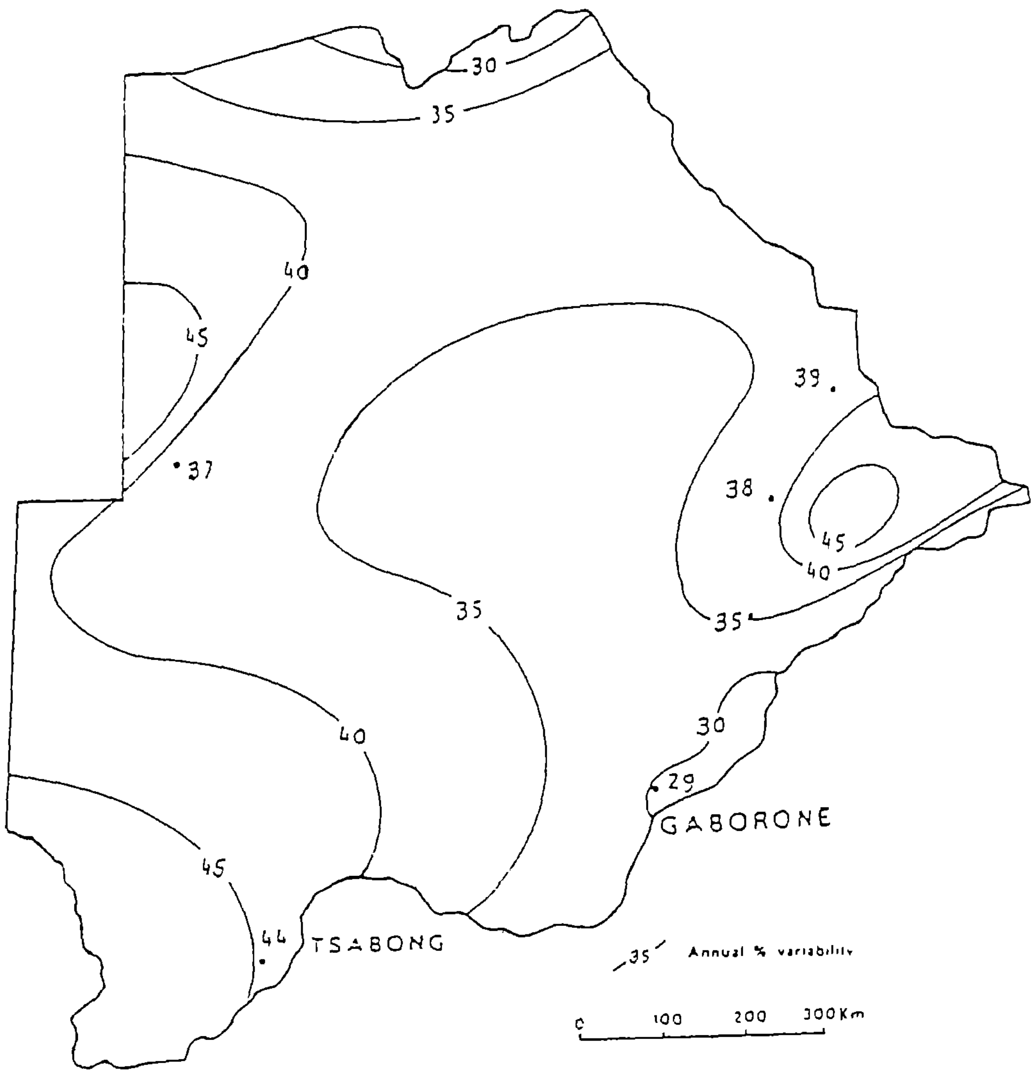

Figure 1(b) Annual Rainfall Variability (mm) over Botswana

? Limited number of observations

Areas of proven or known good groundwater

Areas of known fair - good groundwater potential

Areas of fair - poor groundwater potential

Figure 1(c) GROUND WATER POTENTIAL IN BOTSWANA

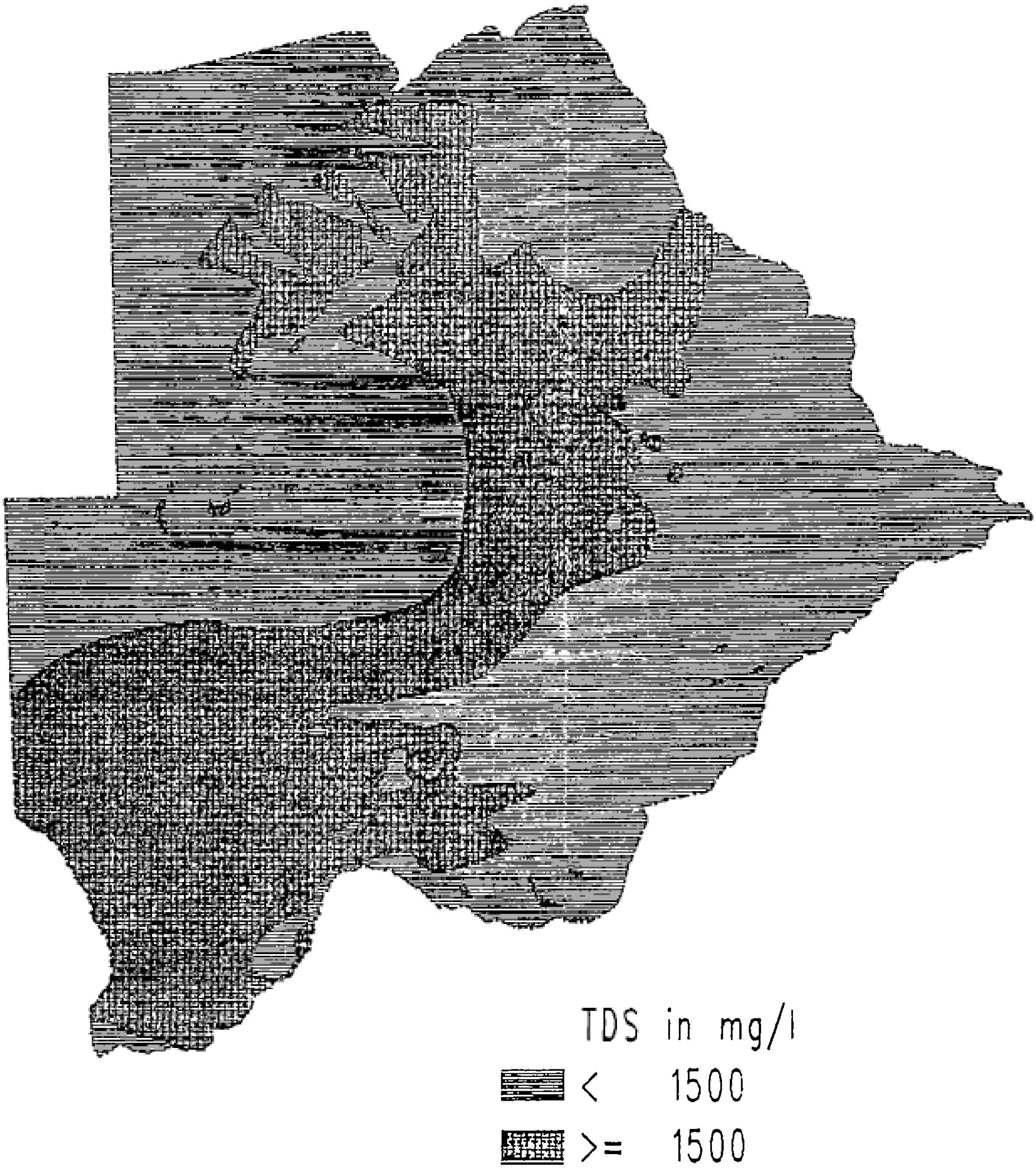

Figure 1(d) WATER ANALYSIS TOTALLY DISSOLVED SOLIDS IN mg/L IN BOTSWANA

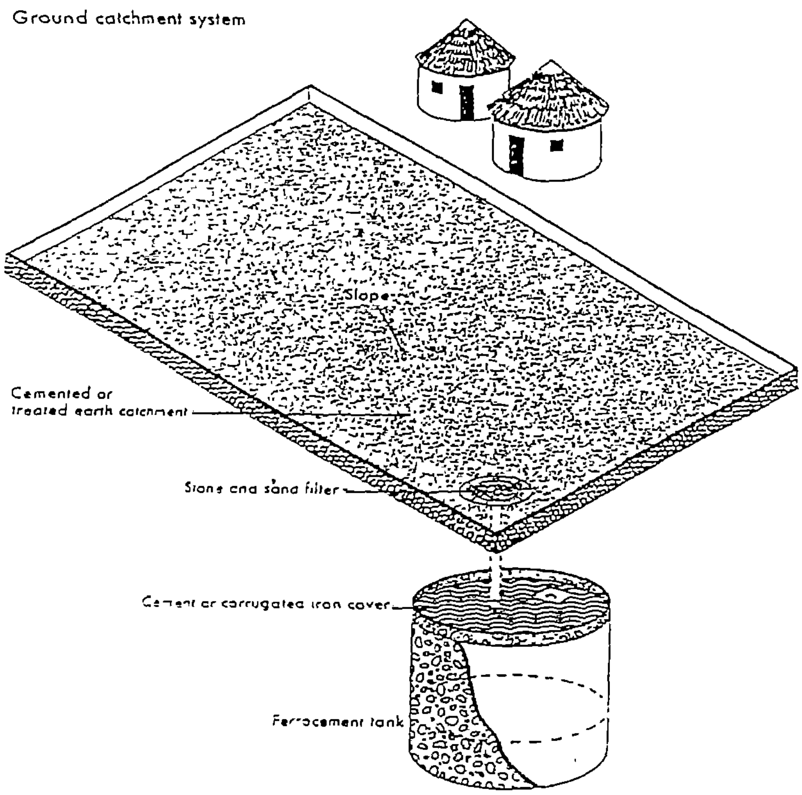

Figure 2(a) Ground Catchment System

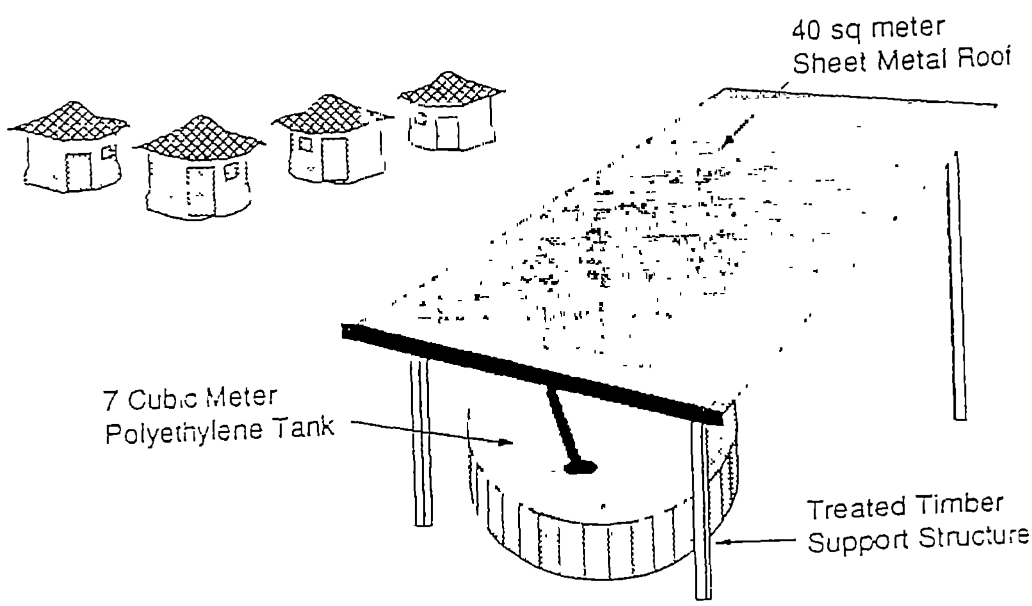

Figure 2(b) Upgraded ALDEP Household Rainwater Catchment System

RAINWATER CATCHMENT SYSTEMS IN NAMIBIA

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INTRODUCTION

The roof rainwater harvesting techniques were introduced in Namibia by missionaries at schools and mission stations in the late 1880's. Since their introduction, little effort was made to improve on such systems and to develop and pre-test new techniques of rainwater harvesting techniques.

With independence in 1990, the then newly established Directorate of Rural Development started to encourage improvements in the design of roof rainwater harvesting systems through its Rural Development Centre at Ongwediva.

At the same time, a Technical Committee for the Namibia Household Rainwater Catchment Programme was formed under the auspices of UNICEF. The committee was tasked with the responsibility to assess available technical options with the aim of finding suitable for implementation under local conditions.

Broadly speaking, the objective of the programme is "to improve household's access to clean drinking water through the production of low cost rainwater harvesting catchment systems attached to housing facilities in rural areas of Namibia".

i) The plastic sheet catchment system with underground ferro-cement tank.

ii) The roof rainwater catchment system with above ground ferro-cement tank.

The proposed systems were pre-tested at the UNICEF/CCN Integrated Area Based Project (AIBP) at Tsandi in Northern Namibia. The findings of the pre-testing are summarised in this report.

PLASTIC SHEET RAINWATER CATCHMENT SYSTEM WITH UNDERGROUND FERRO-CEMENT TANKS

This system is designed to collect rainwater on the ground surface overlaid by a plastic sheet of 25 square metres. The collected water is stored in an approximately 6 cubic metres under ground ferro-cement tank where it should be extracted by a low-cost hand pump. Based on the assumed consumption of litres per capita per day, one full tank would provide safe drinking water to a household of seven members for approximately two months.

The pilot demonstration system was completed in February 1992. A white plastic with a thickness of 250 microns was used to line the catchment area. In the demonstration, the proposed tank was replaced by a plastic lined underground tank to reduce initial costs. The capacity of the tank is 5.65 cubic metres. To avoid animals falling into the tank, the top part is covered with a concrete slab.

Findings

i) The rainfall in 1992 was far below average. Because of this, the long term performance of the plastic lined underground tank could not be assessed especially because the plastic lined underground tank could not be tested under "full load" conditions.

ii) Though the plastic lining for the catchment area has served its purpose well, its durability and resistance to exposure to sunlight and other conditions is unknown.

iii) Very fine soil particles appear to be blown onto the plastic catchment and washed down into the underground storage when it rains. The collection of this material at the bottom of the tank is likely to affect the physical quality of collected water.

ROOF RAINWATER CATCHMENT SYSTEM WITH ABOVE GROUND FERRO-CEMENT TANK

In this system, a corrugated iron roof is used as a catchment area. Rainwater is collected in gutters and directed through a down pipe into an above ground ferro-cement tank. The tank is constructed on a basement of bricks raised about 50 - 60 cm above ground level to allow for easy water extraction through the tap fixed near the bottom of the tank.

Demonstration units of this system were constructed at the UNICEF/CCN IABP and seven primary schools within the IABP area. The capacity of each ferro-cement tank is 5 cubic metres.

Findings

i) Initial performance of this system was found to be satisfactory. However, efficient application is restricted only to buildings with large roof catchment areas.

ii) The storage method of collected water ensures that the quality of water is reasonably preserved. In this system, the risk of contamination is reduced by inaccessibility to the storage tank.

REINFORCED PLASTIC WATER STORAGE TANKS

The Directorate of Rural Development provided 10 cubic metres reinforced plastic storage tanks to several schools during the 1992/93 drought period. Other smaller units were provided by UNICEF through the Drought Relief Programme. The storage tanks provided are meant to serve dual purpose. During the drought period, water is transported to and emptied into the reinforced plastic tanks for storage. The guttering and down pipe system is provided to enable rainwater to be collected during the rainy season. The disadvantage of this system is lack of sustainability of supply. The tanks are imported and are hence costly.

EARTH DAMS

The Directorate of Rural Development is also involved in the excavation of earth dams countrywide. During 1992/93 alone, sixteen new dams ranging in capacity from 7000 cubic metres to 28000 cubic metres were built. In addition, 20 existing dams were de-silted or rehabilitated.

Earth dam excavation is mostly done in areas which are traditionally considered suitable for the development of hand dug wells. In such cases therefore, the earth dam structures act as a source of ground water recharge of shallow wells. The use of available technology in the construction of earth dams makes it an attractive and sustainable programme. Because of the simplicity of tools required, the de-silting of some earth dams were done by community members through the Food For Work programme.

SHALLOW WELLS

Shallow well are by far the most indigenous systems in the rural Namibian situation. These systems acted as water sources for communities for several centuries. Until recently, the digging of shallow wells by the community members was done on a yearly basis, that is, since the wells were largely unprotected, "caving in" occurred as soon as it starts raining.

The provision of adequate and safe drinking water to rural communities is a top priority issue for the Government of Namibia. In an effort to achieve this objective, programmes for shallow well protection have been instituted.

This programme has largely been successfully. It is evident that this success is attributed to the involvement of community members in the planning and execution of projects of this nature.

CONCLUSIONS

1. The roof rainwater catchment system is provided to be a viable option for expansion to schools, churches and other public places. This system is to be promoted in cases where adequate roof catchment areas are available.

2. Namibia normally gets high intensity storms of short duration. The rainy season is also effectively reduced to four months. For the rainwater catchment systems to make an impact on community water supply therefore, the capacities of the ferro-cement tanks need to increased to 10 cubic metres.

3. With regard to the ground catchment systems, further improvements in design and monitoring is required. The plastic lined underground storage may be considered to be suitab.e for use in emergency only but not in producing long term solutions.

4. More information is necessary with regard to the quality of the plastic lining, resistance against ultra-violet radiation and possible degradation due to micro-biological activities or attack.

5. The activities pertaining to construction of earth dams and the protection of shallow wells are to continue with more emphasis placed on communities involvement to ensure long term sustainability.

6. The Supply of reinforced plastic tanks to schools and clinics is meant to provide short-term solutions. For sustainability of such structures, appropriate systems development from locally available materials should be adopted and promoted.

LANDS AREA WATER SUPPLY: THE ALDEP RAINWATER CATHMENT TANK PROGRAMME

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INTRODUCTION

The Land areas are predominately arable with a limited amount of pastoral activities. The small number of livestock are kept primarily for the provision of draught power, milk, meat etc The Lands areas differ in sizes and type of settlements. Some people commute daily from main centres, others move to settle temporarily during the cropping season and some have permanent homes in the lands areas. In general terms farming is dual purpose but normal farmers have three dwelling places; the main home, lands area and cattlepost. Water needs for these different areas differ greatly but the need for water of good quality and sufficient quantity is universal.

BACKGROUND

Supplies of clean drinking water for human consumption are often insufficient in many parts of rural Botswana. This is particularly the case for small farmers and their families in the arable farming sector, those who are the target for assistance under Arable Lands Development Programme (ALDEP). Family members, particularly women, often spend long hours fetching water for household consumption, which is effects greatly the productivity of farming activities. Furthermore, the quality of water obtainable in rural communities is often less than is desirable for human consumption, and this sometimes leads to sickness and disease from water borne parasites and contamination.

The provision of water tanks under the programme was meant to ensure year round water supply for farmers and their livestock. Cattle form an important part of arable agriculture, being the traditional form of draught power. If sufficient supply of water is available for people and cattle especially in the late dry/early wet season, the ploughing can start immediately after the first rains. This ensures that farmers stay longer at the lands and thus improve farm management. The water tanks located on the lands also keep draught animals fit by providing them with water and therefore contributing to timely ploughing, planting and other agricultural operations.

Farmers have however not been extremely enthusiastic about the water tank package for various reasons including:
- lack of awareness about its utility in the farming system.
- lack of qualified builders has been seen to be a major constraint on meeting the demands of farmers who desired to have a water tank.
- The expense of the package which renders the down payment unattainable for most farmers

However, demand for water tanks is now picking as farmers are becoming aware of the advantages of this package and the improved availability of builders. The adoption rate of the water tanks has been higher for the Central region (13%) and Southern regions (11%) and lower for the Maun region (3%).

An improved and simpler design of the water tank catchment with galvanised iron roofing as catchment and over-ground polyethylene tank is now available to farmers. It holds promise of greater acceptance by farmers. It was tested at selected places in the country, prior to being made available as a package. During 1991/92, 169 water tanks were taken up by farmers country wide. In total 852 tanks have been constructed under

the ALDEP programme up to March 1992.
This 169 packages distributed is the largest number of water-tanks that were acquired by farmers in any one year. This shows that farmers are now becoming aware of its importance in their farming activities. Most of the water-tanks are fully utilised except in cases where the tank was poorly constructed.

ALDEP REINFORCED/ BRICK UNDERGROUND TANK

ALDEP has had a water catchment component since its inception. This component was based on the collection of run-off from a threshing floor and storage in an underground tank. This scheme was aimed at providing water for traction animals and for human consumption. Tests on water quality from these tanks have shown that it is often not suitable for human consumption due to high levels of bacteria. There is therefore still an urgent need for ALDEP to provide a satisfactory solution to the problem of adequate human drinking water.

Specifications for Reinforced/Brick Tank 10000 Litres

Ground catchment is not standardised and no moves have been made to improve the capacity or quality. The catchment was assumed to be protected by fence but was not often the case. Originally there were two types of underground tanks the dome and reinforced cement as shown in the figures 1 and 2 respectively depending on soil conditions. The reinforced cement version used treated timber and corrugated iron as the roof closure see figure 2 and figure 3 for the layout.

Advantages and Disadvantages

Advantages
- it is simple uses threshing floor,
- multiple functions of supplying irrigation and for domestic use,
- use natural drainage,
- most economic system.

Disadvantages
- Skilled contractors/builders required to carry out the construction especially for brick catchment tank.
- Maintenance may be a heavy burden if silting-up occurs.
- Low quality water for human consumption from the contaminated of reservoir through waste of birds, humans, animals and plant debris and other materials from the threshing floor catchment area
- risk of animals falling into tanks.
- Rainfall is erratic, reducing the reliability of the supply.

THE MODIFIED WATER TANK AND STORAGE

General

A modified water catchment which consists of a raised roofcatchment and constructed has been trialled by ALDEP at Sese (near Jwaneng) in 1989. In a 500 mm rainfall year, each square metre of galvanized iron roof can collect 500 litres of rainwater i.e. 0.5 cubic metres of water. Rainfall collected in this way can be stored indefinitely in a covered tank without significant contamination. The structure being trialled has a roof area of 24.3 sq.m. Thus, in a year in which 500 mm of rain is received, an amount of 12,150 litres could theoretically be collected. In practise, a water collection efficiency of about 80% is the maximum to be realised, thus the structure could probably only collect about 9,700 litres. The storage consists of a 2250 litre galvanized tank, which takes about 115mm of rainfall to fill.

This trial was quite successful with the tank having filled several times since installation. The water is clean and has stored without any difficulty. The structure itself was very simple to erect, taking only about 3 man days in total. It is of interest that the farmer who hosted this trial has moved his residence to the field in which the tank is located.

However, the structure and its storage has two inter-related limitations. The first is that the present storage tank is not adequate to provide for animal consumption as well as human consumption, especially into the dry winter months. The second is that the roof catchment is also inadequate to provide enough water for the above mentioned purpose, nor would it provide enough runoff for solely human consumption in an extreme drought year.

A modified structure has been designed to overcome the above mentioned limitations. The main changes are;

- The roof area has been increased to 40 sq.m. so that up to 20,000 litres could be collected in a 500 mm rainfall year and at least 7000 litres in a very severe drought of only 200 mm of rainfall. - A 7000 litre capacity tank made of high density polyethylene is used instead of the galvanized steel tank.

Specifications for the Modified Catchment and Storage

Roof Area - 40 sq m.
Roof Dimensions - 8m x 3m
Shed Frames Dimensions - 6m x 3m
Shed Height - Front 3m, Rear 2.5m
Tank Capacity - 7000 litres
Tank dimensions; 1.0 m high, 3.0m diameter

Materials

Treated posts, 6 No. 100mm dia x 4.0 m long.
Wooden beams, 150mm x 50mm x 4.0m long.
Wooden beams, 114mm x 50mm x 5.0m long
Galvanized roofing iron, 16 No. 4.0m x 0.7m
Galvanized guttering
Down pipe
Brackets, 10
Hand pump and tube
Polyethylene tank, 7000 Litre
Bolts and nails
Treated posts (for tank cover); 3 x 3m x 100mm, 3 x 2m x 100mm

The table below shows the average annual supply for a new ALDEP System with 40 m2 roof catchment, assuming average annual rainfall of 500mm.

Annual Average Supply	6.7	8.9	11.2	13.4	(95% prob.) m3
Economically viable tank	3.8	5.1	6.4	7.7	capacity m3

The 7 m3 standard capacity adopted for the new ALDEP system may be suitable. Under an average annual rainfall of 500 mm a new ALDEP system could supply 100% of the drinking water for 2.5 persons, taking into account an average daily consumption of 12 l/c/day.

The following observations are based to the farmers experiences.

The Problems With Polyethylene Water Tanks

Advantages:
- Very simple technique
- Relatively low cost of transportation of components (light weight, not fragile).
- contractor skill in tank construction not necessary.
- Very simple structure rapid to erect (about 3 man days in total).
- High reliability, long life period (polyethylene tank) with good management.
- Optimum storage quality: covering sheet against light and contamination
- Hygienic and easy drawing (Tap)
- Good community involvement because of the easy participation of the rural population in erecting the structure and the simplicity of its use.

Disadvantages
- Centralized maintenance for polyethylene tank.
- tearing of the tank cover from winds,
- the tank collapses when empty causes holes that ultimately leads to leakages,
- the is proven to cattle and children damage.
- Rainfall subject to erratic,
- low water quality due to fecal contamination from birds, humans, lower animals and plant debris;
- the necessity of careful maintenance of the filter to maintain its efficiency.

OTHER WATER CATCHMENT

All the rivers in Botswana get flooded at one point during the rain season and provide a regular water supply for both people and cattle, in spite of the irregularity of rainfall.

Natural surface catchments, such as ponds, haffirs and pans, have always been used for water supply in rural areas as the only source available. These can be improved by means of increasing their duration, capacity and quality of water.

Small dams are being constructed under the Ministry of Agriculture in suitable conditions.Because of the shortage of skilled teams there is inefficiency in investigating sites and supervising projects, which leads to many poorly designed and maintained dams. The dams has been used mainly in the eastern part of the country where there are suitable sites.

Silting-up is a serious problem as it can reduce the storage capacity to zero in a few years. For the protection of the environment it is important that the surface catchment projects must be assessed for environmental impact. Fencing off of the reservoir is essential to prevent cattle from polluting the water.
The water reservoirs are highly dependent on rainwater and may be considered as unreliable water resources when their storage capacity is low. A low quality of water supply in general is experienced due to contamination from animals and plants debris.

CASE STUDY IN FRANCISTOWN AREA ON WATER TANKS

Introduction

As the objectives of ALDEP shows, the aim of the programme is to fight rural poverty especially among the low income farmers who own 40 or less number of cattle.

This study was on the utilization of water tanks in the Francistown area. It is obvious that easy accessibility to water would reduce costs on the part of small farmers and hence in real terms it would be a boost in their production and developmental use of the services provided.

Water tanks have been provided as a package since the beginning of the project. The initial plan was to build water tanks of 10000 litres capacity. They were to be built underground with top covered with galvanised metal sheets adjacent to the threshing floor which would be a catchment area.

The aim has been to induce farmers to stay longer periods at the lands for effective management and implementation of better farming practices.

There has however been an improvement on the underground water tanks - the latest make is the overground polythene tank with galvanised iron roofing as a catchment area.

The Findings

The study indicates that 20 farmers studied only 18 have water tanks. However, the total number of water tanks is 19 because one of the farmers has two water tanks - an underground one and a polythene one.

Most of the water tanks in the area are underground i.e 89.5%. Only 10.5% are plastic water tanks. All the water tanks have been obtained between the period 1984 and 1992.

The study indicate that 80% of the water tanks are being utilised while the rest are not yet in use. One of these water tanks (those not yet used) has just been completed and has never held any water. The other tank is still under construction although at the final stage.

All the water tanks that are not yet in use are planned to be used for family consumption and to water livestock. One farmer however plans to use the water for irrigation in addition to family consumption. The rest of the farmers who are currently using their water tanks use them for family consumption and livestock watering. none of the farmers is currently using the water for irrigation.

Condition of the Water Tanks

Most of the water tanks are not well constructed. Out of the 19 water tanks studied, 12 are not working properly i.e 63% of the water tanks have one problem or the other.

The problem seem to lie with the construction of the water tanks. Most of the complaints are concerned with leaking of these water tanks which emanates from their poor construction. There is a case of 1992 water tank (plastic made) which is reported to be badly constructed. With the first rains of the past year (1992) it has shown signs of leaking. The farmer now feels an underground one would be better. Another water tank, constructed in 1989 has already developed cracks and is thus leaking whereas there is a 1986 water tank which is still in good condition. There is one water tank which has not been constructed yet due to shortage of builders.

Concerning the water holding capacity of the tanks, it could be good had it not been for the damage (cracks etc) inflicted on these water tanks. 12 out of 17 water tanks in use cannot hold water all year round because of cracks and other aspects of poor construction.

CONCLUSIONS AND RECOMMENDATIONS

Looking at the above findings, one can conclude that the utilisation of water tanks in the districts is hampered by the poor construction of these water tanks. As one observation was made by one farmer lack of maintenance also lead to a short life span of the water tanks. The poor performance of the water tanks is likely to create a negative attitude on the other farmers hence they would be hesitant to utilise the package. This could be attributable to the poor monitoring on how the ALDEP packages are utilised and the extent to which they are cared for. For example, it is not indicated how these water tanks are maintained.

Main Recommendations:

i. That after the construction of the water tanks, some inspection be made to ensure that they are built to the rwquirements of the project management to ensure profitable spending of the project's funds and allay fears of the non-durability of the water tanks,

ii. There should be periodic checks to encourage the maintenance of these water tanks,

iii. Constant checks on the performance of these water tanks to detect any deficiency on their performance so that necessary interventions could be made especially if they concern improvements on the make in question.

iv. Scotch carts have been included as a package to assist farmers with extra facility to fetch more water if necessary.

v. Threshing floor has been replaced by roof catchment.

vi. The underground tank is now cemented on top.

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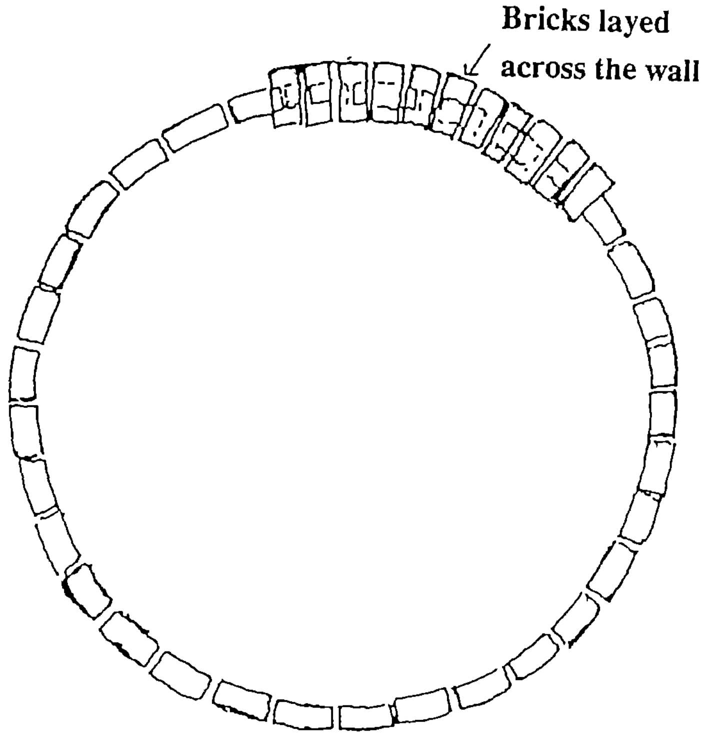

Figure 1(a) The domed Roof

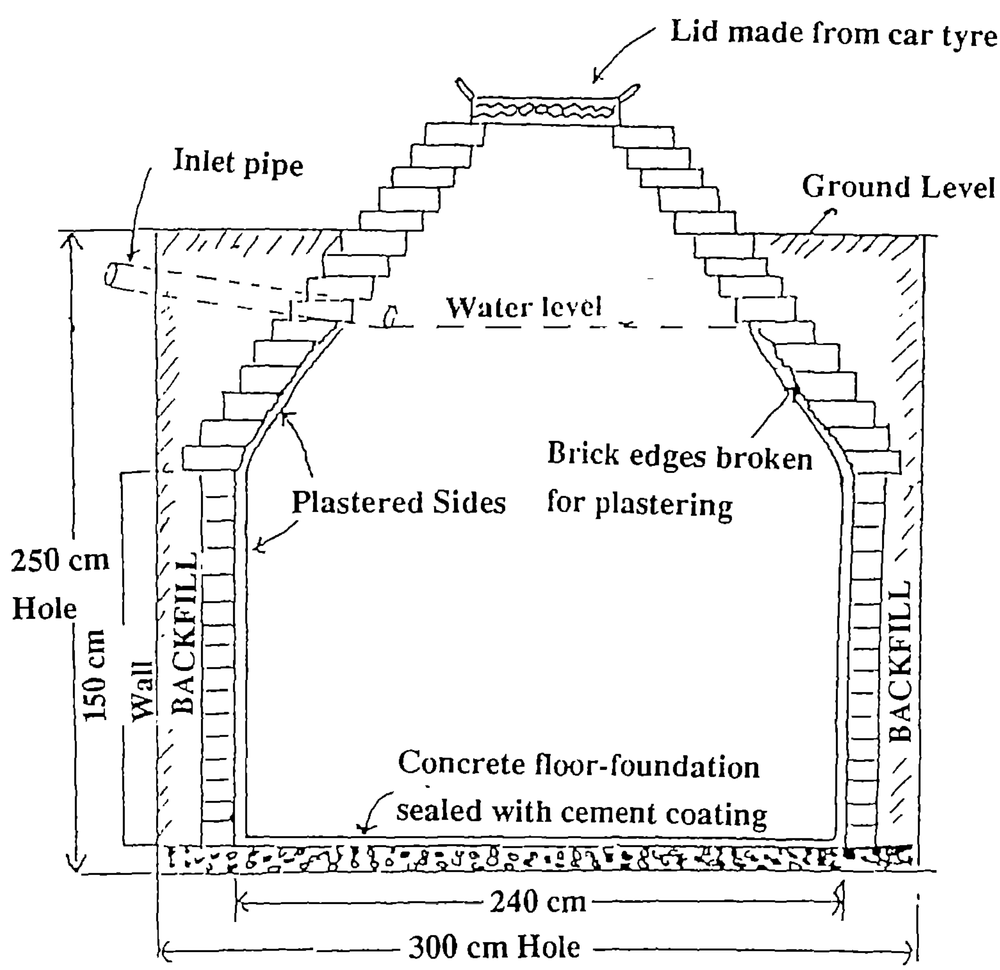

Figure 1(b) Dome underground water tank (Cross section)

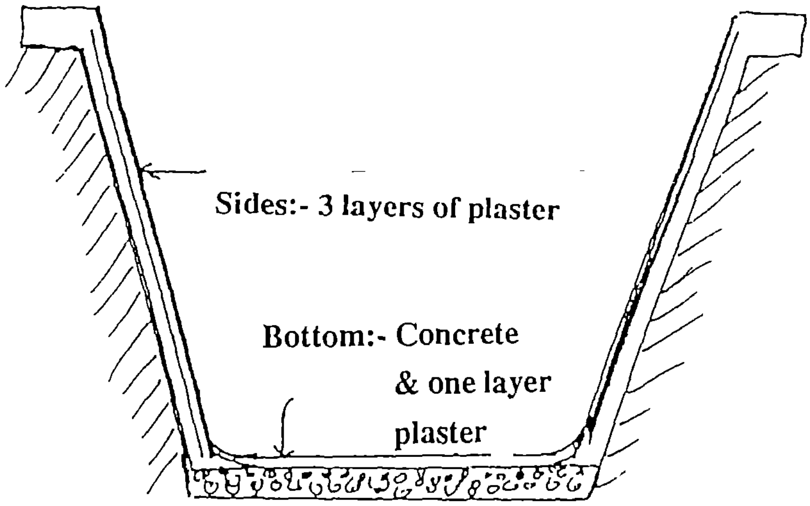

Figure 2(a) The Completed Tank

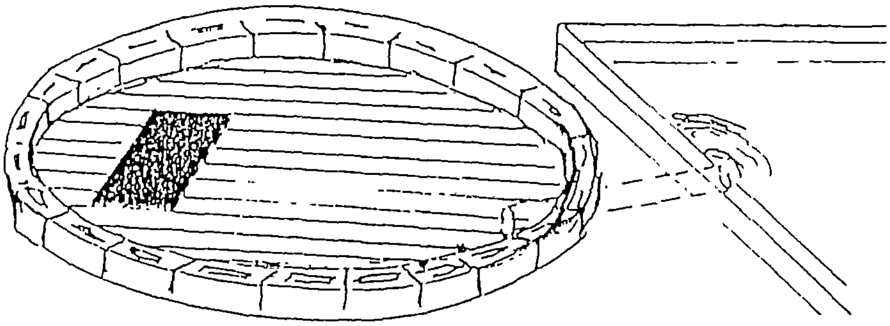

Figure 2(b)

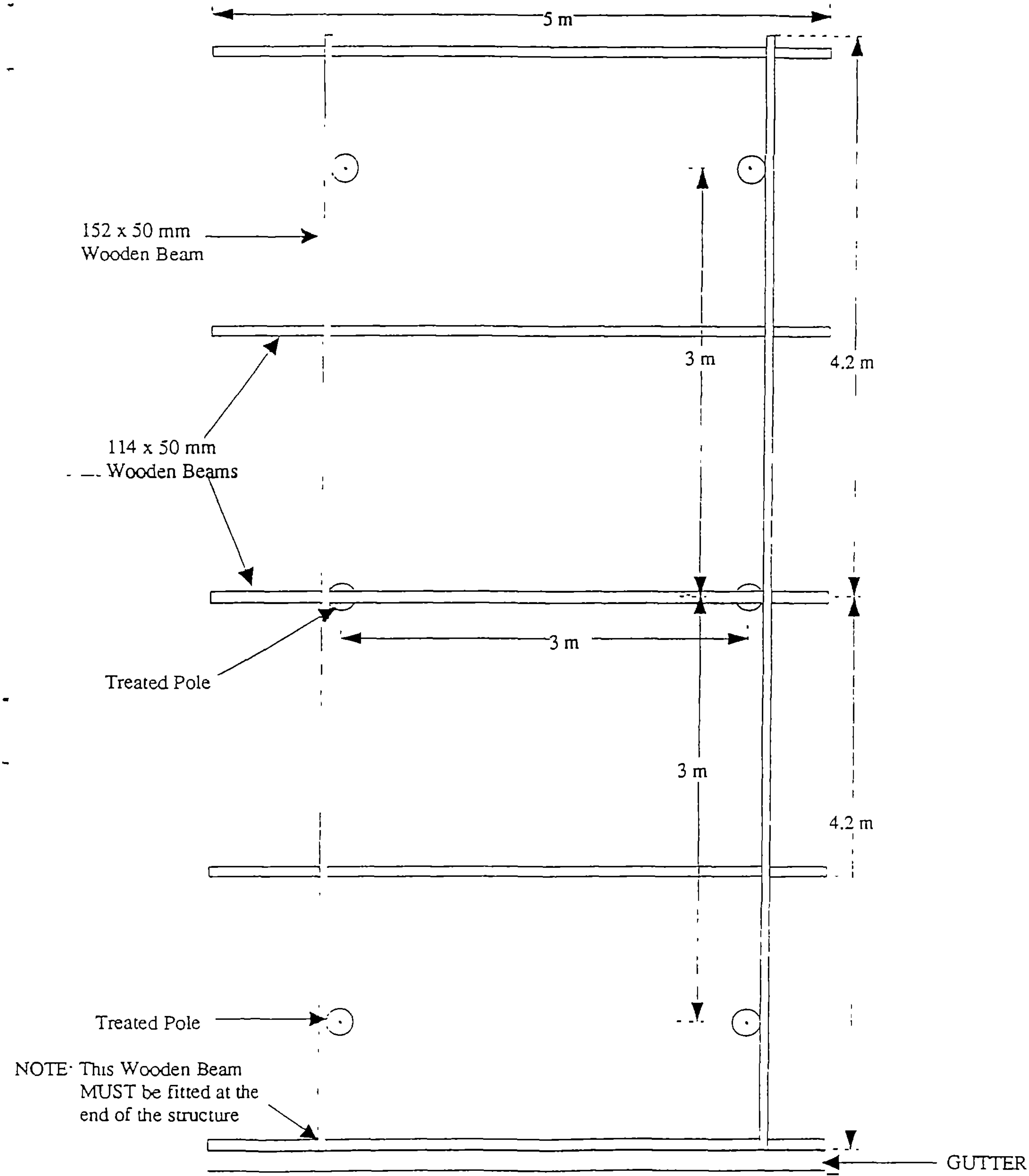

Figure 3 Top view of wooden roof structure

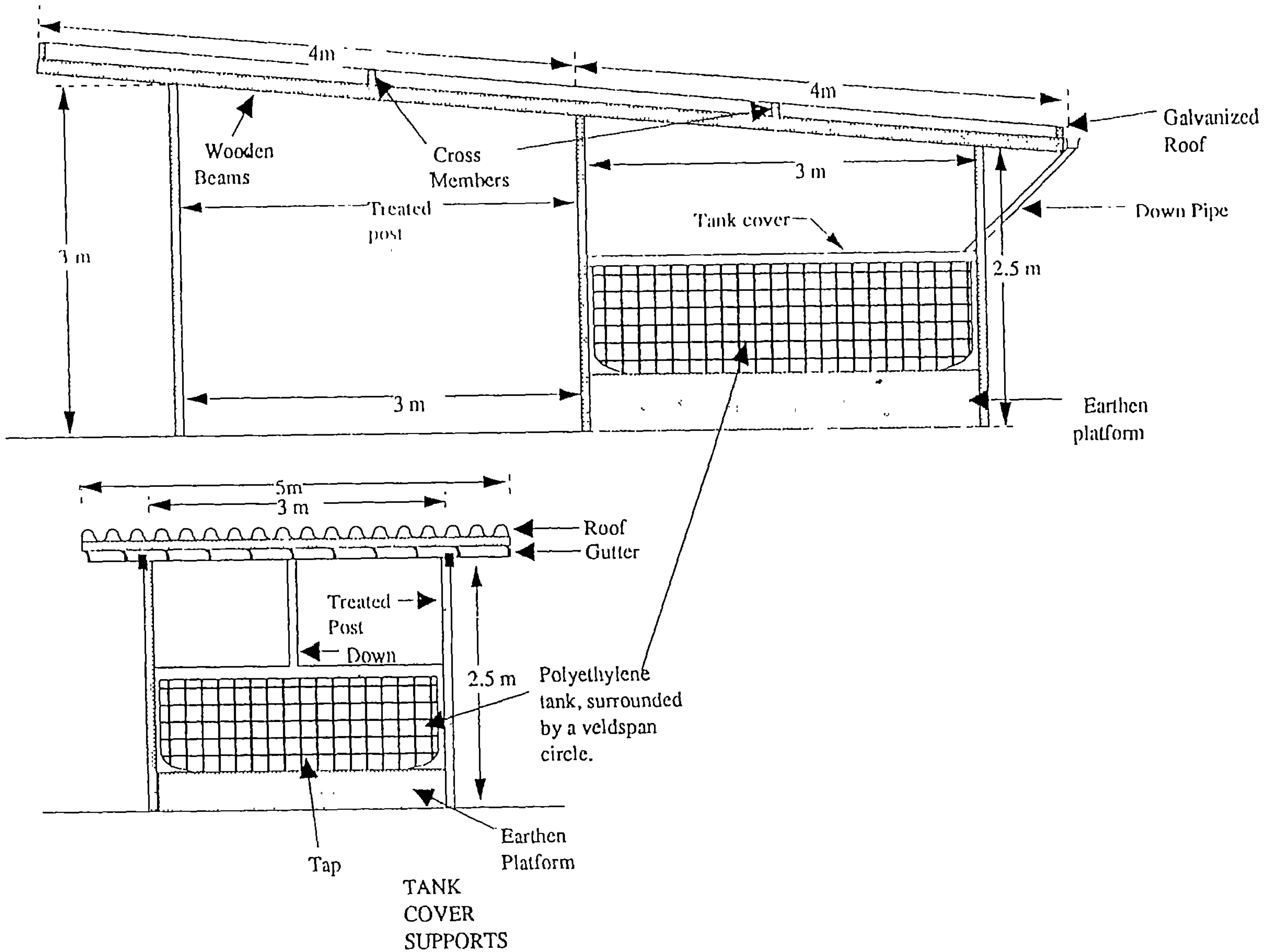

Figure 4 Water catchment and storage - ALDEP

REVIEW OF RAINWATER CATCHMENT SYSTEMS IN KENYA

By John Mbugua
Vice President (IRCSA)*

INTRODUCTION

Kenyan Government ministries of land reclamation water and regional development health, agriculture and livestock have developed water schemes to meet domestic, livestock and agricultural water needs. However, much has also been developed though in small community based projects by multilaterals, bilaterals and hundreds of NGOs operating in Kenya.

Less than 25% of Kenya consists of arable land the rest is classified as arid and semi arid lands. These areas are characterised by low rainfall erratic and unreliable. Recently the government has settled people in these areas and this has created considerable pressure on fragile resource base. These areas are experiencing serious land degradation and soil erosion has rendered many of these areas unproductive and food production per head greatly reduced especially with high population growth.

Achieving food security in these areas has proved a complex problem. One solution will involve creating environment in which food insecure people can achieve secure and sustainable livelihood, though ability to acquire food has many dimensions e.g. production, purchase, or exchange. Rainwater catchment systems at village levels have proved that land degradation could be checked and gullies healed thereby turning unproductive land productive. These activities are highly labour intensive.

The key to optimization of the rainwater resource is to identify, and to introduce acceptable and effective technologies to receive rainwater in cisterns, dams, pans or to control and direct flood waters to prepared bends for crops or fodder production. To achieve this good policies to govern provision development and promotion of water for the nation exist. But they are not very clear and adequate on rainwater utilization for food security, environment conservation and sustainable development. Adequate policies should be able to cover all areas of rainwater catchment systems, that promote village level, as well as large scale river drainage system as national programme.

MINISTRIES INVOLVED IN WATER DEVELOPMENT

A number of ministries are involved in providing water using various technologies. They include:-

1 Ministry of Land Reclamation Water and Regional Development
2 Ministry of Agriculture and Livestock
3 Ministry of Local Government and Urban Development
4 Ministry of Social Services
5 Ministry of Health

BILATERAL AND MULTILATERAL AGENCIES

These are actively involved in the provision of water for various needs. These agencies work in collaboration with either government for large programmes or with some NGOs in small community level projects which are mainly rainwater. These agencies include: SIDA, FINIDA, DANIDA, NORAD, ODA, JICA, USAID, CIDA, Belgium etc. The Multilaterals include: WB/UNDP, UNICEF, FAO HABITAT etc.

Non-Governmental Organizations

Kenyan based NGOs exist in their hundreds and their contribution is high especially in remote areas. NGOs are the greatest contributors to RWH projects at village levels.

For success of projects the following common factors have been recorded in Kenya:

1 Strong local institutions
2 Community participation
3 Social and cultural compatibility
4 Compatibility with government policy
5 Land tenure
6 Settlement or pastoralist way of life

Baringo and Turkana Rainwater Harvesting Projects are good examples of projects that failed because they were build on food for work approach and people worked on them as long as they were paid cash or food. These people also practised pastoralism on community land ownership. Programmes in Machakos, Kitui, Nakuru, Laikipia districts have records of success because of one common thing. They all were well built into the peoples culture. People viewed these interventions as contributions to their efforts. And again people were the principal financiers, maintainers, decision makers etc unlike the previous case. Here land tenure is different from the above pastoralism style while in the latter people are in settlement land arrangement.

APPROPRIATE TECHNOLOGY

To improve living standard of most Kenyans especially drought victims to become food secure a farm model that balances resources and optimizes use of rain water is the way forward. By selecting and adapting appropriate technologies and genetic resources farmers can create an integrated low external input sustainable development systems to their specific biophysical and socio-cultural setting. Such integrated systems can provide farm families with many of their daily needs. e.g. a variety of nutritious foods, wood for cooking and building etc. Combining different plants and animals species and applying a variety of techniques to create good environment for them will help the farmer maintain the productivity of their land and reduce farming risks.

RAINWATER HARVESTING TECHNOLOGIES

Critical resource in this cycle of livelihood activities is water. In arid and semi arid areas the most widespread and accessible water resource is rainwater. In rainfed agriculture good management of water is of great importance. Rainfall may be too low or too high or too irregular, creating high risks of yield and /or unfavourable growth conditions or damage by erosion. Techniques are needed to conserve the available water and/or to guide excess water safely from the field. Where there is not enough rain to grow a crop or where rainfall is very irregular, water harvesting techniques can be used to concentrate rain or flood water in such a way that it can be used for crop growth. Water harvesting not only secures and increases crop production in regions where rainfall is normally insufficient; it can also serve to control soil erosion and to recharge aquifers. An additional benefit is the improvement in soil fertility. Silt manure and other organic matter are "harvested" together with the water. The soil profile stays moist longer, stimulating soil life and improving humus formation, nutrient availability and the soil's capacity to hold water.

Water harvesting is a resource - enhancing technique which due to synergetic reaches its full potential when used in combination with other techniques such as improved seed and application of organic and inorganic fertilizers. Small water harvesting systems with an external catchment areas brings nutrients together with water. But a "within field" catchment harvest less nutrients but control erosion on site.
There are a number of possible water harvesting systems, but in Kenya the following have been reported being tried.

Systems with an external catchment area for collecting runoff water or flood water from small water sheds.

(i) Agricultural use, without any special arrangements where runoff water or flood water is concentrated temporary and water infiltration is relatively high, dry valleys or depressions.

(ii) Simple techniques for water spreading and infiltration by means of low, permeable bunds (ridges) of stones bundled sticks crop residuals or fences of living plants along contour lines.

(iii) Water pockets or pits: holes for seeding, collecting runoff and managing organic matter.

(iv) Half circular or V-shaped ridges used mainly for tree planting and rangeland improvement.

(v) Water collection: graded bunds or furrows divert run-off from cropland, village land and wasteland to tanks located at a lower level: the water is used for supplementary irrigation in dry periods.

(iv) Run-off farming: run-off water from treated (spraying chemicals or clearing gravel to increase run-off) or untreated catchment areas is diverted to lower-lying cropland.

(vii) Run-off farming: run-off water and silt from small watersheds is captured by dams in seasonal stream beds or diverted to cropland. In front of these dams, the silt forms terraces which are used for farming. The infiltrated water makes cropping possible.

Systems with a 'within-field' catchment area called "in situ" waterharvesting or micro-catchment run-off from a small plot (micro-or within-catchment) is captured at one side where it infiltrates the soil and directly contributes to the available moisture in the rooted profile of an individual productive tree or shrub e.g Ngarua.

ATTITUDE AMONGST POLICY MAKERS

Rainfall in many parts of the world is the most widespread and directly accessible source of water. But despite the significant contribution of rainwater catchment systems technologies in improving rural water supply provision in a number of countries in Africa, Asia and Latin America. Policy makers in many countries, donors and many national governments have been slow in switching resources to providing assistance in the development of rainwater catchment systems and other low-cost appropriate small scale water supply technologies. Even worse drought is threatening to kill and maim millions in the whole of Eastern and Southern Africa where at least 20 million people are already malnourished and starving while the potential of rainwater harvesting In the mitigation programmes of drought recovery and preparedness is high. In attempt to create awareness on the potential of rainwater direct utilization, International Rainwater Catchment Systems Association, Kenya has held two national conferences to raise awareness among the Government of Kenya policy makers, donor communities and NGOs in Kenya. Kenya is even lucky to host the 6th international conference on rainwater catchment systems on 1st to 8th August 1993. This will further increase public awareness on role of Rainwater Harvesting in food security environment conservation and sustainable development. A number of research work is currently going on and results will help to reveal the enormous potential of rainwater utilization for social economic development in the third world countries.

LAND AND WATER MANAGEMENT

It is clear from many examples that mis-management of land and water resources is often the basic cause of water scarcity e.g. land abuse practices e.g. deforestation and overgrazing transform water into a prime agent of erosion. It is then apparent flood water must be harnessed for the benefit of both mankind and environment. Jacques Colomban a representative of ORSTOM East Africa in a paper he represented in 2nd national conference on Rainwater Harvesting September 1992 said, Kenya like many African countries only uses 5% of the run-off potential resource. In another literature "Development: a special issue June 1986 reported that two-thirds of the available volume of water end up into floods that is not useful. It is then responsibility of planners to focus their attention to this fact.

Environmental conservation. Travelling across more than 75% of this country you will observe how soils have been washed away deserts spreading, genetic and wildlife resources being placed at jeopardy and water resources being threatened. Most of the resources under stress today are vital to long term economic growth of this country. The causes of this environmental crisis is complex and inter-related but a major contributing factor has been rapid population growth which places intense pressure on a delicate eco-system including soil loss over-grazing desertification and bad agriculture practice. In pastoral areas most of their pastoral systems are at the verge of collapse, the vegetation is so overgrazed that it barely survives.

CONCLUSION

New Approaches

New approaches to the assessment development and management of water resources is needed. These approaches should recognise how widespread rainwater is in use though unnoticed and not documented. These approaches require political commitment and involvement from the highest level of government to the smallest communities. This commitment need to be backed by substantial and immediate investment, public awareness campaign, legislative and institutional changes, technology development and capacity building programmes.

In Kenya special effort by government NGOs and donor communities is needed. International rainwater catchment association Kenya has proposed that a forum be created where Government of Kenya, NGOs donor communities and institutions of higher learning form a national body to focus on efficient and direct utilization of rainwater for food security environment conservation and sustainable development especially in areas already suffering water scarcity.

Holistic Approach

Since water sustains life the effective management of water resources demands a holistic approach, linking social and economic development with the protection of natural ecosystems. Effective management will link land and water uses across the whole of a catchment area or ground water aquifer.

In Kenya there are about 5 government ministries several bilateral and multilaterals plus hundreds of NGOs who are involved in this sector. However co-ordination collaboration and co-operation will require a lot of effort. These different agencies will need to appreciate that much can be achieved through working together and sharing knowledge, information and resources. In arid and semi arid areas in particular, the optimization of direct use of rainwater the most widespread and accessible water resource will ensure rapid economic recovery.

Participation

The participatory approach involves raising awareness about the importance of rainwater among policy makers and the general public. It means that decisions are taken at the lowest appropriate level with full public consultation and the involvement of users in the planning and implementation of their water projects.
Role of government has to be reassessed so that the government will provide the enabling environment so that the community institutions take increase role in the planning and maintenance of their water and water related infrastructures.

Role of Women

Women are providers and users of water. This reality must be reflected in institutional arrangement for the development and management of water resource. Therefore positive policies to address women's specific needs and to equip and empower women to participate at all levels in water resources, programmes, including decision-making and implementation in ways defined by them. Throughout the 42 tribes in Kenya different tribes have their cultures and traditions that discriminate against women in one way or another. There is also some amount of government and other institutions that fail to match expectations as far as equality of women is concerned. Therefore there is much to be done to give women what their role deserve in society.

Economic Value of Water

Managing water as an economic good is an important way of achieving efficient and equitable use and encouraging the conservation and protection of water resources. Therefore wasteful and environmentally damaging uses of the resource should be avoided. It should be noted however, it is a basic right of all human being to have access to clean water and sanitation at an affordable price.

Enabling Environment

The implementation of action programmes for rainwater and sustainable development will require substantial investment in:
(a) Capital projects
(b) Building capacity of people and institutions

Therefore the Government of Kenya will provide an enabling environment in terms of institutional and legal arrangements including those for effective water demand management. Awareness raising is a vital part of a participatory approach to rainwater resources management, information, education and communications. The support programmes must be an integral part of the development process.

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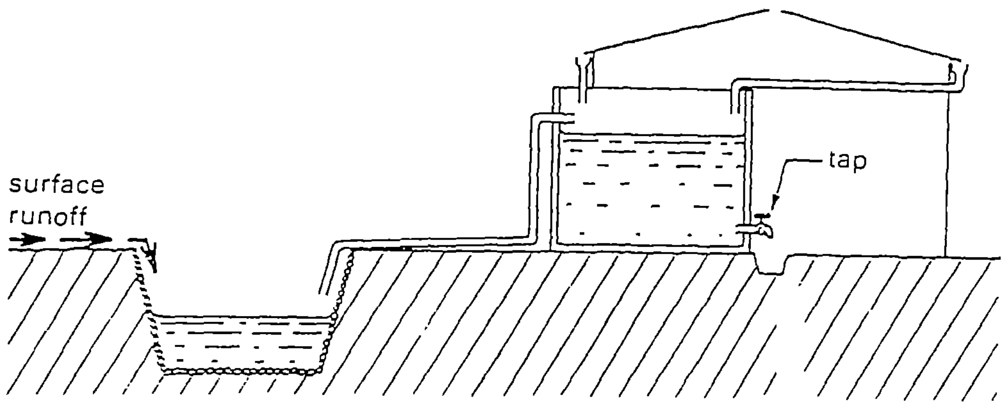


Figure 1(a) Rainwater catchment from roof and ground surface

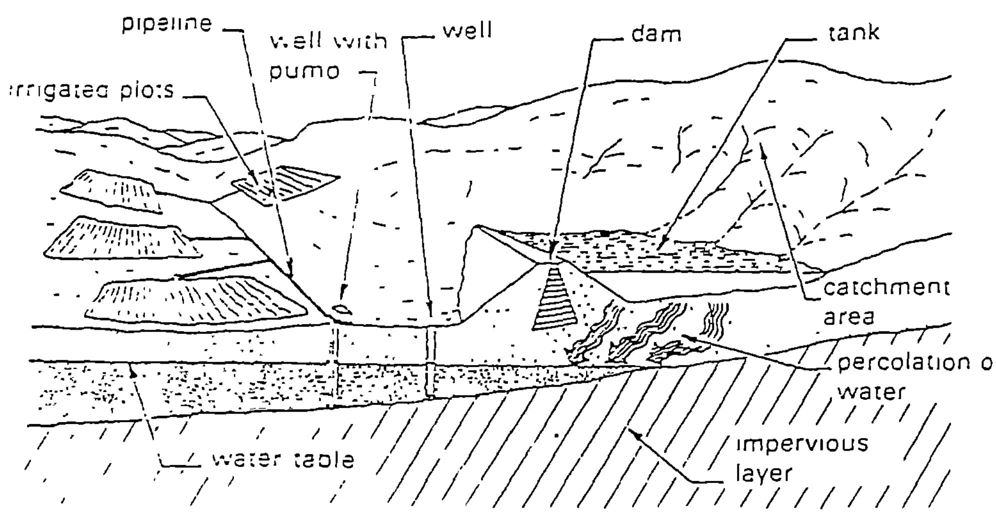


Figure 1(b) Flood Water Harvesting

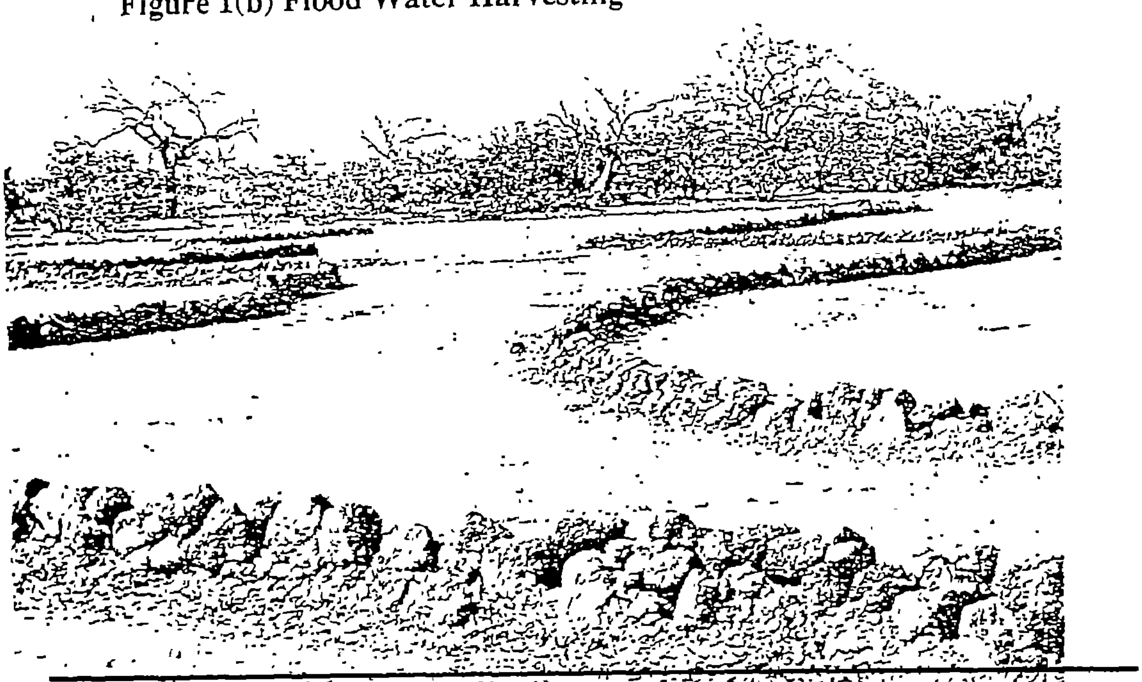
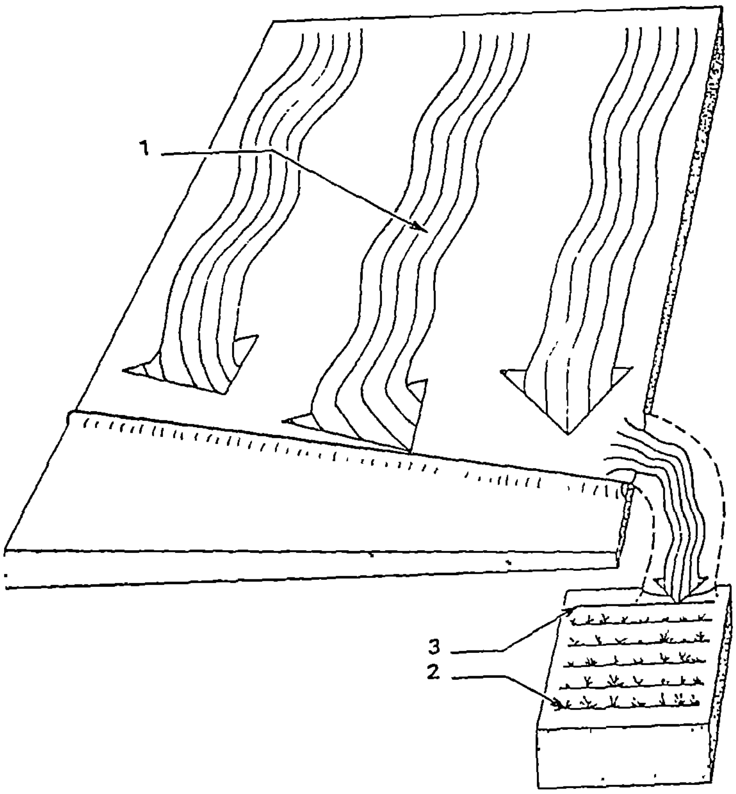


Figure 1(c) Stonelines for rainwater harvesting for agriculture in Burkina Faso

Figure 2(a) Principle of Runoff Farming



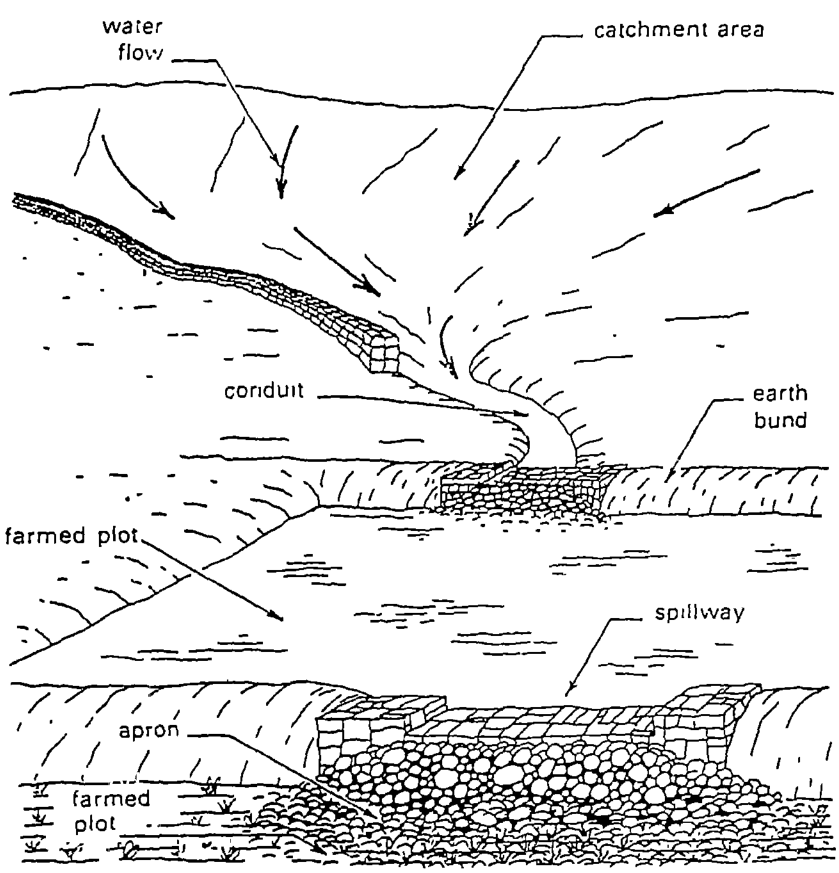


Figure 2(b) Components of Runoff Farming from an external catchment

RAINWATER CATCHMENT: THE BOTSWANA TECHNOLOGY CENTRE EXPERIENCE.

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ABSTRACT

The Botswana Technology Centre has been involved in the promotion of Rainwater Catchment since its inception. The paper outlines the comprehensive rainwater collection system in place at the BTC Headquarters and describes the upgrading of the system as part of the extension of the headquarters currently being considered. The problems of maintaining such a system are also discussed.

INTRODUCTION

Botswana is located in the heart of Southern Africa straddling the Tropic of Capricorn. It has an area of 582,000km^2 much of which covered in Kalahari sand, and a population of 1.3 million (1991 census). Despite the low population density only slightly exceeding 2 persons/km^2 the population is growing extremely rapidly at around 3.4% per annum.

The climate of Botswana is semi-arid with mean annual rainfall varying from less than 250mm in the extreme southwest of the country to more than 650mm in the extreme north . The rainfall is erratic and mainly concentrated in a rainy season lasting from October until April. Evaporation on the contrary is predictable and rates exceed 2000mm per annum in most areas. Due to Botswana's flat topography and sandy pervious soils, surface water sources are limited.

Good quality groundwater is available in many areas of Botswana and over 15000 boreholes have been sunk throughout the country to access this supply. In some areas, however, the groundwater is either too deep, too unreliable or too saline to provide an acceptable supply for domestic purposes. In these areas alternative water sources have to be found or water has to be trucked in by bowser from great distances and at great expense. In such locations, rainwater collection is often the most cost effective option. In the larger villages and urban areas rainwater catchment systems can provide a supplementary backup and help to conserve water.

FERROCEMENT TANKS IN BOTSWANA

During the the early eighties considerable effort was expended to promote the use of ferrocement tanks for rain water storage. These were readily accepted especially for rainwater catchment systems in rural schools and clinics where over 100 such tanks were built. In general most of the surface ferrocement tanks built in Botswana are 10m^3, 20m^3 or 30m^3 in capacity. These have been built primarily insitu, using a corrugated iron formwork based on a design by Watt. (Watt, 1978). The experience with this design of ferrocement tanks within Botswana has been mixed, with a significant number of tanks having failed. In a recent investigation 46 ferrocement water tanks were inspected in the Eastern corridor of the country, of these 8 were empty (four having never been filled) and 4 were leaking badly. A further 8 were visibly weeping, but total water losses appeared to be very small. The remaining 26 were structurally sound and water tight. (Gurusamy/Gould).

There was no specific pattern of failure, but most occured at the joint between wall and slab, the most vulnerable part of the tank due to stress concentrations.

The possible reasons for failure could be attributed to the following factors:

i) Under-design.

While a minimum steel volume requirement for ferrocement construction is 3.5%, the design promoted by BTC in the early 80's (Wilkinson) was far below this number, which resulted in undereinforced Tanks.

ii) Quality of materials.

The quality of materials used in making cementitious mortars is of prime importance, since they determine the eventual quality, behaviour and strength. The findings suggest that the quality of sands used are extremely variable. For Ferrocement operations, the quality of sand used should be clean and free from any deleterious materials and should be within a specified particle size distribution envelope.

iii) Quality of Workmanship.

Ferrocement construction requires skilled manpower. From experience the manpower that carries out the erection of ferrocement tanks is either inadequately trained or not trained at all. The possibility of running a joint programme with the Brigades and monitoring the quality of the works they produce is being considered. With this type of arrangement a certification scheme can be established for contractors involved in ferrocement construction. In this manner the quality of workmanship could at least be controlled and monitored.

iv) Method of Curing.

Botswana experiences very extreme temperature differentials, hence, the curing of ferrocement tanks should be properly carried out and an adequate curing time allowed. Again the BTC experience suggests that an average semi-skilled worker does not appreciate the essence of curing and related strength development especially in the initial curing stages.

RAINWATER CATCHMENT SYSTEMS AT THE EXISTING BTC HEADQUARTERS.

In 1983 the Botswana Technology Centre (BTC) in keeping with a need for bigger accomadation for its growing staff, commissioned the building of a new headquarters in Gaborone. This was in the midst of a drought when the goverment had decreed that no building would be allowed as part of a water conservation strategy. Building permission to go ahead was finally obtained by incorporating a comprehensive rainwater catchment system as part of the plan which provided the possibility of the centre being completely self-sufficient in its water needs. The BTC Headquarters was built during 1984 to an award winning design which incorporated not only the water catchment features mentioned above but also passive solar design features and innovative choices of building materials. A plan of the building and the water tanks are shown diagramatically in Fig 1. A total storage capacity of 240cu.m is provided by 4 underground and 1 above ground ferrocement tanks. A computer model was used in order to design the system to maximise water supply within realistic costs. The rainwater runoff from the roof as well as the car parking areas is collected. To aid with water self-sufficiency, low flush toilets and water conserving faucets were used, cutting down water usage significantly. The whole system was connected to a backup mains water supply. The system is due for upgrading as part of the construction of the new BTC headquarters on the existing site which is due to begin in early April 1993. It will involve integration of the present system with the rainwater catchment envisaged for the new building and upgrading of the tanks themselves.

PROPOSED RAINWATER CATCHMENT SYSTEM FOR THE NEW BTC HEADQUARTERS

General

The existing BTC Headquarters was the first demonstration of the possibilites of Rainwater Catchment for institutional buildings in urban Botswana . The new BTC Headquarters adopts a similar approach but the rainwater will be subjected to a high degree of use. It will have a plan roof catchment area of approximately 900sq.m with a courtyard catchment contibution of 180sq. m. A runoff collection efficiency of 0.85 has been adopted for estimating the collection capacity. The rainwater collected will be primarily used for low flush toilets, and for evaporative cooling. The evaporative cooling technology being implemented is actually based on very old principles that originated in the Middle East. The new Cool Tower system is driven by an evaporative cooling fixture that is located at the top of a tower. Water from the rainwater storage tanks is circulated within the specially designed mechanism, and evaporation is induced. The heavier cool air at the top of the tower naturally drops down the tower shaft and is diverted into a building or an exterior space for use. The actual water consumption per tower is determined by the level of temperature and humidity present, as well as the water circulation rate within the mechanism. Wind speed, which accelerates the output of cool air is another variable.

A total of four Cool Towers have been designed for use on the New BTC Headquarters, and a variety of additional applications in Botswana are being actively pursued. Rainwater will also be used to replenish one exterior and one interior fountain. The movement of water and subsequent evaporation will add to the overall cooling strategy for the building.

The water for the landscape will be drawn from the existing underground water tanks. As a demonstration of the technology an in-line purification filter will be incorporated in one line leading to the fountain, for drinking water.

The total water available for storage was calculated on the basis of mean monthly rainfall figures for Gaborone since 1925. The monthly consumption volumes have been adjusted to compensate for seasonal variation in demand. The net economical storage tank capacity of 85cu.m was determined by comparing the monthly inflow and outflow rates (see table 1). Below is the storage breakdown.

4 x 5cu.m Header Tanks.
4 x 5cu.m High Level Tanks
4 x 5cu.m Low Level Tanks.
1 x 25cu.m Courtyard Tank.

All the tanks are located on stands at the corners of the building as shown on the General arrangement plan drawing.

The bulk of the rainwater will be consumed in the evaporative cooling towers during the dry, hot summer months from September to February, with an estimated consumption rate of 21cu.m litres per month. But during the cold and the rainy season, the cooling towers will not be operatonal which will result in a substantial saving. Despite allowing for low flush toilets of 1 lit./flush on the ground floor and 3-4.5lit./flush on the first floor, the consumption rate of the toilets is still quite high at 19m3 per month. Further savings in the water is achieved by allowing for dry urinals in the male toilets, and low flow toilets in all of the sinks.

Water Management in the Building

As already discussed there are 12, 5m3 above ground water tanks and 1 No., 25m3 underground water tank resulting in a net combined storage capacity of 85m3. To understand how the system works, the process has been divided into the rainy season and dry season operations.

i) Rainy Season Operations.

In peak rainfall situations, rainwater roof catchment will be collected into a guttering system which terminates into the four high level water storage tanks located on the first floor (see fig. 2). Once the high level tanks are full, overflow will occur through a 65mm uPVC pipe into the low level tanks on the ground floor. The ground water tanks have been designed with a control system that automatically switches on pump "P2"(on Figure 3) which pumps the water to the header tanks above the roof level from which water is drawn for internal use in the building (see fig 2). With continued rainfall a situation will be reached whereby all the tanks at all levels will be full, and all excess rainwater will overflow into the coutyard and into existing BTC underground water tanks to be used in landscaping. The courtyard underground tank acts as a overflow backup for the system.

ii) Dry Season Operations.

During the dry season, when demand exceeds supply, the system assumes a different operation. It is assumed that at the begining of the dry season all the tanks, at all levels, are full, with no replenishment from rainwater or otherwise. The dry season is during the winter months when the evaporative cooling load does not exist. At this time, only toilets will be consuming water. Continuous drawoff from the header tank will reduce the water level to its acceptable minimum. When this situation is reached the control system will activate the pump "P3" (see fig. 3) from the underground tank to replenish the header tank through the ground floor tank. Once the water in the under ground tank reaches it's minimum level, the pump "P3" will switch off. At this point, the only tanks containing water will be the ones on the first floor. Once "P3" switches off, pump "P1" will automatically switch on, drawing off water from the first floor tanks to the header tanks. This will be the last resort in the process. Finally the tanks on the first floor will reach their minimum design levels, and the pump "1" will automatically switch off, and thereby bringing the mains water supply from the Water Utilities Corporation into operation (see fig.4). This will continue until the next rains arrive and the rainy season operation will repeat.

With this arrangement, approximately 500m3 is anticipated to be harvested over a roof catchment area of 900sq.m and courtyard area of 180sq.m. An extra 20cu.m in overflow is channelled to the existing BTC underground ferrocement tanks to be used for landscaping. Supplementary supply from the Water Utilities Corporation during the dry period is only 65cu.m or 14% of the monthly total "internal" water consumption requirements.

The completed BTC headquarters will give an impressive example of the unlimited use of "free" rainwater.

FUTURE FOR RAINWATER CATCHMENT AND STORAGE TANKS

There is a large potential for the use of rainwater in both the rural and urban areas. While the rural area emphasis is on the rainwater being used for agriculture and animals, rainwater can be used in a lot of ways in urban areas, where the water tarriffs are quite high. The BTC Headquarters is a living example of what is possible.

However, several lessons arising from managing a Rainwater Catchment System needs to be highlighted. In particular the maintenance management of the system has been problematic due to a lack of systematic maintenance procedures and poorly trained personnel. With the oportunities arising from the expansion of the BTC, the existing Rainwater Catchment System will be upgraded and a fresh approach to managing the system based on the BTC experience will be undertaken. This will involve proactive maintenance systematically implemented and training of staff involved in the implementation.

The future for ferrocement tanks in Botswana looks very promising, but will need a lot of support from the Government and Donor agencies by way of funding and marketing of the technology. The cost of ferrocement tanks compares quite favourably with tanks of other materials. The main advantage of ferrocement tanks is in its durability and it also creates employment in the rural areas as it can involve some self help. The main obstacles in the selling of the product has been due to lack of marketing strategies, public ignorance about the technology and the general public's preference for "ready made to deliver" tanks. The situation is worsened by the offer of a variety of storage options readily available from South Africa.

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Month	Mean Monthly Precipitation (mm)	Monthly Inflow (m3)	Monthly Outflow (m3)	Outflow Factors	Adjusted Outflow	Inflow-Outflow Differential (m3)	Storage (m3)	Waste (m3)	WUC Supply (m3)
January	97.4	88.8		1.3	45.4	43.4	88.5	3.5	
February	84.4	77	34.9	1.35	47.1	29.8	118.3	33.3	
March	72.7	66.3	34.9	1.3	45.4	20.9	139.2	54.2	
April	43.7	39.9	34.9	1.2	41.9	-2.1	82.9		
May	13.7	12.5	34.9	1	34.9	-22.4	60.5		
June	4.6	4.2	34.9	0.85	29.7	-25.5	35		
July	3.5	3.2	34.9	0.7	24.4	-21.3	13.8		
August	4.6	4.2	34.9	0.75	26.2	-22	-8.2		8.2
September	14.9	13.6	34.9	0.85	29.7	-16	-24.3		42.3
October	42.8	3.9	34.9	1.1	38.4	0.6	-23.7		23.7
November	64.2	58.6	34.9	1.2	42.9	16.6	-7.1		7.1
December	91.6	83.5	34.9	0.9	31.4	52.1	45		

Table 1: Estimated Rainwater Catchment Inflow and Outflow Rates

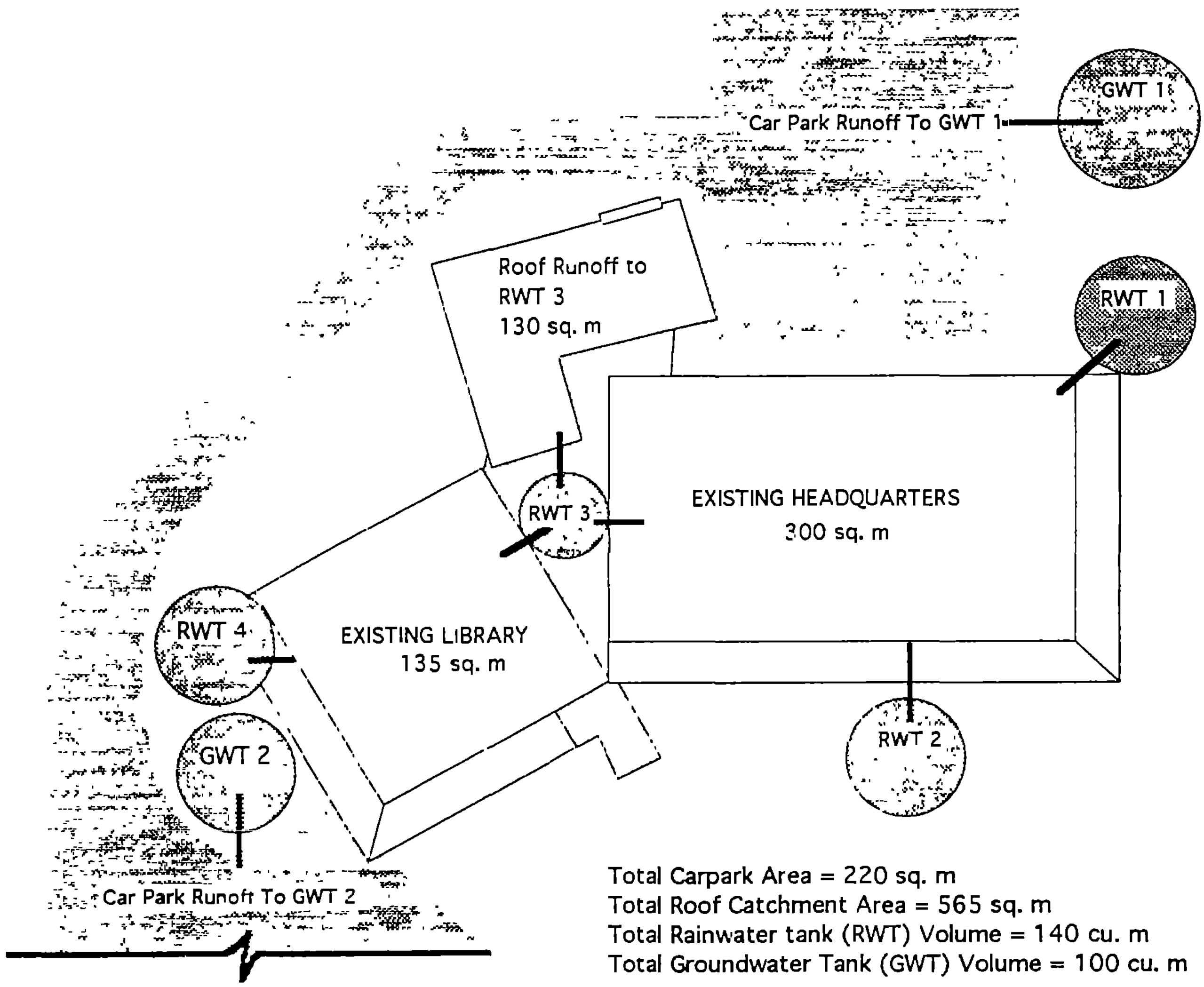


Figure 1. BTC headquarters site plan showing rainwater catchment

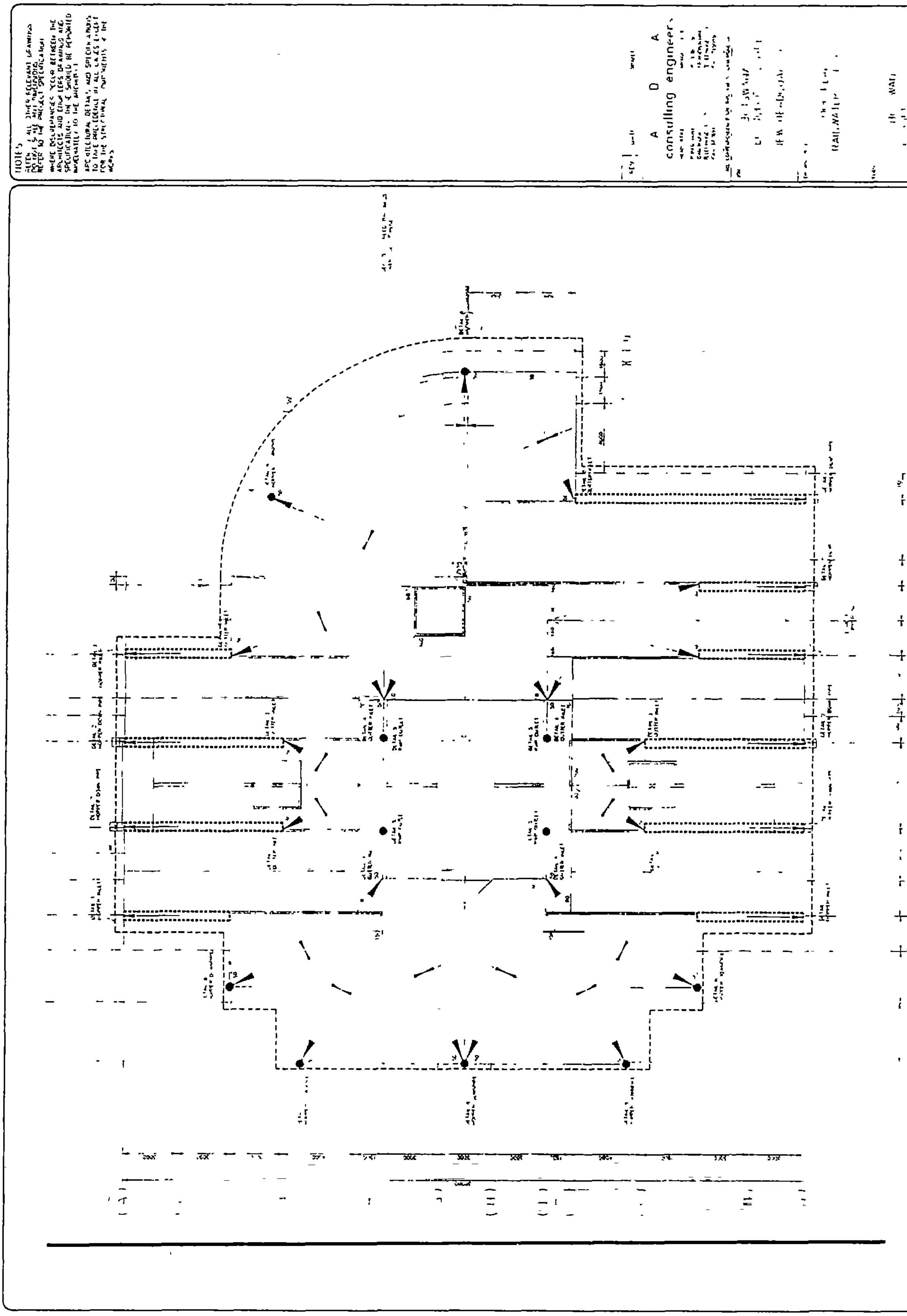


Figure 2. Roof Plan, Showing Roof Catchment Flow Pattern.

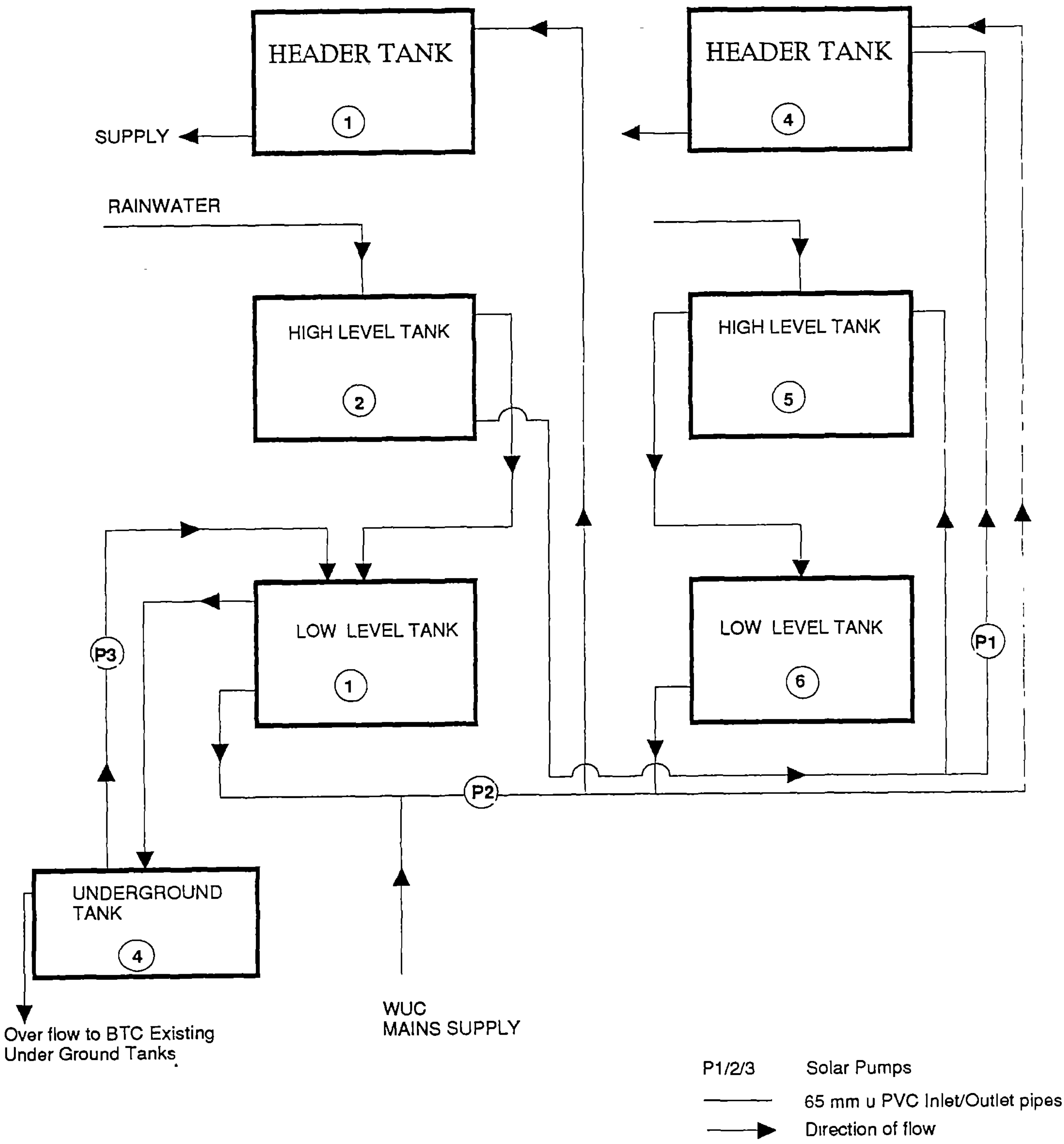
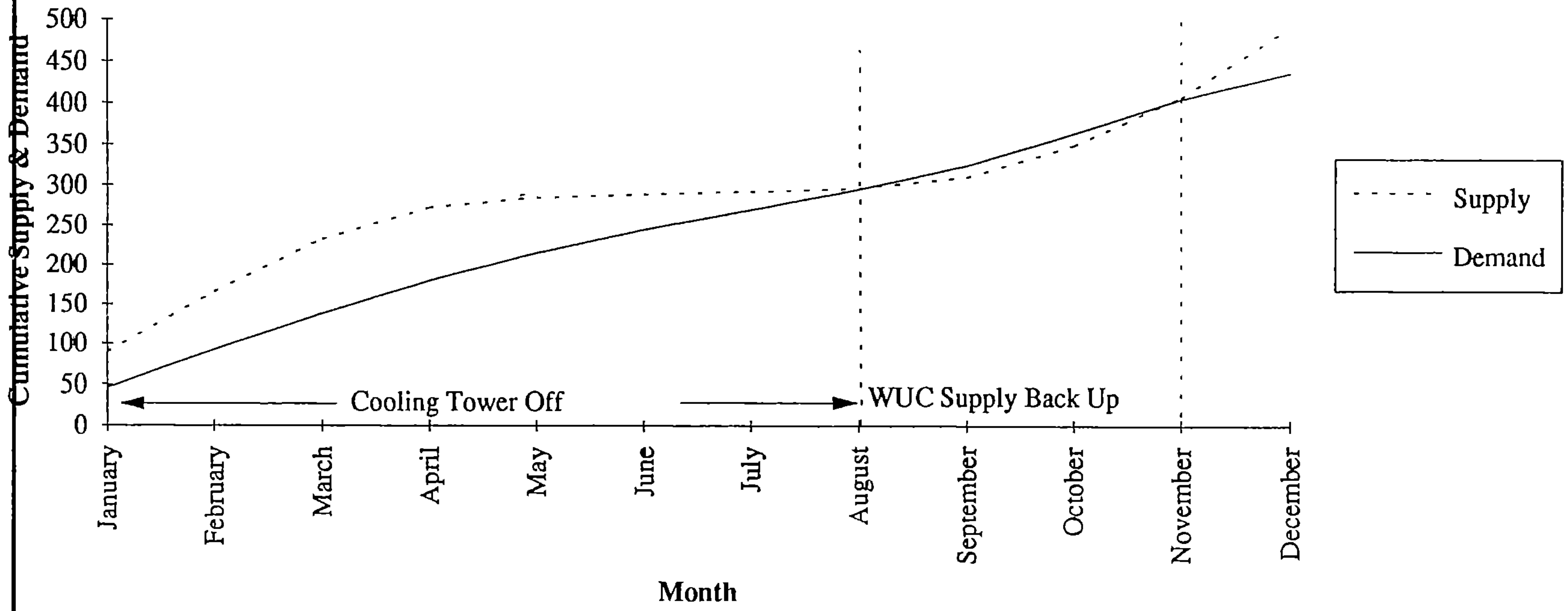


Figure 3. New BTC Headquaters Water Management Flow Diagram

Fig 4 Annual Cumulative Rainwater Catchment vs Demand



ECONOMICS OF RAINWATER COLLECTION

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INTRODUCTION

Rainwater has been an important source of water for present and past generations of people not only in Botswana but in many parts of the world. Rainwater has been used for both domestic and agricultural purposes. In Botswana where water has a high premium due to the arid and semi-arid nature of the environment the ability to harness rainwater to supplement other sources of water results in savings in water that would have been supplied from these sources. Thus there is a substantial economic gain in the form of deferred capital for water schemes involving public portable treated water (Appan, 1982, p. 225).

Rain water as a supplement to traditional sources of water supply becomes important in rural settings especially in Botswana. In some rural areas the water obtained from wells is saline and in the absence of other sources of water, rainwater becomes a major source of water for domestic and other uses. In other rural areas some settlements are very far apart and sometimes it becomes more economical to rely on rainwater as the major source of water. Thus with increasing demand for water as a result of increasing population growth and rapid urbanization the effective collection of rainwater can be an important contribution to sustainable development, particularly rural development.

Systems used to collect rain in Botswana and elsewhere have been classified by Gould (1992) depending on the type of catchment surface being utilized. These surfaces include roof, ground and rock catchment (within fields) and external hill slopes for runoff farming. This paper focuses on mainly on the collection of rainwater using roof catchment systems.

The roof catchment system consists of three segments: a catchment surface which is usually a roof, a gutter and downpipe which act as a channel for the water, and a storage container usually a tank into which the rainwater drains. The cost of the catchment system adopted will depend on the costs associated with these three segments of the system. The container or the tank is usually the most expensive part of the roof catchment system. Thus in the discussions on the costs associated with various components of the system more attention is focused on the tank.

With the availability of various types of roof catchment systems in Botswana and other parts of the world, it is useful to select catchment systems that are cost effective and have proved to be acceptable with regard to community concerns involving economic, social and institutional considerations. This study thus presents an overview of various studies on the economic aspects of roof catchment systems in both Botswana and other countries. Recommendations are given in the paper on the types of roof catchment system that are likely to be cost effective in the effort to provide sufficient amounts of safe drinking water, particularly in rural areas of Botswana.

Finally there is some space given to the modes of financing the acquisition of roof catchment systems.

REVIEW OF PAST COST STUDIES ON ROOF CATCHMENT SYSTEMS

Introduction

Available studies done on different types of roof catchment systems in Botswana and elsewhere are briefly reviewed in this section of the paper. The importance of this exercise is to examine the cost effectiveness of the different systems and their acceptance in the communities in which they are used. It is hoped that lessons can be drawn from these studies to enable recommendations to be made on the development of catchment systems that are both cost effective and affordable.

Review of Information on Rainwater Tanks

Of the three components of a roof catchment system the tank is the most expensive. The roof is assumed to be given since it must be available for a household or for a school in the first place. The cost of gutters or the down pipes which direct water to the tank is considered very little compared to the cost of the tank. Therefore for purposes of this paper the discussion on cost of roof catchment systems will be limited to the tank. Data provided by Gould (1991a) and Gould (1991b) form the basis of the discussion in this section of the paper.

Table 1 shows information on costs of rainwater tanks in Gaborone compiled by Gould (1991a). For galvanized iron tanks and ferrocement tanks the table indicates that the larger the volume of a tank the higher the cost. Thus the cost of a galvanized tank varies from P530 for a 2.25 m^3 tank to P1440 for a $9m^3$ tank. The same observation may be made for the ferrocement tank. The cost of a ferrocement tank varies from P3000 for a $10m^3$ tank to P4500 for a 20 m^3 tank manufactured by the Botswana Technology Centre. The ASAL/KIDP ferrocement tank with a volume of 46 m^3 costs P6000.

On a cubic meter (m^3) basis it may be observed that there are economies of size. For both the galvanized iron tank and the ferrocement tanks cost per cubic meter (m^3) decrease as the size of the tank increases. In the case of galvanized iron tanks the cost per m^3 decreases from P236 to P160 for volumes of tanks ranging from 2.25 m^3 to 9.00 m^3. For ferrocement tanks the cost per m^3 decreases from P300 to P225 and then to P130 as the volume of tank in cubic metres increases from 10 to 20 and then to 46 for the ASAL/KIDP ferrocement tank. A look at the annual equivalent cost (AEC) per m^3 at the last column of Table 1 shows that the most cost effective type of tank is the ASAL/KIDP ferrocement tank with an AEC/m^3 of P6.5 which is the lowest cost. AEC/m^3 for galvanized iron tanks are generally high ranging from 47 to 32 depending on the capacity while the AEC/m^3 for ferrocement tanks are generally lower ranging from 15 to 6.5 depending on the capacity.

Tables 2a and 2b give information on costs of rainwater catchment tanks in Africa and Asia respectively. According to Lee and Visscher (1990, p11) tanls are assumed to last for 30 years. No maitenance costs are included in the cost figures. It is also assumed that where there are two rainy seasons, the tanks supply tripple their capacity each year, i.e., they are filled and emptied three times each year. Where there is one rainy season, it is assumed that the tanks supply twice their capacity. The calculation of the annual equivalent cost (AEC) per m^3 of water supplied is based on the above assumptions. The costs indicated in Tables 2a and 2b are inclusive of labour and material costs and are up to date as at 1989. For the African data the information shows that there is generally economies of size in the various types of tanks indicated in Table 2a although sometimes the information given is conflicting. The information also shows that ferrocement tanks, especially ground tanks, exhibit considerable amounts of economies of size. Therefore ferrocement materials may be recommended for the construction of tanks in Africa, particularly for larger sizes of tanks. The Asian data shown in Table 2b also indicate that ferrocement materials are worth exploring for construction of water tanks.

Modes of Financing the Acquisition of Roof Catchment System

In order to encourage the use of roof catchment systems for obtaining rainwater to supplement other sources of water for household use or for agricultural purposes it is important to make the system affordable to those who want to acquire them, otherwise only the rich will be able to afford them.

One effective means of self-help tested in other countries is that people can form societies and contribute enough money monthly until at least one member can finance their tanks. In the subsequent months enough funds can be generated including amounts for dealing with inflation to enable others to acquire their systems.

The government can also finance the acquisition of catchment systems through subsidies or grants; the idea being that the capital which would have been used to develop alternative sources of water is now channelled into financing households or institutions to acquire rainwater sources.

SUMMARY AND CONCLUSION

This paper has briefly discussed the need for rainwater to supplement other sources of water in various communities. In some settlements in Botswana rainwater may infact be the only source of water since other sources may be saline or not available at all. The paper has also used data on cost of water tanks which is the major cost component in rainwater catchment systems to indicate that despite the existence of other materials for constructing water tanks, the ferrocement material has proved to be cost effective not only in Botswana but in other parts of the world and its use should be further developed.

In the process of developing rainwater catchment systems in Africa and in Botswana in particular, there is need for research into alternative sources of materials and for research into the benefits and costs of these materials. Finally, there is the need to find ways and means of making rainwater catchment systems affordable to households and institutions.

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Table 1

COMPARATIVE COST OF RAINWATER TANKS IN GABORONE

TYPE OF TANK	**Volume**	**Cost** (Pula)	**Cost/m³** (Pula)	**Life Exp.**	**AEC*/m³** (Pula)
Galvanized Iron	2.25	530	236	5	47
" "	4.5	870	193	5	39
" "	9	1440	160	5	32
Polyethylene (ALDEP)	7	750	107	10	11
Brick (Council)	10	5000	250	10	25
Ferrocement					
BTC	10	3000	300	20	15
BTC	20	4500	225	20	11
ASAL/KIDP	46	6000	130	20	6.5

Source: Gould, J. E. Rainwater Catchement Systems Development in Botswana. Final Report submitted to the Botswana Technology Centre, Gaborone 1991, p. 65

* Annual equivalent cost (AEC)

Table2a: Costs of Rainwater Catchment Tanks in Africa (Lee and Vissher, 1990)

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.

Table 2b: Costs of Rainwater Catchment Tanks in Asia (Lee and Vissher, 1990).

System	Vol m^3	Cost $	AEC $/$m^3$	Country
Reinforced Cement Jar	2	25	0.17	Thailand
Concrete Ring	11.3	250	0.29	Thailand
Wire Framed Ferrocement	2	67	0.37	Philippines
Wire Framed Ferrocement	4	125	0.35	Philippines

AEC = Annual Equivalent Cost per cubic meter of water supplied.
Assumption: Life expectancy of 30 years assumed.

Source: Gould, John E. "Rainwater Catchement Systems for Household Water Supply". In Environmental Sanitation Reviews No.32 December 1991, p.38.

RAINWATER CATCHMENT IN ZIMBABWE

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BACKGROUND:

Zimbabwe has been very active in the area of promoting rural water supplies through the Ministry of Health and Child Welfare, Inspectorate Department. Moreover, as far back as 1974, the Ministry of Health has also through its research department, the Blair Research Institute played a major role supporting rural water supply and sanitation activities within the country being responsible for basic research which has led to the development of technical options now being used in different parts of the country.

One of the widespread and directly accessible sources of water all over the world is rainfall. Although Zimbabwe has experienced a severe drought in the past years, the rainwater catchment technologies have not been as wide spread as one would hope it to be, especially during times of abundant rainfall.

The Technology Options:

Basically, there are three options which have been tried in some of the provinces in the country and these are as follows:

1. The Rock Catchment (Dwala) tried in Shurugwi district of the Midlands province as far back as 1968.

2. Raised pavement of a cement floor area tried in Wedza District of Mashonaland East Province.

3. The roof catchment which is widespread in all provinces of Zimbabwe. This technology is still being used in most of the government housing schemes in some very dry areas of the country.

Construction and Operation:

(i) Rock Catchment or Dwala

The first option of the rock catchment or dwala technology is where construction is done on a slope side of an outcrop . A wall of bricks is built from the foot of the mountain rock to the required height of rock in a V shaped form. At the bottom of this rock a brick cement tank is constructed and a roof of either concrete slab cement or iron/asbestos sheets is used to cover the tank. An inlet pipe is fixed to the tank with some wire mesh fitted to strain all the foreign bodies so that they do not enter the tank.

Depending on the terrain of the area and where the people are situated, an outlet pipe is fitted to be used for drawing water or to lead it to the village for consumption if the slope allows, when the slope does not permit a good flow of water to the user community then - the tank is constructed with a strong cement roof over the top and almost level with the natural ground. The top slab will be constructed with a hole in one side of the circumference so a pump can be fitted to draw water from the tank as is done on the ordinary well. When the catchment area of the mountain rock is big enough to harvest more water, many tanks are built and connections are made from one tank to another and this way the water is greatly clarified because of time taken on sedimentation.

The water tanks that are built underground are usually more permanent than those built above ground, the latter which usually develop some leaks after sometime.

In some cases of rock-rain water collection, the corrugated iron tanks are used and these are only used above ground for if they are buried underground they rust and wear out within a short period of time.

Most of the construction that has been done on tanks was done with cement aggregate and river sand with some reinforcements inside the walls. The amount of cement therefore required has always been the biggest constraint of this option.

(ii) Raised Cement Floor

The second option of a raised cement floor area is comparatively a very simple option which can only benefit single families who may opt to spend a few dollars on cement to build their own pavement.

This kind of option did not go very far with the people because it involved being built near homes and keeping the surface free from pollution by small children proved very difficult. The cement area also needed to be raised from the ground to a height that would not allow flooding water from the surrounding ground from passing through the pavement. However, inorder to raise this pavement, a lot of stones or bricks were required.

To these raised pavements some underground tank would be constructed and some pipes fitted to lead the rainwater into the tank through a screen to filter all the other solids from entering the tank.

With this option the tank is fitted with a pump to draw water for domestic use and the favourite pump for this option has always been a Blair Handpump.

(iii) Roof Catchment

The third final option is the most widespread option in the whole country and is still being used in most areas in the communal lands and in some institutions. This option of technology is the rainwater catchment from roofs. The option is simply a way of building on existing facilities. What really happens is people begin by building their own houses or building schools or other structures which are often roofed with some corrugated iron or asbestos sheets. these vast areas of roofs yield a lot of rainwater which usually goes to waste.

With money and realisation, people have decided to build tanks and collect all the water from such roofs. The tanks are either constructed of bricks, concrete or they use the commercial corrugated iron tanks. In this case, all that is needed is to have gutters erected on to the roofs and connections are made to lead the water into the tanks.

This method is widely used by Ministry of Construction and National Housing especially in areas where they have constructed houses for extension workers for Ministries of AGRITEX, Health, Education and Local Government in the most dry areas of the country. This last option is but one very common system which still remains a system in use in most areas. However, although these systems have been tried in Zimbabwe, they have had their own problems and these are listed below as follows:

CONSTRAINTS OF THE SYSTEM

The Rock Catchment or Dwala System

- Although the catchment area is built in a V-form, there is need to completely enclose the area where water is collected from. This then means the question of money comes in.
- The system is usually constructed on a maintain rock away from homes so it becomes difficult to monitor cleanliness.
- The area may be polluted by animals like baboons, etc.
- In a lot of cases, the pipes and walls are vandalised leading to failure of repair of the system.
- The costs of construction of the tanks and piping are so high that the involved community sometimes fails to meet them.
- The system has never proved to be a lasting solution to community water problems.
- The system in the long-term proved to be unsuccessful because of maintenance problems.

The Raised Cement Pavement System

This system was never widespread in most provinces because of the following constraints:

- Labour to provide bricks/rocks for raising the pavement.
- The tank needed to be an underground one and that meant water had to be pumped up using some kind of pump - Blair Hand Pump or other.
- The cost of the pump was an inhibiting factor.
- Maintenance of the pump proved hard because individual families could not raise the money.
- Since this facility was near the home, children were difficult to control from playing on the pavement hence polluting it everytime.
- Cement floors exposed to hush weather did not last for ever; they developed some cracks.

Roof Catchment

The roof catchment system is one of the commonest ways of providing water to communities.

- The biggest problem was money for construction of vast areas that would give enough water throughout the year.
- Where tanks have been provided to collect water from extension worker's houses, the guttering fell off and was never repaired.
- Sometimes the corrugated iron tanks developed leaks and never got any attention so the system simply broke down.

- In most areas the amount of water collected did not last the whole year because of the size of the tanks.

- The corrugated iron roofs sometimes produced a lot of rust which in turn affected the water.

- In most rural homes, the roofs of houses contain all sorts of dirty items thrown over by children which in turn pollutes the water.

- Without proper management of closing the tanks during the first rains, to run the water to waste until the roofs are washed enough to produce clear water, the first roof water collects a lot of dirt into the tank which makes the water very unpalatable.

- The maintenance problem which is common in all systems has proved to be the most discouraging factor in pursuing these technologies. Now the Ministry of Health having studied some of these mentioned problems has not taken a very serious stance in pursuing these technologies although they are surfacing in other circles like in some private institutions belonging to NGO's or others.

The water and sanitation wing of the Ministry of Health at Blair Institute which has done a lot of research and development, on technologies on water supplies, has not seriously looked at this particular system for inclusion in its research programmes. It is hoped that with money and time, during good rainy seasons, however research teams will go out in full force to investigate the technology more.

One of the main problems facing this system was how the community itself would contribute continuously to the maintenance aspect. Added to that is the huge costs involved in implementing these systems.

WATER HARVESTING IN AGRICULTURE AND HORTICULTURE.

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Botswana's rainfall is irregular and it is logical to try to even out the moisture content of the soil, so that it is available to the plants during the entire growing season. This can be done in several ways, but cost is the limiting factor. When we consider ordinary field crops, like fodder and grains, we cannot spend much money on water catchments and water tanks, but in horticulture the chances are greater due to high value crops. Grain growing costs today are often much higher than we normally estimate, because there are a lot of hidden subsidies.

A rough calculation of how much water falls as rain in Botswana and how much runs into the country via rivers, shows that there is approximately 200 000 cubic metres per person from rain and 20 000 cubic metres in water inflow. Water harvesting should therefore have a great future.

Food needs to be grown where the people are and the high costs of transport and storage have to be avoided, and that will exclude expensive pipelines.

A water plant for Botswana will be presented in a book about productive homesteads. Here only make a summary of water and water usage is given (by the author).

1. The daily general minimum need of water for everybody is **Security Water.** This security water need is of course different for different people and for different types of businesses. A private home may need a daily 100 litres or even less security water per person to keep the household and the hygiene programme going, but a small industry may need additional cubic metres per day and a brewery may need thousands of cubic metres a day.

   A small farmer or horticulturist must have security water to grow a minimum amount of crops so he can carry his business through a low rainfall period until normall rains start again and water is available from dams and rivers. Growing of crops requires approximately 1 cubic metre of water per square metre a year, which corresponds to 1000 mm of rainfall. We must however remember that this is based on a year round production and it is the average of the water need for many different crops. Nobody wants to start a business anywhere before he has a guarantee that he has security water.

2. There are **other water sources** beside the security water provided by the commune or the state. Costs may be high but if we can pay for it with production such water can be used. The value of such water depends on the production costs and the competition when you market your product or produce. At Sanitas we think that water costs must not be more than 10 % of the price of a plant or a produce. Agriculture is normally saved by the state in most countries via subsidies in periods of weather disasters, but horticulture never gets this help, which makes the horticultural industry economically healthier than ordinary agriculture. The first step in achieving selfsufficiency in food production is to **decentralise food production and food storage.** Food storage can in Africa to a great extent be replaced by "continuous crop growing and food production 12 months of the year" based on suitable crops. Under **other water sources** we have a) water from own boreholes b) water from micro or macro catchments c) reuse of waste water d) dew.

WATER STORAGE

The cheapest way to store water is as moisture in soil. Underground water tanks can only serve for drinking water for people and animals and for irrigation of very expensive crops. Dam water collected from a catchment area can be used for all kinds of activities, and such water can be used for agriculture, if the costs of dam building is written off over many years.

Often the depreciation period is too short, which makes the water too expensive to use, and no or little employment is created though the water is there, often evaporating into the air, because there is no surface protection of the dam water. If the price is right short term water holding dams can be used for quick crops part of the year, if **supplementary irrigation** of crops in the field is used.

The income from productivity due to the availability of water is rarely considered. Low prices on water may not pay for the construction of a dam, but **the tax money from increased productivity will.**

A 50 years writing off period including maintenance for 50 years, possibly equal to the building cost, could give us a reasonable water price and be the basis for mass employment of people in various fields including agriculture. Tax from income returns the capital to the state treasury, and the capital can be recycled.

Recycling of capital is the only chance poor nations have, and the Ministries of Finance should keep this in mind when planning. **A busy nation that needs no unemployment subsidies but rather pays taxes must be the final goal.**

SO WHERE DO WE START?

The most logical start is direct water harvesting to growing crops. To make crop production safe in the grain sector means in Botswana an additional gross income of P50 millions per year, if we go for selfsufficiency of 200 000 tons of grain per year. This goal can be achieved by:

1) giving plants a larger soil volume to take moisture from. In other words give them access to greater water storage volumes, which will bring the plants through periods of drought. So the first step is to reduce the plant number in all fields, but of course with **a uniform plant stand,** otherwise low plant numbers have no value.

   a) wide row spacing and wide spacing in the rows
   b) accurate seeding and seedling protection from pests
   c) use the most drought resistant varieties

   Total yields in Botswana will be greater than 100 000 tons annually just by applying these recommendations in the present farming community.

2. The second step is to reduce farming cost and make water storage even more secure for the plants. We reduce the ploughed areas of a field to 25 % and only weed the remaining 75 % of the land.

   a) by ripping strips deeper and storing water deeper we give the roots cooler conditions in 25 % of the field.

   b) the remaining 75 % of the field should be kept as water catchment, but also as a partial water storage facility in periods with heavy rainfall. To give the in the strips harvested water a chance to penetrate under the catchment areas is part of the permanent strip strategy. Some will of course also penetrate directly through the surface of the catchment areas. This happens with very slow rains.

By applying these measures as well the yield in Botswana will pass 200 000 tons, and thus give selfsufficiency in grain food.

THE SOIL MOISTURE CONTENT

Some people have taken as their special duty to use instruments to measure the soil moisture in various places within a field but every field, independent on the catchments and the storage facilities will end up at "field capacity" in a particular volume of soil moistened by rain. If we measure the moisture immediately after a rain, we will of course measure higher readings in the surface of the soil.

Water movement in deeply ripped permanent strips will be rapid downwards, but at the top of the harder catchment ridge drainage is relying on **sideward water movement** due to the hard pan-like ridge. We could therefore theoretically expect to find higher values in the surface layer of the ridge than in the surface of the strip.

In other words the strip reaches field capacity in the surface layer quicker than the harder ridge or any area compacted by traffic between the rows. After a certain number of hours or days all moistened areas with drainage facilities have moved to field capacity.

What is of interest is of course not the percentage of water in a soil sample, but **the volume of soil moistened to field capcity.**

I include the first soil moisture water study I made in 1967-68. We clearly see that water of course moves "downhill" and not uphill.

This **volume** of wetted soil in the strips is of course the key to successful permanent strip cultivation. **To measure soil moisture contents with instruments without referring to the volume wetted has of course no value whatsoever for agriculture.**

With sprinklers on dry soil shaped as indicated in the sketch the water movement towards the loose strip is clearly showing that water moves due to gravity and capillary forces and wets the soil to field capacity along a front in the soil.

The moisture of course remains at field capacity in this position until more water is added or a drying process is started. When water is added at the surface of the field, free water can continue to move as a front.

When the soil however is drying the water at the surface is lost rapidly, but deeper situated water is not lost very fast, because it is relying only on the capillaries for a slow movement towards the surface. The large pores and cavities of the soil at field capacity have only small amounts of water, partly in the vapour form.

The question we must ask is of course:"where did the water go and where is the water now stored?" The soil needs time to reach field capacity via drainage. We will find water "still travelling" to its final destination. Travelling to the frontline of wetting.

The value in soil moisture studies is thus questionable, if they are not based on direct soil observations in dug-out profiles during the period, when rains start and a distinct wetting frontline can be observed in the profile. During the winter we have excellent chances to study water movements in the soil by digging profiles after accurate application of fixed water volumes during fixed periods of time. Mist nozzles and heavy output sprinkler nozzles can be compared.

All my moisture studies are based on water profile studies with water sprinklers on dry soil and by studying profiles after the first rains. Such studies have shown that underground pans may be as important as hard surfaces for water concentration to plant root zones. Based on these studies, I have in an unpublished paper suggested that we create "a wavy pan" not only in the desert sands but with any soils. The wavy pan variation could also be a transition method to be used by farmers with no special eqipments for the permanent strip with hard surface run-off ridges.

The wavy pan idea is in fact the same as the permanent strip, but we use cultivation between the rows, so that we create an underground bow-shaped water catchment by cultivating deeper close to the strip and very shallowly in the centre between the rows. The surface of the interrow area thus appears to be level, but underground is a "wavy pan" that stops the water from penetrating deep between the rows, and gradually there is an underground seepage to the deeply ripped strip. Se sketch of wavy pan idea. A single wheelspoor in the field may have the opposite effect. It collects and keeps free water, which will evaporate.

The wavy pan idea can be adopted by most farmers immediately, because it means cultivation weeding between the rows at any time of the year and chisel ploughing or ripping of fixed strips after harvest and in spring to control weeds. The weeding in spring should be combined with the seeding of the crops, so a weeder-seeder must be developed from existing or new tools or material. Animals, small tractors or large tractors can be used.

If maize is grown two dry years in a row in strips, there may not be enough moisture the second year, if the early rains are not concentrated to the strips by ripping and shaping of the ridges immediately after the harvest. Even so, on heavy soils it is very difficult to get the moisture needed for a 6 week period of drought, if the plants are exposed to the December-January heat. Early or late planting is a must, if we wish the plants to survive drought in the very hot period of December - January.

In the past it was surprising that maize had been produced on strips in Sebele that only have "sorghum potential", and are only 50-75 % suitable for maize. This year mainly due to late planting (nov.12-20), in shallowly ripped strips, worked just before planting, the use of 100 kg per hectar of fertilizers, the use of an untested new variety, no strikes on the wheels to facilitate uniform water penetratrion to the strips, water evaporation losses due to water standing for almost a day beside the strip on an hard surface not broken by wheel strikes, the crop wilted after 4-6 weeks without any rain at all. The 3 weeks before this rainfree period, there was very little rain as well. There was rain enough for a maize crop, but it was not utilised and saved in the best way. A flat land plot of 2 hectars stood up as well, but it had no crops last season, when the strips had quite a good maize yield.

Sorghum is less sensitive, and strip trials at Sanitas in the middle of the eighties and now this year at Sebele clearly show that sorghum can grow and produce heavily in spite of very little rainfall, if given large soil volumes, whereas closely planted sorghum will burn during the heatwaves of December-January, which happened to the control plots at Sebele this year.

Sorghum should also be planted early, and with wide spacing in deeply ripped strips secure yields can be obtained every year in most of Botswana. The lower the number of plants we use the more drought resistant the crop will be. The yield however is regulated by the tillers. In a year with very low rainfall there will be a yield with low plant numbers, but only with one head per plant.

The low numbers may not till at all in a very dry year, but with increasing rainfall the yield will increase, and 12 000 plants can produce 50 000 sorghum heads per hectar, which we had at Sanitas in the eighties. I believe we should not exceed 18 000 plants of sorghum per hectar until we have created larger soil volumes in strips. I believe that 12 000 plants will give the safest average yields over many years, provided this low number is planted in ripped strips with water concentration to the strips.

Uniform plant stands with low numbers is the key to future success. Shallow cultivation is for the moment the only weed control method to recommend in heavy soils. Scraping with blades works on sandy soils, but cultivation to 50 mm depth is necessary on heavy soils, increasing the depth to 100 mm close to the strip to take advantage of a subsurface pan for water harvesting to the strip. This is the wavy pan variation of the permanent strip method.

We must study the plant growth.

An extremely important study in addition to the profile study is of course the study of the plant behaviour. Plants, especially sorghum, will till when there is moisture, and this tilling is caused partly by the release of nitrates in the soil, because the nitrogen available to the plant is the factor that influences side breaks more than anything else. In a nitrogen starved soil very little or no tilling will take place. Therefore plants demonstrate nitrogen deficiency symptoms as an early symptom of water stress in periods of low rainfall.

To count the number of plants and the tills in the various plant stands in the field is a good way to demonstrate the availability of more moisture in the ripped permanent strips.

We must study soil profiles and the plants, which summarise everything about moisture and moisture movement, and moisture utilisation by the plants.

THE STRIP SPACING

The permanent strip has many applications for many different crops, and the distance between the permanent strips can vary from a few feet to many metres. The cost of working strips can be extremely low with time.

We cannot store water in the root zone in excess of field capacity, because then we poison the roots with reduced nitrate (nitrite) and free manganese from oxidised manganese in welldrained soils.

Shallow soils, and shallowly ploughed soils may after rains have water in excess of field capacity for several days, and that is why the roots of plants on shallow soils turn brown and become diseased and are attacked even by weak pathogens, which only go to work in water saturated soils or slowly drained soils with weakened root systems. The lack of oxygen is the most common basic cause of plant disorders and poor plant growth.

WATER TANKS

At Sanitas we have over many years been interested in water storage in underground water tanks, and we have such systems for smaller growing areas, but the capital needed for storage is so great that, we have not used it for larger areas of growing, because we have a "cheaper" source of water in the Gaborone Dam.

However, temporary storage facilities, where collected water can rapidly be used in permanent strips for an initial **supplementary irrigation** to start crops early and safely is desirable.

This is the most promising field of water harvesting I can think of for a great number of small farmers in Botswana once they have accepted the principles of the permanent strip as a growing method. One single water application to a given soil volume in a permanent strip in September or early October, would bring the crops into the rainy season in most years. To grow before the weeds become a major problem must be our basic goal for future farming improvements.

The seed should be with the growers by September 1 to make early planting possible. Plant food can come from composted kraal manure and organic matter on the farm. Imported fertilizers are not needed in this country, if we utilise local plant food sources.

A NEW TYPE OF AQUADUCT?

At Sanitas we try to think in terms of productivity and profit, and this is necessary for all private enterprises.

Therefore we have played with the idea of building aquaducts and aquaroads. We have built a 25 m aquaduct model, but we have not built an aquaroad yet. The aquaduct has 4 functions: 1. A water pipeline 2. A water tank 3. A growing area 4. A Fence.

Aquaroads could be hollow structures suitable for transport like any other road, but combined with water transport in the road itself, it might be more economical for both roads and pipelines. The possibility of making huge amounts of solar heated water in such roads for a township or for the growing of winter crops should also be looked into.

THE RAINWATER-SEWAGE WATER MIX.

In climates with low irregular rainfall like in Botswana, we have totally ignored the most suitable irrigation method available, and that is **supplementary irrigation.**

Permanent strips with soil volumes of a minimum of 100 litres of lose soil per root system collect the late rains from the previous season and the amount of water needed in spring for early planting will depend on the amount of water available already in the strips. Early planted maize will grow well during the cooler parts of September and October without additional water before November. Weather data should provide us with a suitable planting date to bridge the gap between planting date to the weeks we can expect safe rains. Sewage water could here be used.

THE PERMANENT STRIP FOR WATER PURIFICATION?

Supplementary irrigation with sewage water combined with rainwater catchments on interstrip areas as used with the permanent strip method can be developed into a water purification water collection system.

By applying sewage water more than once and by draining off excessive water from the strips by the use of a drainage pipe system, we may be able to build viable water filters over many hectars of land.

This would pay for the water filtering by the safe crops produced, which could be in excess of 5 tons per hectar of maize, if more than one sewage water application is made during the growing season.

Twenty years ago, we tried to use supplementary irrigation of soil strips for the growing of tomatoes. Perforated pipes normally used for overhead sprinkler irrigation were turned upside down and placed on the strips. We jetted the water into the strip only and rapid wetting down to 500 mm depth took place. The catchment areas then collected rainwater as well.

Very little water was needed for tomatoes because of this initial heavy position irrigation in the strip. You can also use heavy output sprinkle systems to concentrate the irrigation water to the strips by irrigating overhead after the ridges and the strips have been made. More water is lost in this way, but it would be a cheaper system to use for less expensive crops like maize, because the moving of the pipes would require less work. Heavy output nozzles must be used to get rapid run-off to the strips.

We have the chance of using temporary water reservoirs made of scoped out reservoirs in the ground, which may keep water for a few days or weeks only.

Assuming we get 20 mm of early rain and such reservoirs are filled up in the very field where we wish to grow maize. We can rapidly, with movable pumps and pipes, pump this water to the strips and wet them to more than 600 mm depth during the rain or immediately after. The rain itself may only have wetted a flat field to 15 cm depth and the strips, because of water concentrating ridges, to 30 cm depth, but by irrigating supplementary from collected water, we can saturate the strips to field capacity 60 cm deep and have a safe growth for up to 6-8 weeks in the early spring when evapotranspiration is low.

By looking at the supplementary irrigated crop as a dryland crop, it will be in balance with the rainfall after the early strip soaking at planting time. Such crops should give safe yields in the region of 2-3 tons per hectar, if we plant 8000-10 000 maize plants uniformly in the strips.

Even salty water, can be used for supplementary irrigation in water harvesting schemes. To dilute salty water or use it as it is for certain crops should be looked into, because there is a lot of salty water in Botswana. The old man saltbush, spinach, redbeets, fodder beets, tomatoes and melons may grow well on salty water, all depending on the salt content. **Combined with rain water concentration** the chances of growing more crops are there.

A 1967 - 68 profile study of wetting of freshly made strips and interstrip areas

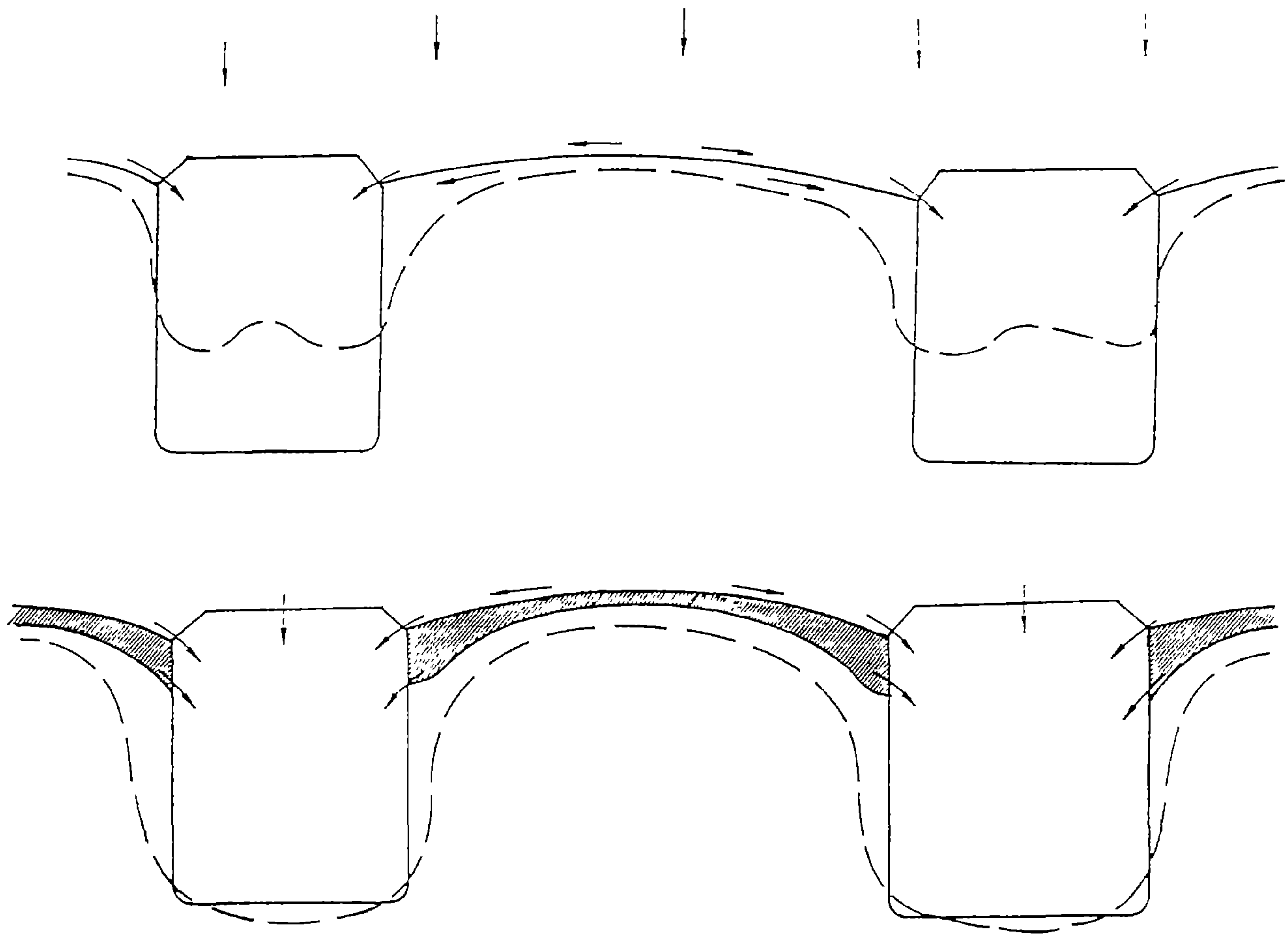

Figure 1

Permanent strips with catchments cultivated shallowly will provide water concentration at surface and pan level. In heavy soils the surface collection will be dominating, but in Kalahari sands there is an important underground sideward movement of water on hard underground pans. The pans must be shaped to encourage water movement towards the ripped strip. In a study in Malotwana wetting between the strips was 150mm but in the strip 450 mm after a 25 mm rain early in spring. The wetting was studied one day after the rain by the digging of profiles in the field. This is the basis for the wavy pan idea, where farmers can cultivate between rows, but use cultivators and blades that favour the creation of a wavy, underground pan. The permanent strip method will thus be available more rapidly to small farmers with great weed problems. A wavy pan underground will survive erosion forces better than a ridge, which on sandy soils will disappear in one season

GROUND BASED RAINWATER CATCHMENT UTILISING SALT PANS
"A Supply Scheme for Domestic Use"

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INTRODUCTION

In the recent past, water supply in western Botswana has been typically achieved through extensive borehole drilling in areas where the likelihood of either finding no water or finding saline water is high. In the more distant past and continuing until today, rainwater catchments often served as a major source of water for cattle farmers in the area and for the domestic needs of the indigenous populations. These catchments are primarily associated with salt pans, with the pan itself acting as a semi-impermeable surface for temporary water storage. Dams or reservoirs are dug into the pan and these fill with water during rains, or with the pan draining into an aquifer into which wells are dug. In these areas of Botswana nearly all villages are situated at pans.

Proximity to a pan was of particular importance to Remote Area Dwellers as a primary source of drinking water. Although much has been achieved in the past 5 years in the provision of potable water to most RAD settlements, lack of access to locally available water in some settlements forces the continued importance of pan catchments.

One such settlement is Zutshwa. Zutshwa is located some 65 km south west of Hukuntsi in the Kgalagadi District of Botswana. (See Figure 1) The Kgalagadi is a sand filled basin which covers much of Botswana, its main features being its lack of any permanent surface water and abundance of finely graded sand. Zutshwa supports a population which varies around 250 persons.

The Settlement of Zutshwa has long been plagued by having no locally available potable water supply. Sub-surface water in the vicinity of the settlement is extremely saline, some boreholes being over 5 times more saline than sea water. While prospects for the economic development of the settlement are good, this lack of locally available water has delayed long awaited developments in the social and educational sectors that could not otherwise be supported without water, The settlement currently relies on water trucked from Hukuntsi by the Kgalagadi District Council (KgDC), an extremely costly programme, and from limited yields from a solar desalination plant designed and installed by the Rural Industries Innovation Centre (RIIC) in 1986. Reliance on these supply strategies will restrict further development of this settlement.

The Lutheran World Federation, after unsuccessful efforts to find potable groundwater in the vicinity of Zutshwa, identified a number of alternatives that could be investigated in an attempt to solve this problem. They are as follows:

- Further drilling in an attempt to find fresh water. Repeated attempts have shown that the likelihood of success is very small and is perhaps the most expensive option.

- Reticulation from the nearest borehole of acceptable salinity (27km) to be used in a reverse osmosis process. This is a new technology in this area, still being tested. Reticulation, costs are very high (P400,000).

- Expanded solar desalination to perhaps 300 stills. This will need a high level of support from the KgDC Water Department and will therefore most likely be unmanageable and unreliable (P200,000).

- Continued Council water trucking with a current trucking cost at P0.20/litre of water. Not a valid long term solution (P90,000 per annum or P60,000 in conjunction with the current desalination yields).

- Resettlement, an option with social ramifications and likely to be strongly resisted by the inhabitants of the settlement.

RIIC's involvement in the development of the settlement has increase significantly in recent years. The availability of a saline ground water source led RIIC to initiate a community-based salt production project. The success of this project as an income generation source for the community has stimulated other production ventures, all of which are administered by the recently formed Maiteko Tshwaragano Development Trust. Understanding that the sustainability of these projects and the long term development of the settlement depended on a water provision solution, RIIC proposed to Council to develop a pilot rainwater catchment scheme in Zutshwa Pan to provide drinking and cooking water to the entire settlement population throughout the year.

RIIC undertook to prove the feasibility of such a catchment scheme by making trial excavations at the edges of Zutshwa Pan with temporary catchment aprons. Preliminary results were very positive and led RIIC to seek funds to develop a full scale pilot water catchment scheme. The KgDC also agreed to collaborate in this project by paying for
labour costs involved with the project under its Labour-based Intensive Works Programme. Work began in June 1992.

PROJECT DESCRIPTION

A simplified description of the system is given here. Three 5.8m diameter by 3.1m high (average water depth 2.6m) underground concrete and brick tanks have been constructed in Zutshwa Pan about 80m from the pan edge. (See Figure 2) The tanks are connected in series and are covered with pre-cast concrete slabs supported by steel beams. (See Figures 3 & 4)

These tanks are situated in the southwest corner of the pan, adjacent to the dune. Dunes on pans in the area are located at the southwest side of the pan, being formed by the prevailing northeast winds. Sand and clay from the dune have been eroded on this side of the pan, forming a hard sloping surface that carries rainfall rapidly toward the pan centre. This erosion also seems to have altered the geological features of the pan. Excavations have revealed that only highly compacted sand and clay layers (making hand excavation possible) to a depth of 3m exist while the rest of the pan is mostly calcrete.

During any significant rainfall (typically more than about 3mm), water begins running off the areas adjacent to the pan and from the pan itself toward the pan centre. This run-off is diverted by a catchment apron made from Cinva Ram moulded stabilised sand and clay blocks mounted on a concrete slab. This diverted water drains into the first tank inlet. Once this tank (68m3) is full, water spills over into the second and then third tanks. Should all the tanks fill (205,000 litres), excess water overflows onto the pan. Should the pan fill with water, it will not flow into the storage tanks (water from the pan has a high likelihood of being contaminated) because of the elevation difference between the system outlet and the pan centre.

Water is pumped by an operator from the appropriate tank by a suction mounted on a specialised donkey cart. The operator makes 3 to 4 trips to the settlement centre (2 km) per day to supply a ration of at least 5 litres per person per day. It is estimated that the water should last throughout most of the year. Subsequent replications of the system will increase yields proportionally.

INITIAL RESULTS AND DISCUSSIONS

The storage tank construction has been completed to a point where they could begin collecting water, although they have not yet been plastered. A temporary catchment apron was erected in December 1992 to test the water collection capabilities of the system during a period when rains were expected. This temporary apron was made by lining Cinva Ram moulded stabilised sand and clay blocks on the catchment area and back-filling and compacting sand and clay behind them (once the apron slabs have been poured, these blocks will be mounted on them).

Details of rainfall and collection are given below:-

Trial Excavation

Date	Rainfall (mm)	Duration (minutes)	Water Collected (m3)	Comments
April 92	8	?	20	Trial excavation of 55m3. Apron made from excavated material
03-05-92	13	?	45	Tank full. Overflow 20%

Pilot Plant (Operations began June 92)

Date	Rainfall (mm)	Duration (minutes)	Water Collected (m3)	Comments
19-12-92	1	?	---	
21-12-92	5	?	3	Apron ~60% effective
23-01-92	1.4	10	---	
25-01-92	5.2	10	8	Apron ~80% effective
28-01-93	6.6	over 6 hrs	9	Apron ~80% effective
30-01-93	21	45	88	Apron severely damaged during rainfall causing reduced collection. Estimate of lost water could be as high as 50%

This data is shown on the accompanying graph. (See Figure 5) Although adequate data has yet to be collected, the results indicate that the system will most likely begin collecting water after 3mm to 5mm of rainfall. The 28-01-93 data shows that even with low rainfall and low intensity, the system is still able to collect significant amounts of rainfall (this amount of water collected from an 85% efficient metal sheet roof would need a roof area of 1600m2). Data for low intensity rainfalls of large amounts needs to be collected to correlate the effect of low intensity rainfall on runoff. However, the rainfall patterns in the area are such that large rainfalls are usually of high intensity.

The water collected so far contains high levels of suspended clay particles that will require appropriate filtering before distribution begins. A sedimentation tank built into the first storage tank is not effective in removing the contaminant.

Of primary interest in proving the viability of the system is the rainfall data from 30-01-93. This was a very high intensity rainfall, dropping 21mm in about 45 min (28mm/hr). The temporary catchment apron was not durable enough to withstand the impact of the high volumes of water it was required to re-direct. In some places the blocks were swept away by the force of the oncoming water causing the loss of all water collected from the upstream side of the apron. Everywhere else along the apron, there was evidence that the water had eroded flow paths underneath the blocks or had actually spilled over the top of the blocks. Nevertheless, 88 m3 were collected in the tanks. It is difficult to estimate what additional volume could have been collected had a more durable permanent apron been in place. If losses are estimated at 50%, 132 m3 would have been captured, filling 65% of the entire system's storage capacity in a single 21mm rainfall. This single rainfall convincingly illustrates the potential of rainwater catchment as a solution to Zutshwa's water availability problem.

As of 31-01-93, there was 102 m3 stored in the tanks (the first tank was full and the second 54% full), about 50% of the total capacity. This is equivalent to 20 weeks of water at the rate that the Water Department is currently trucking water for use by the community (extension staff water excluded).

The existing data, although meagre, has been extrapolated to determine what amount of rainfall would be required to completely fill the tanks. This rainfall would most likely have to fall in a single event. The worst case example, taken by assuming that there were no water losses during catchment, shows a linear relationship between rainfall and captured runoff that would yield 200m3 after a 42mm rainfall (lower line on graph, see fig 5).

A perhaps more realistic extrapolation takes losses into account that will not occur once the system is completed. It must be cautioned that there is very little data to support the estimates of the losses incurred during the 13mm and 21mm rainfalls shown. However, based on the estimates quoted earlier, one could expect 200m3 to be collected after a single rainfall of about 27mm (upper line on graph). This quantity of rain is a distinct possibility, even in drought years. The superlinear nature of this curve is also more realistic than the linear one (the linear relationship being more appropriate for metal sheet roof run-off), illustrating both the higher run-off coefficients and effective areas of collection associated with higher rainfalls. Unlike metal roof catchments, the product of the rainwater collection area and the run-off coefficient is a strong function of the total rainfall and its intensity.

Although perfectly acceptable if it should occur, the system was not intended to fill in a single rainfall. It should also collect more than 200m3 per year (a total of over 450m3 throughout the year is needed to give 5 litres per person per day), being achieved by gradual emptying of the tanks through use and their refilling during rainfall.

It is not yet possible to accurately predict the total amount of water that will be collected from this catchment area in one year because of uncertainty in the rainfall-dependent effective catchment areas and run-off coefficients. However, it is estimated that the catchment area will collect more that 1000m3 per year, indicating that storage is at least 20% of the collected water. If J. Gould's interpretation of the data for rainfall patterns in Tsabong (based on the computer model by B. Latham) is used, a 200m3 storage should be sufficient to yield 500m3 throughout the year. However, the preliminary data so far collected seems to indicate that we have underestimated the amount of water that can be captured by the pilot scheme and therefore the amount of water that would be available for community use. Data is currently insufficient to speculate further. After more data is collected, it may be fitting to increase the storage of the pilot scheme by adding more tanks.

COSTS

The following represents an estimate of the costs involved in the project. It must be borne in mind that these are the development costs and as such can be reduced for subsequent installations. This reduction will probably be in the range of 15 to 25%.

Materials	30000
Kilometrage	9500
Labour	10500
Skilled labour	4000
Contingency	6000
Total	60000 Pula

FUTURE DEVELOPMENT

The system has proven itself capable of collecting large volumes of water and the technology deserves full consideration as a primary source of Zutshwa's water requirements. Water filtering to remove the suspended impurities from the water is the only major technical task to be assessed. This will be achieved either by using an in-line filter and backflushing into the tanks or less desirably, by using a flocculent. A large portion of the catchment area has been fenced and the tanks will be sealed. If the level of organic material that enters the tanks can be kept to a minimum the stored water will undergo self-purification and hopefully, any bacteriological contamination will be minor. Otherwise, chemical purification will be required.

After the system has operated effectively for a prescribed period and replications of the system are complete, a pump station will be constructed to bring water to the settlement centre.

Zutshwa is one of the last remaining settlements in Northern Kgalagadi Sub-district that has no locally available potable water source. This has increased the perception that the water problem should be solved quickly and therefore also increases pressure from policy makers that feel resettlement is the best option. A significant part of rainwater harvesting's technical feasibility has already been shown. On a social level it must be noted that:

- This is a technology that has been utilised, albeit in a somewhat primitive form, by the Remote Area Dwellers for as long as they have existed.

- It is a technology easily understood by the settlement dwellers, particularly since its success partially depends on understanding its use limitations, i.e., water is not unlimited and must therefore be conserved and rationed.

- The technology can be operated and maintained at a local level and will promote self-reliance since minimal support from outside the community will be required.

- It is an extremely cost effective option.

Rainwater harvesting may be the most practical technological solution to ensure the Zutshwa's sustainable development.

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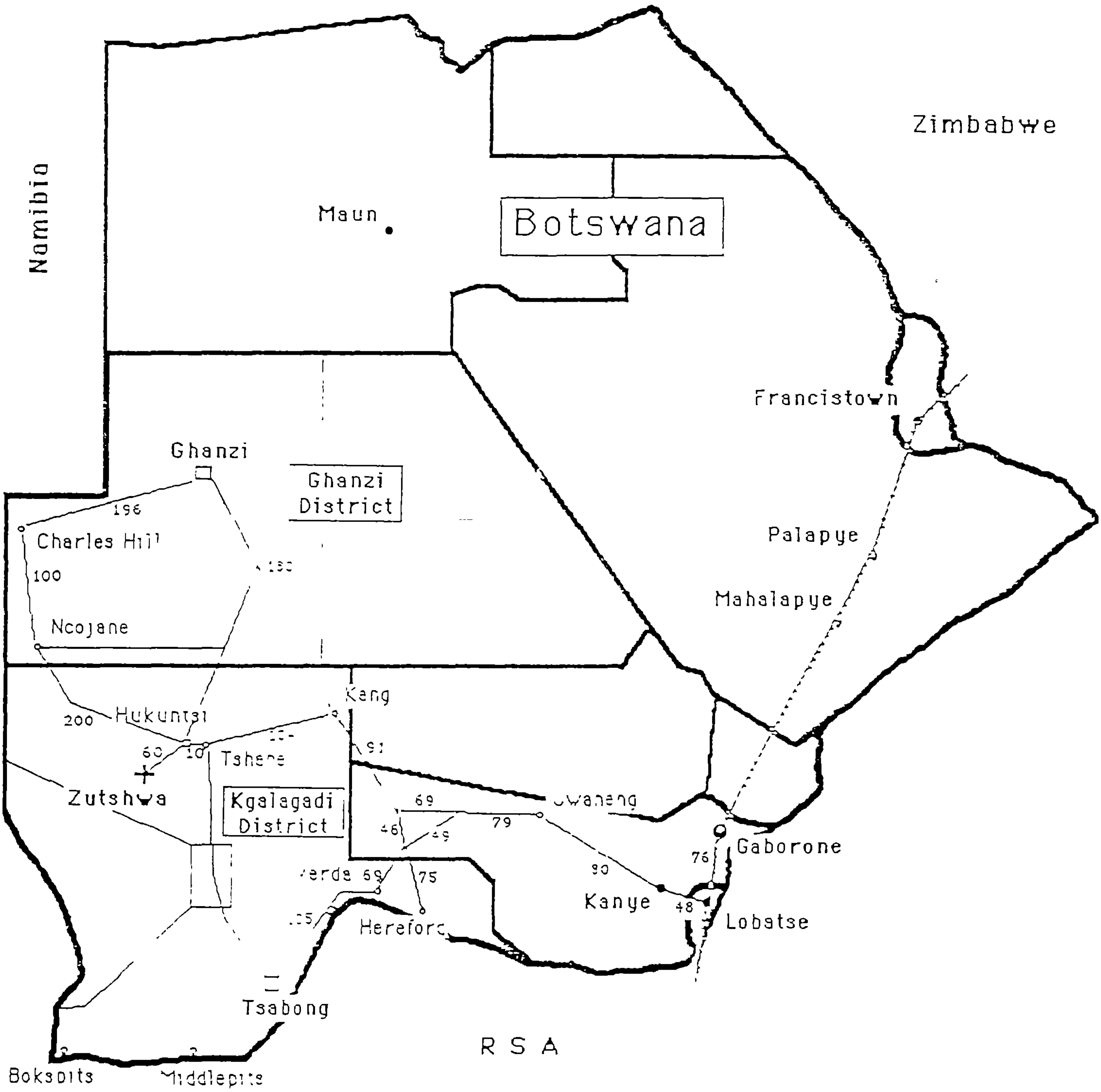


Figure 1. BOTSWANA

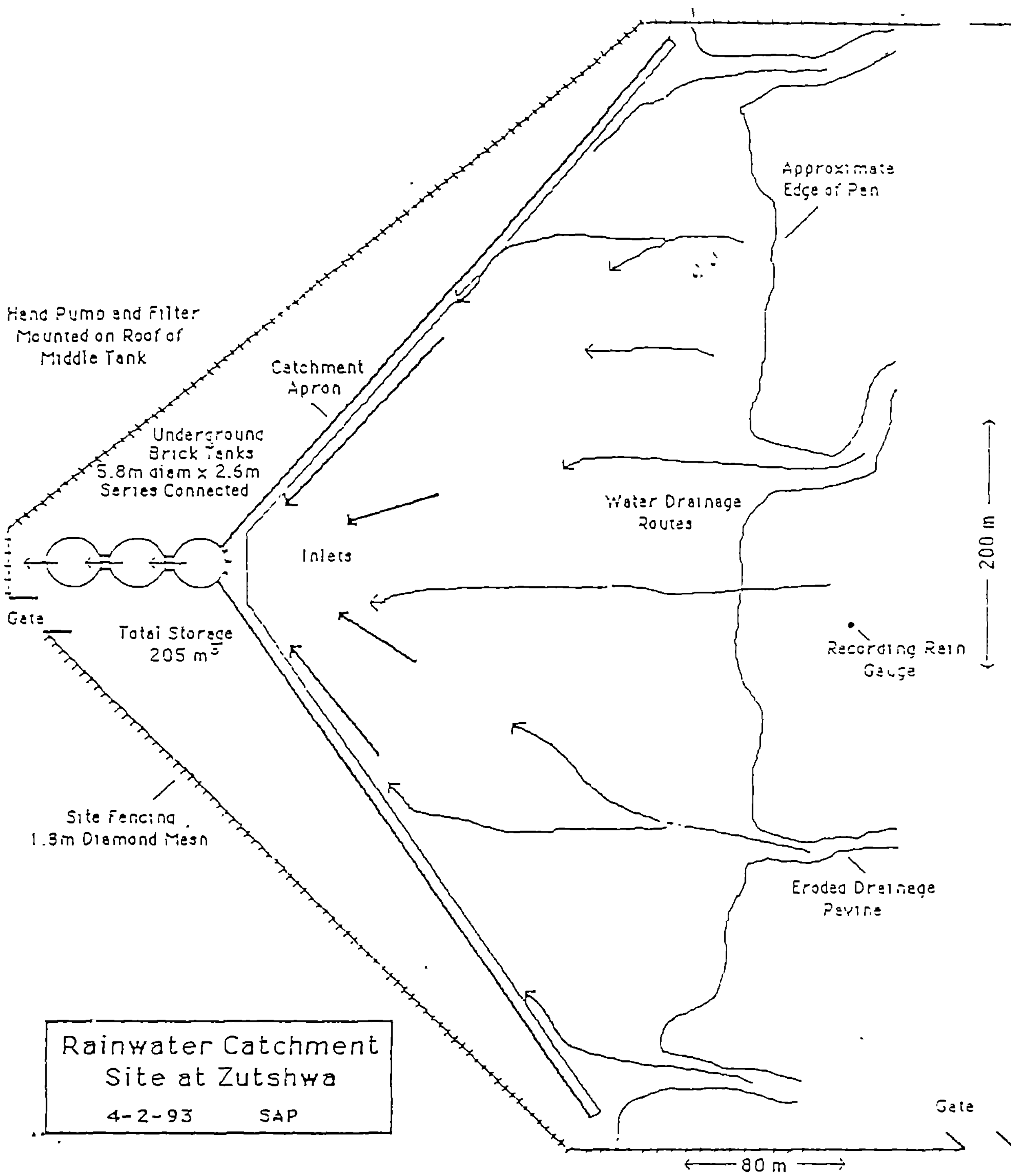

Hand Pump and Filter
Mounted on Roof of
Middle Tank
Catchment
Apron
Underground
Brick Tanks
5.8m diam x 2.6m
Series Connected
Gate
Total Storage
205 m³
Inlets
Approximate
Edge of Pan
Water Drainage
Routes
200 m
Recording Rain
Gauge
Eroded Drainage
Ravine
Site Fencing
1.8m Diamond Mesh
Rainwater Catchment
Site at Zutshwa
4-2-93 SAP
Gate
80 m

Figure 2

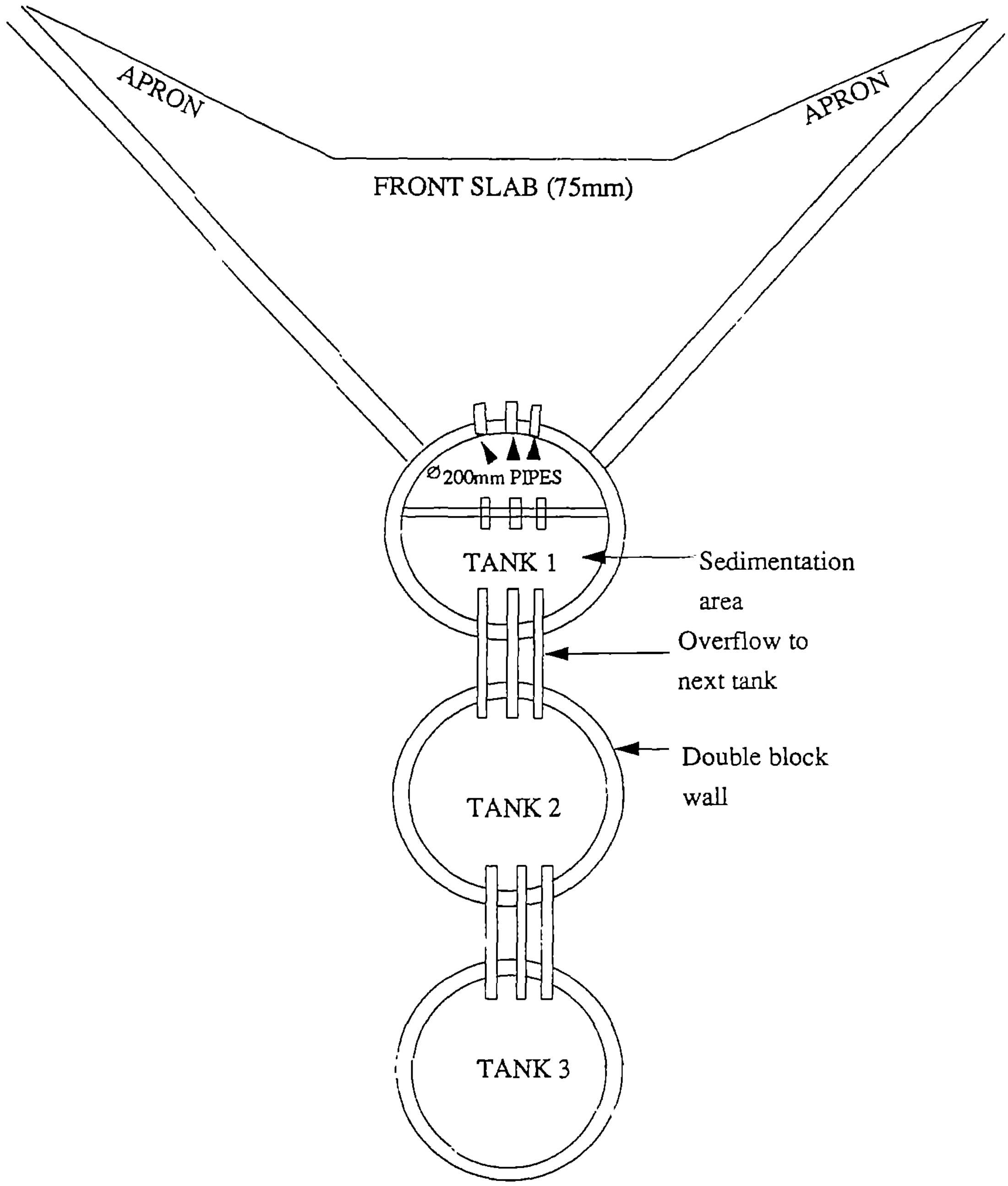


Figure 3. PLAN SHOWING APRON/SLAB/TANK1

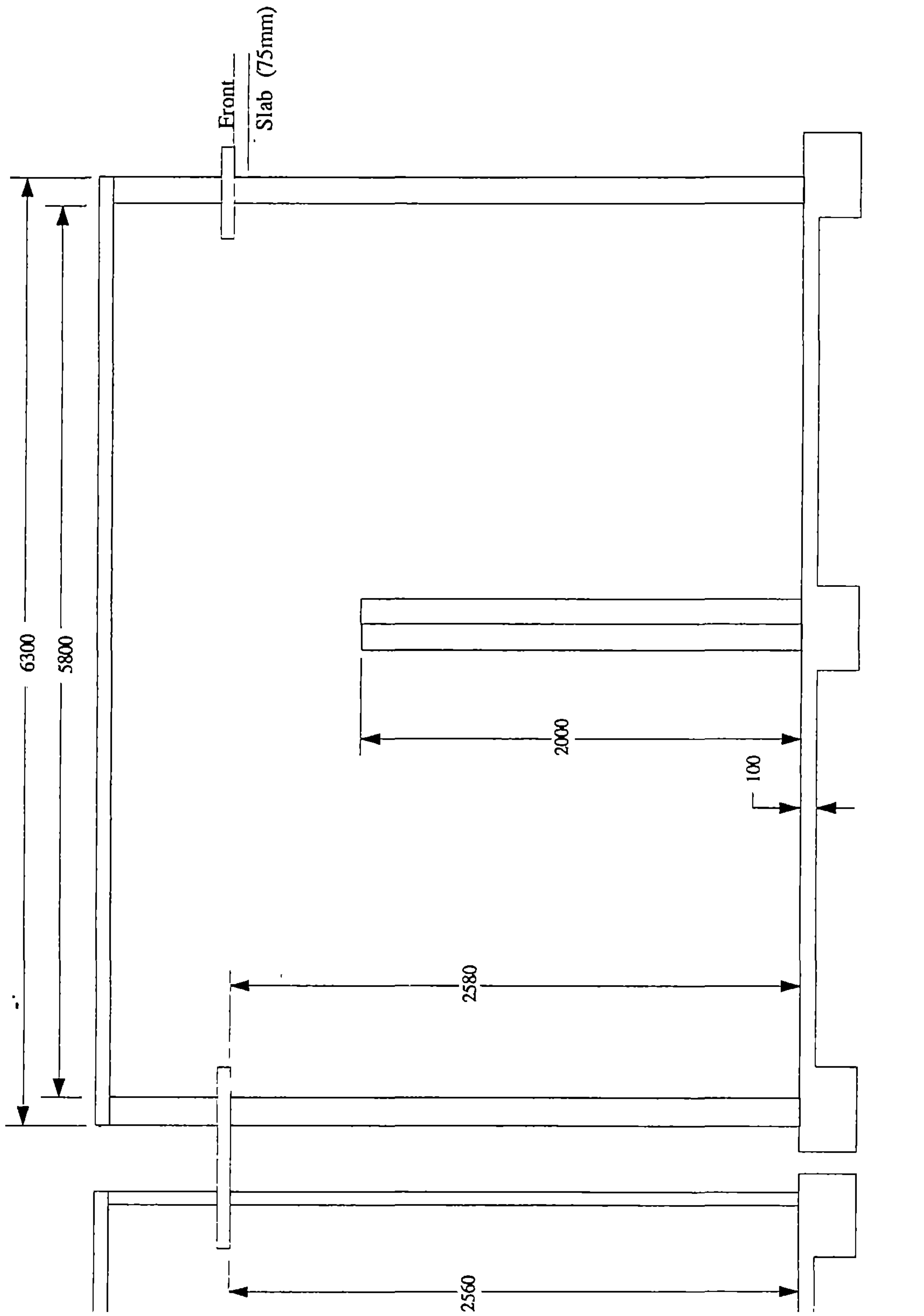
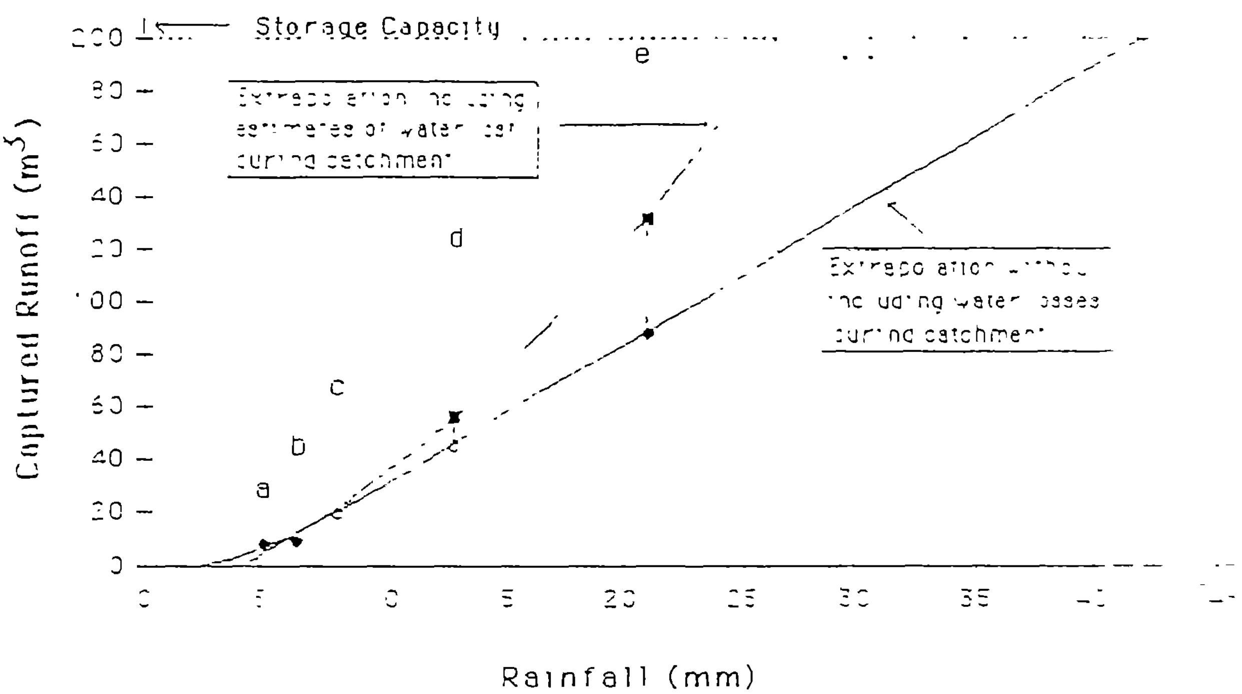


Figure 4. Cross Section, Tank No. 1

Available Data for Rainfall Collection at the Zutshwa Rainwater Catchment Project

1-2-93



a 25-01-93 5.2mm over 10 minutes

b 28-01-93 6.6mm intermittant over 6 hours

c April 1992 ~ 8mm - time data not available

d 03-05-92 ~ 13mm - time data not available.
Captured in trial excavation with evidence of overflow
Actual capture = $45m^3$, with estimated 20% spillover
possible $56m^3$ capture

e 30-01-93 21mm over about 45minutes.
Temporary apron washed away in places, water spilled over the top of the apron and water eroded underneath the apron - all due to high flows Actual capture = $88m^3$ with estimated 50% losses, possible $132m^3$ capture

Figure 5

RAINWATER CATCHMENT SYSTEMS APPLICATION AND TECHNOLOGY: TANZANIA COUNTRY REPORT

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INTRODUCTION

Tanzania lies on the East African coast between latitudes 1° Sand 12°S and longitudes 29°E and 42°E. It occupies an area of 937,062 square kilometres. Its climate is equatorial and sub-equatorial. The mean temperature varies, ranging from below 20°C to above 30°C. The annual rainfall varies greatly also, with areas receiving below 400 mm and those with over 2,000 mm. The national population is presently about 25 million people.
The practice of harvesting rainwater for various uses has been in existence for many years in Tanzania. Its impact on the country's water supply has not been significant, though, despite a few individuals and communities that have utilized rainwater on a rather large scale. Despite its considerable potential in Tanzania, rainwater harvesting has not been accorded due attention until recently when the government and external support agencies recognized it as one of the potential sources to help meet the national objective of taking clean and safe water within 400 metres of every home by the year 2002. As a result of this a number of projects in rainwater catchment have been undertaken in various parts of the country. It is hoped, therefore, that in the near future, this technology will be one of the mainstream technical options in the water supply efforts by both the government and external donors.

STATE OF THE ART OF RAINWATER CATCHMENT SYSTEMS IN TANZANIA

There is limited amount of literature on rain water catchment practices in Tanzania and only limited research has been done in this area. But, as already mentioned, this practice is known to exist in different parts of the country, although at rudimentary levels.

Rooftop catchment systems have been constructed, mostly by missionaries, at different locations around the country, for churches, hospitals, schools, community centres and for their homes. These systems have been built also by external support agencies, and so did the government of Tanzania. In the southern region of Mtwara rock catchments have been constructed along with subsurface ferrocement groundtanks. Groundtanks have, likewise, been built in the neighbouring region of Lindi.

In central Tanzania, in Dodoma region, a number of ferrocement cylindrical standing tanks have been constructed, for rainwater storage, by the Ministry of Water in cooperation with a nongovernmental organization (NGO), "Water Aid". A large number of ferrocement standing tanks for private households have been built in Kagera region in the northwestern part of the country, through a project called HESAWA (Health through Sanitation and Water), funded by the Swedish International Development Agency (SIDA). In Iringa region, in the south west of the country, rooftop catchment systems were constructed by the African Medical Research Foundation (AMREF) and an NGO called CONCERN. UNICEF has supported construction of rainwater storage tanks for health centres in Kilimanjaro region, northwestern Tanzania. There are also many other small scale rainwater catchment systems in other parts of the country like the University of Dar es Salaam, parts of Tanga, Morogoro, Coast and Shinyanga regions.

Runoff farming is also being practised, particularly in the semi-arid areas of the country. In these areas farmers do some kind of rainwater harvesting through valley farming, which involves intensive cultivation of valley floors, where runoff from slopes is concentrated. (Hatibu, 1993). In parts of Tabora, Shinyanga and Dodoma regions farmers have developed a system of rainwater harvesting which involves diversion of water from ephemeral streams to valley fields subdivided by bunds of 25-100 cm. height, to form cultivated reservoirs (paddies). The collected runoff is stored in these reservoirs for use by transplanted rice.

ONGOING PROJECTS

There are a number of projects for rainwater catchment that are currently being executed and also those that are planned for implementation. Planned projects are in response to one of the strategies for the implementation of the national water policy, which encourages the promotion of rainwater harvesting technology through the use of applied research and extension services. A research project was jointly undertaken by the Water Research Division of Tanzania's Ministry of Water, Energy and Minerals and the Centre for Housing Studies of the Ardhi Institute. The first phase of this project, whose primary objective was to review the current knowledge, practices and attitudes of people with regard to rainwater harvesting techniques/systems with the aim of improving and popularising such methods, has already been completed. The second phase will involve construction of ten pilot systems for rainwater harvesting, in each of the two research areas of the first phase. This is planned to take off sometime this year when funds are secured from the financiers of the project, namely, the International Development Research Centre (IDRC) of Canada.

As has already been mentioned rainwater catchment systems are being constructed in northwestern Tanzania through the HESAWA project. This programme has shown signs of success, as a number of households are already benefitting from the systems. A research project called The Soil-Water Management in semi-arid Tanzania is being executed by the Sokoine University of Agriculture (SUA). This project, launched in 1991, is sponsored by IDRC of Canada and covers four villages in Hombolo, Dodoma region. It aims to develop, test and introduce appropriate and socially acceptable management interventions for improving soil-water availability and use by plants in the semi-arid zones of Tanzania. One of the research objectives is rainwater harvesting, whereby management of rain runoff for crop production is being studied.

FUTURE PLANS AND DEVELOPMENTS

Future plans, as far as rainwater harvesting is concerned, are guided by the strategies for implementation of the National Water Policy which, firstly, is directed to promoting the rainwater harvesting technology through the use of applied research and extension services. Secondly, the strategy is to coordinate efforts between the Ministry responsible for water and other institutions and NGO's in developing the rainwater harvesting systems.

Urban institutions and households will be encouraged to have their own emergency reservoirs and rainwater harvesting systems within their premises. Rooftop catchments pilot systems will be constructed under the second phase of the project mentioned earlier. This exercise will be initiated in Dar es Salaam and Shinyanga regions but will be spread to other regions later. With regard to runoff farming systems a research project is being planned by the Department of Agricultural Engineering and Land Use Planning of the Sokoine University of Agriculture. This four-year project will evaluate and promote rainwater harvesting techniques in semi-arid areas of Tanzania in order to improve farming in those areas. It will involve field trials on three sites, two in the semi-arid zones of Same and Mwanga districts of the Kilimanjaro region and one near the Sokoine University of Agriculture in the semi-arid zones of Morogoro region. A micro-computer based agro-hydrological model of the rainwater harvesting process will be developed to facilitate transfer of the technology to other areas. This will be done in collaboration with researchers from the University of Newcastle upon Tyne-England. Funding for this project is expected to come from IDRC-Canada and, overseas development authority (CDA) ODA - UK.

POSSIBLE LESSONS FOR BOTSWANA FROM THE TANZANIA EXPERIENCE

In Tanzania one of the reasons that has contributed to the low level of success in providing water to the people has been due to dependency on costly and sophisticated technologies involved in the water supply systems. In such technologies community participation has been seriously lacking. Operation and maintenance has also been poor, rendering the systems to run inefficiently and for a short life. Rainwater harvesting systems provide a simple technology, appropriate for a poor, developing country like Tanzania or Botswana. The activities involved are in line with the beneficiary - participatory approach that is lacking in other conventional water supply projects. It seems, therefore that Botswana can draw a lot of benefits by promoting, on a larger scale, rainwater catchment systems in both rural and urban areas.

It so happens that the inhabitants of some areas, especially the rural areas, are not quite aware of the benefits they stand to gain by adapting the rainwater catchment technology. It would therefore be useful to construct model/pilot systems in the midst of villages, which will help to educate the people and hence popularise the technology.

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Figure 1. The Regions of Tanzania.

PLANNING AND RAINWATER MANAGEMENT

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INTRODUCTION

Rainwater management is a comprehensive planning approach founded on the principle of altering the natural flow of rainwater within a system in order to (1) minimize the negative impacts of excess rainwater and (2) maximize the utility of the rainwater resource. Rainwater management systems incorporate a variety of tools and techniques for the implementation of a particular strategy, and are appropriate in urban and regional contexts.

In contrast to rainwater management, rainwater catchment is a technique that emphasizes the capture and storage of rainwater for use at a later time. Rainwater catchment techniques are applicable under a variety of situations, particularly in isolated, rural and agricultural contexts in semi-arid climates. Dams are built as a source of water for cattle and irrigation while small-scale catchment/storage systems provide water at the cattle post. The emphasis on rainwater catchment is understandable in this situation, since the primary concern is the provision of water to a specific site.

From a planners perspective, rainwater catchment is most interesting as a component of a coordinated rainwater management strategy. Rather than focusing on the technical aspects of catchment and storage at an individual site, the planner is concerned with the ways in which various conservation techniques are integrated into a comprehensive plan for managing and controlling rainwater.

This paper considers the potential for the implementation of integrated rainwater management strategies for large, complex, urban/urbanizing areas. The discussion addresses the need for rainwater management strategies and the composition of a typical strategy, concluding with the presentation of a sample rainwater strategy for the Mmamokhasi Catchment Area in Kanye.

THE NEED FOR A STORMWATER MANAGEMENT STRATEGY

Man has long grappled with the problems of water supply and use, sewage disposal, storm drainage and flood prevention, but in most cases the models presented consist of solutions to a single aspect. The tendency is to respond to each crisis with narrow solutions which address the immediate needs but ignore the need for a coordinated strategy.

The prevention of floods and the supply and conservation of water can only be accomplished by the cumulative effect of many individual actions. But the impact of each will be insignificant, and might even be counterproductive, if not part of a comprehensive plan that takes into account the hydrologic system of the village, town or region.

The key to devising efficient, effective and economical rainwater solutions is to learn and respect the ways that water moves through the village or town. Young developing countries such as Botswana have the opportunity to avoid the pitfalls of developed countries by considering a comprehensive approach to rainwater management modeled after the natural drainage system. This is a less costly, more efficient and appropriate approach than traditional ones which emphasize the narrow implementation of hard, technical solutions.

Despite our desperate need for water, we continue to dirty and misuse it. Every new rain storm sweeps dirt, debris and faeces from the streets and open spaces into the streams and dams. The combined effect of rapid urbanisation, increased amounts of impervious materials, inefficient and sprawling settlement patterns and their impact to the natural drainage network, and the design (or lack thereof) of drainage and flood control determines the rainwater management strategy to be taken.

PREPARATION OF A RAINWATER MANAGEMENT STRATEGY

The successful management of water requires comprehensive efforts, individual actions and a perception that storm drainage, flood control, water supply, water conservation and waste disposal are all facets of a much broader system. The framework should be constructed so that the consequences of governmental efforts and the cumulative effect of individual actions can be appreciated.

Rainwater management strategies vary according to the specific conditions of each area. The individual components or projects are less important than how they are coordinated into the comprehensive system. For example, one of the most serious concerns related to rainwater in most towns and village in Botswana is how to minimize the negative effect of soil erosion caused by runoff. The implementation of a comprehensive rainwater management strategy allows us to identify areas where erosion is likely to occur, and thereby propose specific actions for minimizing the impact of erosion.

The preparation of a rainwater management strategy requires a thorough understanding of the spatial and physical characteristics which influence stormwater behaviour. Typical considerations include, but are not limited to, the following:

- existing and proposed land use
- physiography
- topography and landform
- slope
- geology and hydrogeology
- soils (with emphasis on erosion and percolation characteristics)
- climate (with emphasis on rainfall and evaporation characteristics)
- land cover (with emphasis on type and permeability)
- susceptibility to erosion
- pollution characteristics

Once the physical conditions are known, the specific techniques required to toward realize the management goals must be considered. Under typical circumstances most techniques fall under one of the following general categories:

1) **Rainwater Catchment Systems:**
The purpose of rainwater catchment systems is to store water for use or delayed distribution at a later time. They range from small-scale systems that catch rainwater close to the source of impact (roof and ground surface catchment with storage in a tank or cistern) to large-scale dams which store assembled stormwater at the bottom of a catchment area. In both cases care must be taken to minimize pollution when

the water is for human consumption.

2) **"Soft" Runoff Control Systems:**
A soft runoff control system can be used to slow the flow of stormwater, to reduce erosion and to detain or retain the rainwater so it can percolate into the soil. Measures for slowing the flow of water include the construction of check dams in stream beds and the modification of the stream channel to increase the length of flow (constructed serpentine method). Detention/retention measures include re-channelling the flow of water onto areas where percolation is likely (planted areas are particularly good) and the construction of dry ponds and expanded flood zones along stream channels. Related and complementary measures include (1) the planting of trees and vegetation to increase the soil's capacity to absorb excess rainwater, a difficult measure to implement in villages such as Kanye since goats, donkeys and cattle tend to eat most species before they reach maturity and (2) the retention of existing vegetation, particularly on steep slopes where erosion is most likely to occur.

"Hard" Runoff Control Systems:
The purpose is to redirect the flow of stormwater toward lower catchment areas as quickly and safely as possible. Also referred to as traditional"or engineered systems, these are particularly well-suited to roadside applications on steep slopes. Hard solutions are generally more costly than soft ones, and they short-circuit the implementation of methods which encourage the percolation of water into soil. This is an important shortcoming, since soil percolation acts as a filtering method, helps prevent floods, protects water quality and replenishes the water supply.

A SAMPLE RAINWATER STRTEGY FOR MMAMOKHASI CATHMENT AREA, KANYE

To illustrate how a stormwater management strategy can be implemented for a large Tswana village, the Mmamokhasi Catchment Area in Kanye was selected as a sample case. Based on a detailed analysis of the spatial and physical conditions summarized in the next section, four types of management zones were identified (see Table 1 for the summarized characteristics of each zone). Once the characteristics of each zone were analyzed, a general strategy was proposed followed by specific action for implementation. The final step in this process would be a detailed investigation of potential sites followed by design and engineering.

Summary of Significant Physical Conditions in Kanye

Kanye is a large village located in the southeastern region of Botswana. Growth has been rapid since independence, the population increasing from 10,664 in 1971 to 31,341 in 1991. Deficient planning has resulted in a sprawling, inefficient and often uncoordinated village structure that has grown outward from the original settlement on Ntsweng Hill to cover an area of 37 square kilometres. Approximately 20% of this figure is composed of steep hills, streams and low-lying flood plains that have been declared non-development zones.

Like most other villages in Botswana, Kanye lacks even a rudimentary rainwater management system. Rainwater management techniques have been implemented on an ad hoc basis, with the emphasis on the capture of rainwater at three dam sites and the limited application of roadside drains along the main roads. Kanye is situated in the Limpopo drainage basin. Waterways are limited to ephemeral streams and dongas. There are three closed catchment areas where water collects at Mmakgodumo, Kanye and Mmamokhasi Dams. All other streams flow unhindered toward the Limpopo River and South Africa.
Mmamokhasi Dam is the largest of the three dams while the Mmamokhasi Catchment Area is the second largest catchment area. Five major stream systems

terminate at the dam.

Water is supplied by a large, high yielding aquifer located on the southwestern edge of the village. It has been estimated capable of supplying Kanye with water beyond 2010. Ground water recharge rates are estimated to be approximately five-percent of the mean annual rainfall (27.5) millimetres. Since the majority of aquifers are likely to be fractured, only about 35% of the recharge (approximately 10 millimetres) is likely to be recovered. It is unclear whether steps to increase the absorption of excess rainwater in developed portions of the village would improve the groundwater supply, since the extent of the aquifer recharge zone in not known.

Soils are characterized by sands and loams with scattered areas of exposed bedrock.

Humidity is low, which is due in part to the high rate of evaporation. Approximately 480 millimetres of rain fall during an average summer as compared to 40 millimetres during the winter, with severe periods of drought occurring periodically. The spatial distribution and duration of rainstorms is irregular, although rain often falls during intervals of two to four days with long dry spells between. There is usually one day each year when more than 50 millimetres of rain is reported, and one day every ten years when more than 100 millimetres of rain falls. Cases of extreme rainfall are typified by a torrential downpour of 30 to 40 millimetres per hour over a four to eight hour period. Such storms usually result in severe erosion, the blockage of drainage channels and the accumulation of thick layers of soil on roads and other paved surfaces.

Within the developed portions of the village, indigenous vegetation has been more or less removed, accelerating runoff and reducing the soil's capacity to absorb water. Erosion is endemic throughout the village, the result of rapid growth and uncontrolled urbanisation in the lower catchment areas. Nearly all hillside roadways are poor quality dirt tracks built without proper drainage. Some of these roads have been placed directly into the slope, furthering the erosion process.

The lack of an adequate sanitary waste disposal system threatens Kanye's precious ground water reserve; only one third of the households have toilet facilities.

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TABLE 1

GENERAL CHARACTERISTICS OF PROPOSED RAINWATER MANAGEMENT ZONES, MMAMOKHASI DRAINAGE BASIN, KANYE

	CHARACTERISTICS
1	**EXISTING BUILT-UP AREAS:**
-	Flat to steep slopes.
-	Soils predominated by sands and loams, with shallow soils in scattered rocky areas.
-	Severe gully erosion along small streams, drainage channels and roadways.
-	General loss of all indigenous vegetation, extensive areas of exposed soils.
2	**FUTURE DEVELOPMENT AREAS:**
-	Flat to moderate slopes.
-	Soils predominated by sands and loams.
-	Limited erosion along small streams.
-	Indigenous trees and bushes more or less preserved, grass layer more or less removed.
3	**HILLS:**
-	Generally steep slopes.
-	Shallow soils and scattered areas of exposed bedrock.
-	Limited gully erosion along small streams and paths.
-	Indigenous trees and bushes more or less preserved, insignificant grass layer.
4	**LOWER CATCHMENT AREAS:**
-	Ephemeral streams and associated floodplains.
-	Flat to moderate slopes.
-	Soils predominated by sandy loams.
-	Areas of extensive erosion along water courses caused by down-cutting (gully deepening and widening) and head-cutting (extension of the channel into unsullied headwaters areas resulting in an enlarged network of developing tributaries).
-	General loss of indigenous vegetation, especially along eroded streams and flood plains, heavily reduced grass layer.

TABLE 2

RAINWATER MANAGEMENT STRATEGIES AND RECOMMENDED ACTIONS FOR MMAMOKHASI DRAINAGE BASIN, KANYE

1	**EXISTING BUILT-UP AREAS:** STRATEGY: To reduce reliance on the village water supply, to prevent erosion and reduce the flow of excess runoff. ACTIONS: Extensive installation of small-scale rainwater catchment and storage techniques (rooftop/ground surface + cistern) on individual plots. -Installation of small to medium scale detention/retention techniques to slow the flow of runoff and increase the capacity of soil to absorb rainwater. Control and direct the flow of runoff toward the lowercatchment areas through the implementation of a roadside drainage system.
2	**FUTURE DEVELOPMENT AREAS:** STRATEGY: To prevent erosion and reduce the flow of excess runoff ACTIONS: - Same as above, the implementation of detention/retention schemes and drainage system to occur in conjunction with development.
3	**HILLS (CONSERVATION ZONE):** STRATEGY: To prevent erosion and encourage the percolation of rainwater into the soil ACTIONS: - Conserve and protect existing indigenous vegetation - Implement a permanent moratorium on future development
4	**LOWER CATCHMENT AREAS (CONSERVATION ZONE):** STRATEGY: To prevent erosion and reduce the flow of excess runoff ACTIONS: - Conserve and protect existing indigenous vegetation - Fence-off severely eroded areas to encourage a natural healing process. - Slow the flow of runoff, prevent the transport of eroded soil downstream and increase the capacity of soil to absorb rainwater through the use of medium to large scale detention/retention techniques (see Figures 1-3)

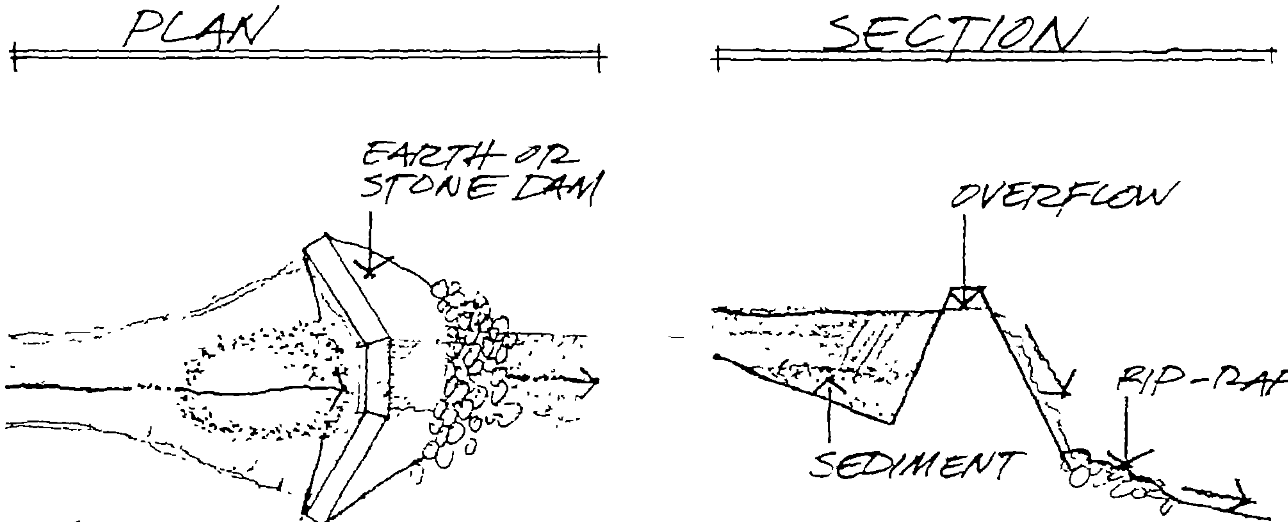

Figure 1 Example of a placing a check dam within a stream bed in order to to prevent erosion and slow the flow of water.

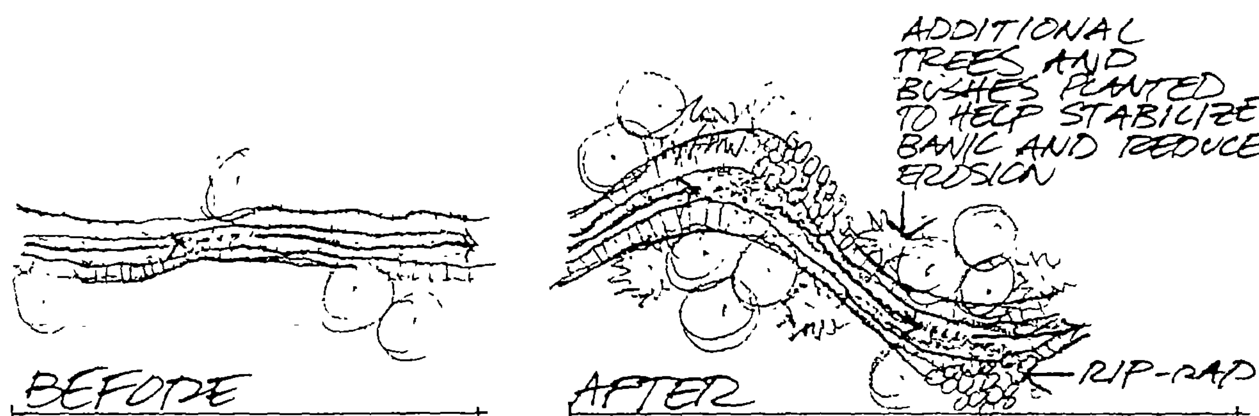

Figure 2 Example of modifying the meander of a stream in order to prevent erosion and slow the flow of runoff.

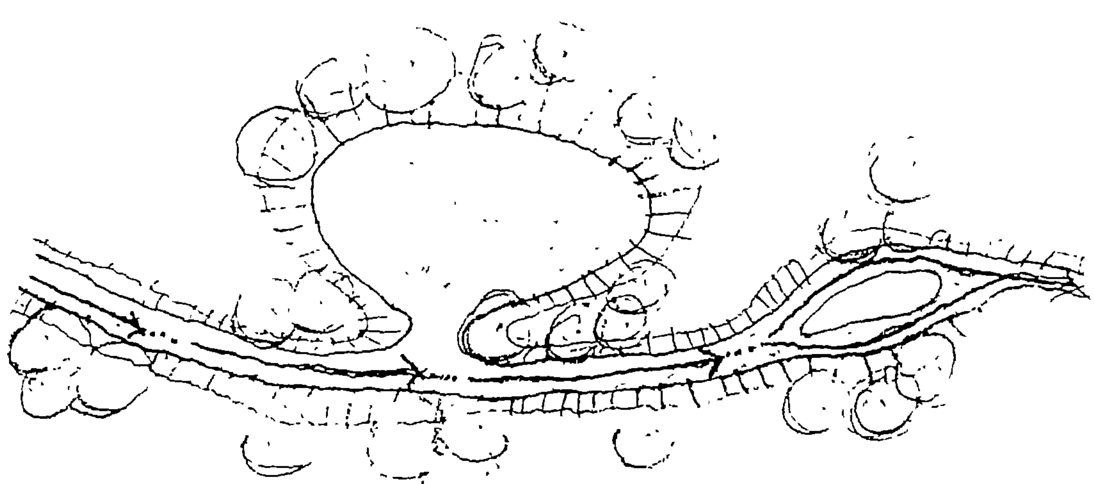

Figure 3 Example of modifying a stream bed to allow the pooling of water following a rainstorm (dry pond).

SAND AND GEOTEXTILES IN RAIN HARVESTING

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INTRODUCTION

Drinking water is vital to human life, but it is becoming more scarce every day. Pollution and soaring treatment costs plus a continously increasing population, make it necessary that new ideas are generated for simpler and safer ways to obtain the precious liquid.

This paper analyzes the use of a sand filter and of geotextile membranes in gutters where water is collected for drinking and domestic purposes and the benefits that this can provide to rural users. Rain water is almost free from salts and any heavy contaminant, but common problems are turbidity levels, debris, insects, etc.

As the collecting surfaces are exposed to atmospheric dust carried by winds or breezes; and if the period between rains is somewhat extended the turbidity can be so high that bacterial contamination can be gross and dangerous. As a side effect people might reject the water for aesthetic reasons and use water which is less turbid but with unknown higher contamination levels.

In order to reduce this "turbidity problem" two approaches have been tried in numerous previous tests. The first is to use some kind of "first portion diverter". There are different types of diverters, most of which do not comply fully with the intended purpose. Although better than nothing, unfortunately in the majority of cases, they either do not function properly or they divert either too much (unnecessary waste of water) or too little, which still allows the passage of considerable amounts of dust particles.

A second option is to have a filter which intercepts the water previous to storage. In many cases a typical slow sand filter made out of a 200 litres drum is used to good effect. This is a good option and the only drawback is in keeping the filter clean through some kind of maintenance schedule and to disinfect the water as these filters can be a source of aerobic bacteria growth.

The third option is to have a filter at the collecting surface. The surface itself can be so designed as to present a filter, either in all its area or in the last portion of the harvesting element. Practicalities like the difficulties in cleaning a normally thin layer of sand, have not yet yielded a popular system, and thus this option is but scarcely utilized in the prevention of high turbidity.

As most of the small surfaces used for collection are house roofs, the final option is to place some kind of filter in the gutters or downpipes. A filtering element in the downpipe is not advisable, as it may become a bottle neck which could cause the water to spill over the edge of the gutter if it is an efficient filter. On the other hand, if inefficient because of a too open porous structure, turbidity will be enhanced. Therefore, the correct way to prevent turbidity in the collected water is by means of a filter in the gutter itself. The investigation of a filtering aid placed along a gutter is now considered. Two systems were tested.

The first is a filter made out of sand and the second a geotextile layer. Both were placed in the collecting gutters to two different roofs.

SYSTEM 1 - GUTTER WITH SAND FILTER

Description of system

Two identical roofs, side by side, with the same elements, slopes, orientation and exposure to wind and dust; but having separate collecting gutters and downpipe outlets.

One of the roofs acted as a "standard" and the other as a test element.

Roof type: Conventional corrugated Zn coated iron plates.

Roof area: 4.19 m^2
Gutter type: Material same as roof.
Rectangular shape.
Height: 0.11 m; Base: 0.10 m

Ratio roof area/gutter length:
2.15 m^2 of roof/m of gutter.

Filter type in gutter (TESTED SYSTEM):

Sand filter with a supporting layer of geotextile fabric, occupying the whole length of the gutter.

Sand characteristics:

First layer of 2 cm of sand
Sand: 100% 2-4 mm

Second layer of 2 cm of sand
Sand: passing through 700 micron mesh.

The sand was thoroughly washed with running water and then set in the gutter while wet.

SYSTEM 2: GUTTER WITH GEOTEXTILE FABRIC

Description of system.

Two identical roofs, side by side, with the same elements, slopes, orientation and exposure to wind and dust; but having separate collecting gutters and downpipe outlets. One of the roofs acted as a "standard" and the other as test element.

Roof type:
Conventional corrugated Zn coated iron plates.

Roof area:
4.19 m^2

Gutter type:
Material PVC
Semi circular in shape
Height: 0.08 m; Diameter: 0.13 m.

Ratio roof area/gutter length:
2.15 m^2 of roof/m of gutter

Filter type in gutter (TESTED SYSTEM):

A geotextile fabric covering the whole internal surface of the gutter. Some loose small stones were placed at the bottom of the gutter in order to prevent movements of the fabric.

Geotextile characteristics:

Type:	Polyester geomembrane
Mass/unit of surface:	210 g/m^2
Thickness:	2.3 mm (under 0.5 kPa)
Porosity:	92% (under 0.5 kPa)
Diameter of fibre:	27 microns
Normal permeability:	0.003 m/s (under 2 kPa)
Normal through flow:	158 _/s (under 100 mm water head)
Tranverse permeability:	0.0006 m/s (under 2 kPa)
Melting point:	260 °C

MODUS OPERANDI

Before beginning the series of tests all the roofs, surfaces were properly cleaned. Each downpipe outlet fed into a plastic container.

Immediately after rainfall the collected water was visually observed and analyzed for turbidity and total aerobic bacteria (Total plate count).

After the initial cleaning the roofs were not disturbed again. The tests began in January 1992 and ended in March 1992.

RESULTS

SYSTEM 1:

Turbidity levels

STANDARD	TESTED SYSTEM
8.0	2.8
1.0	2.4
13.0	13.0
6.9	5.2
3.5	4.8
5.4	4.2

Up to this point the sand was still dirty. The turbidity ratio (Turbidity of Standard/Turbidity of Tested system) changed from this catchment onwards as the rains washed out the very fine insoluble grains that the sand was still holding

The following table is considered to present the proper or clean or "in regime" data.

STANDARD	TESTED SYSTEM
8.9	3.9
6.0	2.1
8.4	1.9
17.0	10.0
8.7	6.8
2.7	1.4
8.8	1.9
5.4	3.2
3.3	2.5
2.1	1.7
2.9	1.7
7.8	5.4

STANDARD CATCHMENT AVERAGE TURBIDITY = 6.8

TESTED SYSTEM AVERAGE TURBIDITY = 3.5

% TURBIDITY REDUCTION (AVG) = 49%

Total plate count bacteria

STANDARD	TESTED SYSTEM
27	4 320
57 300	65 800
106	15 500
400	2 000
2 033	8 355
1 500	2 700
7 530	18 400
620	51 000

STANDARD CATCHMENT AVERAGE COUNT = 8 689

TESTED SYSTEM AVERAGE COUNT = 21 000

% INCREASE IN BACTERIAL LEVELS = 142%

SYSTEM 2

Turbidity levels

STANDARD	TESTED SYSTEM
16.0	4.4
18.0	4.0
10.0	2.5
2.1	1.0
15.0	2.0
7.0	3.9
2.7	1.9
4.7	2.2
6.7	3.7
5.5	2.7
22.0	6.0
9.1	1.8
18.0	9.0
7.4	5.8
3.0	2.0
7.6	3.2
5.2	2.6
2.7	1.9
2.8	1.6
2.1	1.2
5.6	3.7

STANDARD CATCHMENT AVERAGE TURBIDITY = 8.2

TESTED SYSTEM AVERAGE TURBIDITY = 3.2

% TURBIDITY REDUCTION = 61%

Total plate count bacteria

STANDARD	TESTED SYSTEM
9 700	24 100
9 870	200 000
723	22 600
36000	105 000
80500	82 600
106	3 535
323	803
200	4 260
192	585
36900	19 800
8500	6 000

STANDARD CATCHMENT AVERAGE COUNT = 18 160

TESTED SYSTEM AVERAGE COUNT = 27 243

% INCREASE IN BACTERIAL LEVELS = 50%

ANALYSIS OF THE RESULTS

In order to obtain a definite idea of the benefits and drawbacks of the options

tested, different characteristics should be considered. These are:
* ease of construction
* cost/life expectancy
* performance

Ease of construction

The filter type gutter system although simple to make, takes time and there is a need to have the appropriate sieves. Carefully sieving and more careful sand washing is needed to have a filter in proper condition. As it can be seen from the turbidity data, the first harvestings were very high in turbidity because of insufficient washing. This may take a great deal of water, which in fact is what is lacking in the areas where these systems are to be used.

The option of just placing a geotextile membrane in the gutter is on the contrary very simple and quick. It can be done in a few minutes and no special structure or activity is required to do this job. The membrane can be affixed to the gutter by any means: clamping, tying, gluing, etc.

Cost/life expectancy

In both cases the cost is minimal. The sand should be locally available, and the geotextile is a very inexpensive material. A gutter for a rural house of 60 m^2 is approximately 16 metres long. If a gutter has an internal perimeter of 0.3 m (0.1 m height and 0.1 m width) the area of geotextile need to cover all the interior surface of the gutter would be
16 m x 0.3 m = approx. 5 m^2.

The cost of these membranes is in the region of R.4-/m^2. So the total cost for a Gutter with geotextile system is approximately R20.- (approx. U$D 7-; 1992). The membrane is made of polyesters and these materials when in direct contact with UV rays from the sun loose their strength and become brittle after one year of use. However, as there is no need for the membrane to be moved once it has been affixed in the gutter, its life expectancy increases to three or four years. The only maintenance required is for it to be cleaned every season as it collects a multitude of insects, debris, etc. But this will not reduce the life expectancy already predicted.

Performance

The most important parameter to consider is turbidity. As stated, this is the most troublesome characteristic in harvesting rainwater. So, if the aim was to obtain rain water free of turbidity, both systems performed well. Nevertheless the ratio

Ease of construction/turbidity reduction is far better for the system gutter + geotextile than the one for the system sand filter in gutter.

As it was mentioned, the simple use of a geotextile is easier and simpler to install and the turbidity reduction is also far more effective: 61% reduction achieved by the geotextile membrane compared with a 49% reduction for the sand filter. A very important factor is that in this turbidity reduction an added advantage is the collection of all the insects, stems, leaves, etc. which are prevented from entering the collected water. In the turbidity measurements, these elements do not play any part, but they are always present when there is no filtering element at all. And this means a great improvement over the plain catchment without using any filtering aid.

A drawback is the rise in the aerobic bacterial level which is higher in the filtered water than in the standard unprotected catchment. This can be expected, as the geotextile material can be seen as a nest for the growing of bacteria. In any case it is considered important and advisable to disinfect the water by either boiling it or by adding a chlorine releasing chemical.

GEOTEXTILE MEMBRANES - BACKGROUND

Geotextiles, as known and used today, were first used in connection with erosion applications and were intended to be an alternative for granular soil filters. Thus the original, and still sometimes used, term for geotextiles was "filter fabrics".

Geotextiles form the largest group of geosynthetics and their rise in growth during the past 10 years has been nothing short of awesome. They are indeed textiles in a traditional sense, but consist of synthetic fibres rather than natural ones like cotton, wool and silk. Thus biodegradation is not a problem. The fibres are made into a flexible, porous fabric by standard weaving machinery or are matched together in a random, or nonwoven manner. Some are also knit. The major point is that they are porous to water flow across their manufactured plane and also within the plane.

The fibres used in geotextiles are made from the following materials, listed in order of decreasing use:

* polypropylene
* polyester
* polyamide (Nylon)
* polyethylene
* others polymers and glass

The basic polymers are made into fibres by melting them and forcing them through a spinneret, similar in principle to a bathroom showerhead. The resulting fibre filaments are then hardened or solidified by one of three methods: wet, dry, or melt.

In the particular case of this study, the geotextile used in the different tests was the **U-24 Bidim geotextile** manufactured by Kaymac Industries in South Africa and marketed by Kaytech (ex Noel Hunt Pty, Ltd.) A very important characteristic is that among the geotextiles this is one of the most resistant to UV light and also has a very good wettability (an advantage for filtration as used in the tests).

In the filtering process it is important to note that these materials provide an efficient filtration which consists of a compromise between allowing liquid to pass unhindered through the geotextile and its capacity to retain all sizes of dirt particles. The material has a very high permeability due to its high porosity and has a pore dimensions compatible with common particles found in this type of gathering. Its durability is high and the cost is low. The geotextiles are available in any town within SA, and fortunately, due to its many uses, it is beginning to be found in almost every hardware shop.

CONCLUSION

Two ideas have been tested in order to produce a system that could yield drinking water from rain harvesting without presenting the most typical problem: high turbidity levels.

A sand filtering gutter system and a geotextile fabric filter gutter system have been designed and tested.

The construction needs and the results from the sand filter, although positive, in the opinion of the researcher are not good enough warrant selection.

The second system, the gutter covered internally with a geotextile fabric is far more successful and presents an innovative solution to the stated problem of high turbidities.

Average reduction of 61% in Turbidity Units, plus the bonus of eliminating insects, stems, leaves, and debris, are striking enough and achieve the proposed goal.

The only drawback seems to be the incapacity to eliminate bacteria and thus the collected water should be disinfected before it is used.

But above all, the system is simple to install, very easy to use and maintain, with a good life expectancy and minimal cost.

This technology, developed using geotextiles, can be considered as a highly promising and a typical example of what should be Appropriate Technology solutions.

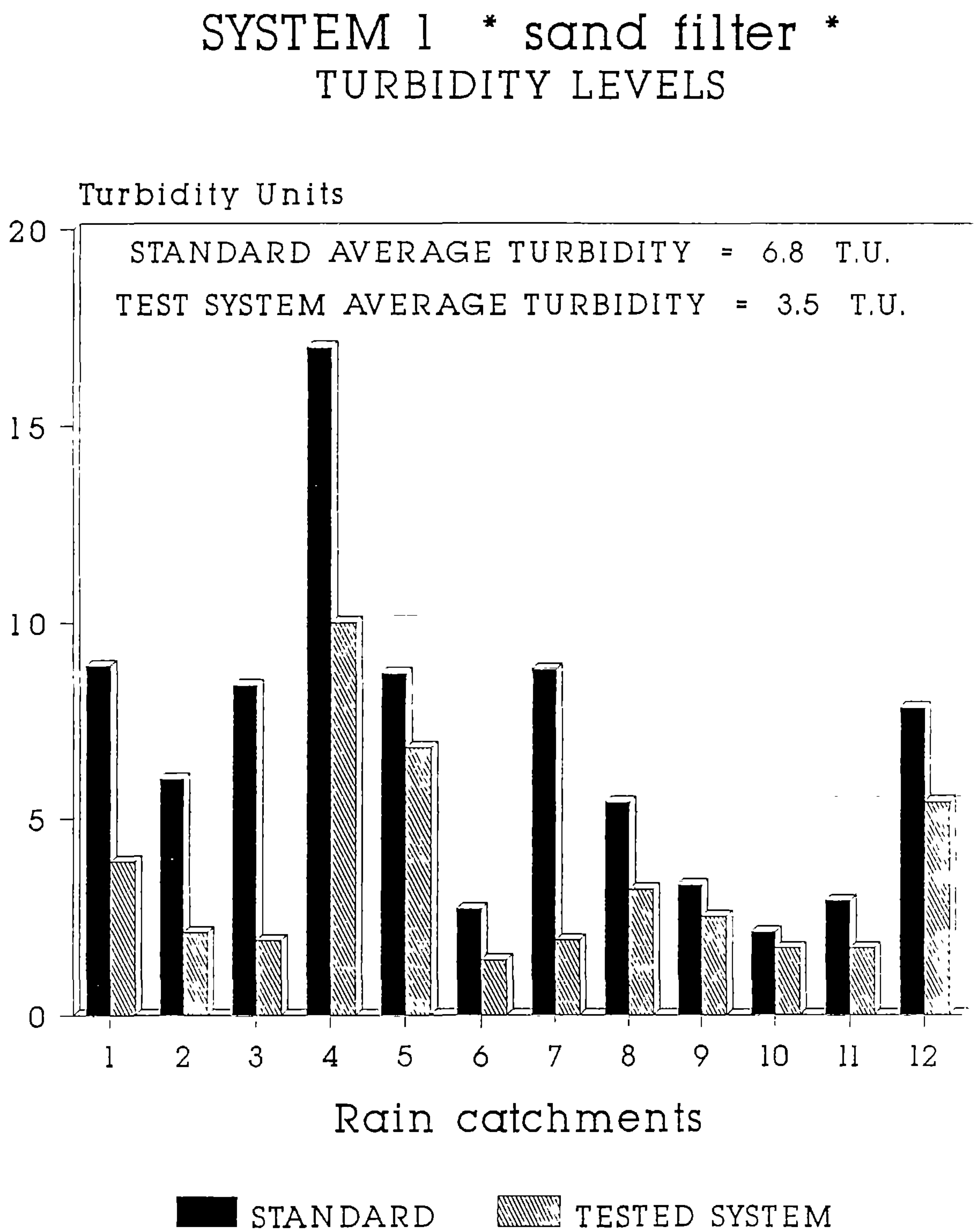

SYSTEM 1 * sand filter *
TURBIDITY LEVELS
Turbidity Units
STANDARD AVERAGE TURBIDITY = 6.8 T.U.
TEST SYSTEM AVERAGE TURBIDITY = 3.5 T.U.
0
5
10
15
20
1
2
3
4
5
6
7
8
9
10
11
12
Rain catchments
STANDARD
TESTED SYSTEM

Figure 1

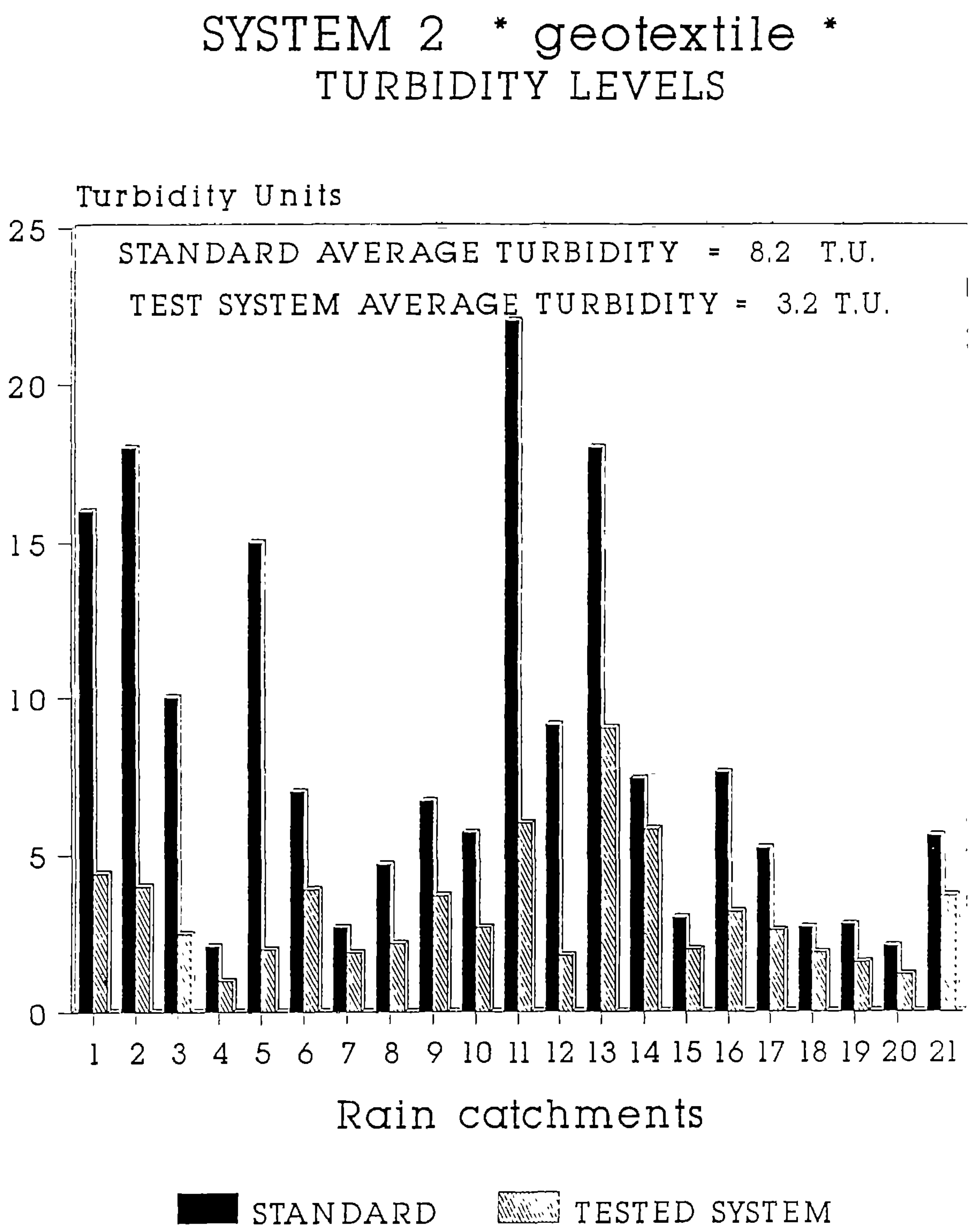
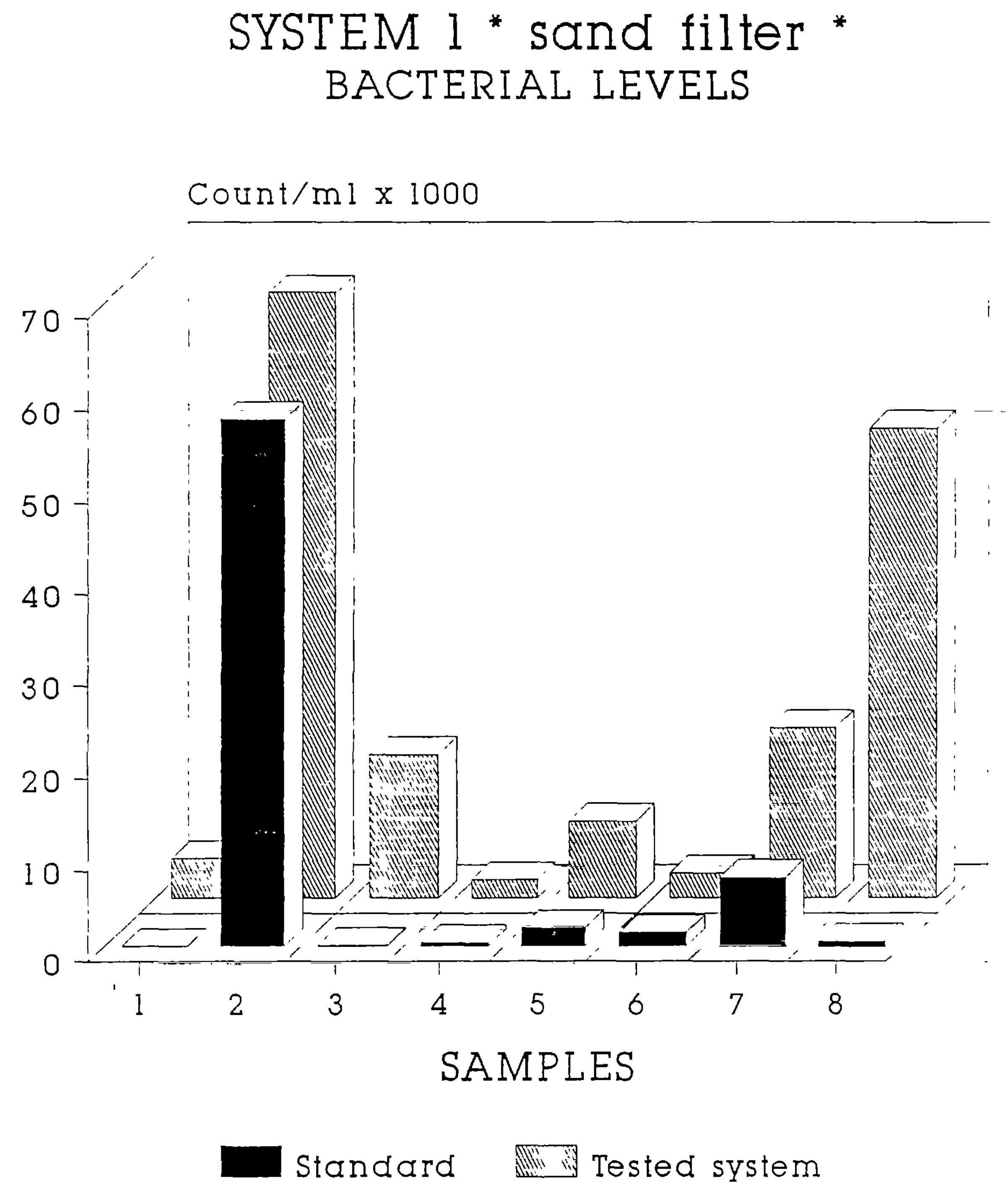
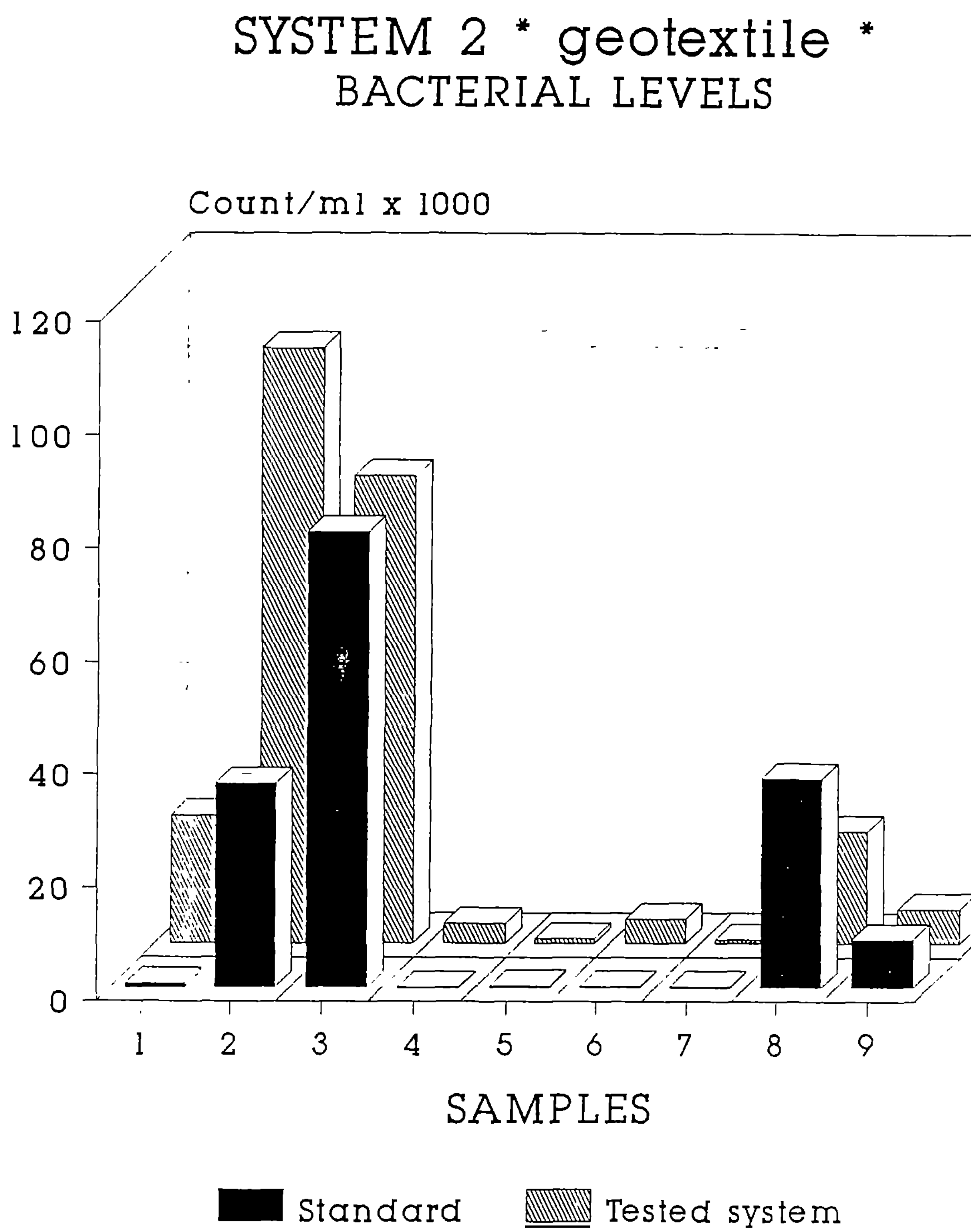

SYSTEM 2 * geotextile *
TURBIDITY LEVELS
Turbidity Units
STANDARD AVERAGE TURBIDITY = 8.2 T.U.
TEST SYSTEM AVERAGE TURBIDITY = 3.2 T.U.
25
20
15
10
5
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
Rain catchments
STANDARD
TESTED SYSTEM

Figure 2



STANDARD AVERAGE COUNT = 8 700/ml
TESTED SYST. AVERAGE COUNT = 21 000/ml

Figure 3



STANDARD AVERAGE COUNT = 18 160/ml
TESTED SYST. AVERAGE COUNT = 27 243/ml

Figure 4

HOW TO PLAN AND IMPLEMENT A WATER TANK PROGRAMME Capable of producing 400 large tanks annually

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INTRODUCTION

This paper explains how to plan and implement a water tank programme capable of producing 400 water tanks annually. Each tank can have a volume of either 46,000 litres or 80,000 litres. Most of the paper presented are taken from a UNICEF/DANIDA programme in Kenya which has built 800 tanks (46,000 litre volume) and 800 double VIP-latrines over the last two years.

A potential donor might think that the set-up of the programme is too elaborated but experience *has shown* that there appears to be *no* short-cuts if the target is a production of about 400 *tanks* annually. However, a smaller water tank programme than presented here might be an advantage if a smaller production output with a higher cost per cubic metre tank volume are acceptable.

In this paper the programme set-up consists of 4 procedures:

1) An Agreement between a donor and a ministry.

2) A Plan of Operation

3) A Plan of Activities

4) A Work Plan which gives a detailed description of

4a) Surveys, agreements, designs and bills of quantities

4b) Training

4c) Construction works

THE AGREEMENT

1) An Agreement between a donor and a ministry. The agreement is usually based on a document called:

PLAN OF OPERATION

2) A Plan of Operation which describes:

a) Long-and short-term objectives of the
programme. b) Priority areas for implementation. c) Plan of Activities. d) Training and production targets. e) Personnel requirements of programme staff and consultants. f) Transport requirements. g) Budget defining cost-sharing between donor and ministry. h) Time frame for implementation of the programme.

PLAN OF ACTIVITIES

3) A **Plan of Activities** describes *the* work to be carried out:

a) Establishment of offices and store. b) Identification of organizations with related objectives. c) Compiling relevant information from identified organizations. d) Survey of target areas to determine demand for tanks. e) Formulate a Work Plan. f) Mobilization of principals and parents. g) Formulate procedures for procurement, storage and deliveries. h) Training programmes for local staff in the positions of:

* 1 surveyor of schools,
* 2 store-keepers,
* 5 supervisors of contractors,
* 60 contractors.

THE WORK PLAN

4) Work Plan describes in details how to implement the Plan of Activities in the following aspects:

4a) Surveys, agreements, designs and *bills* of quantities

a) Determine demands of tanks and gutters at schools by compiling data from questionnaires.

b) Draw up designs and bills of quantities for tanks and gutters to be constructed .

c) Obtain quotations on materials, tools and equipment as well as select suppliers

d) Purchase requirements from selected suppliers.

e) Standardize delivery notes for delivery of materials to schools.

f) Set up written agreements with schools on repair of old tanks or construction of new tanks and gutters.

4b) Training

a) Advertise training courses for builders through the office of the Labour Officer and select trainees by *means* of personal interviews. b) Train 2 store-keepers in receiving and delivering materials. c) Make 20 sets form-work for building domes on the tanks.

d) Train 65 builders, divided into three teams, in building tanks and gutters on contractor basis using photo-manuals which will be used for quality control of the contractors' work in the field

e) Evaluate the builders' performance and group them as follows*

The 5 most capable builders to be supervisors.

The next 20 most capable to be A-Contractors who will be in charge of construction teams.

* *The* remaining 40 builders *to be* B-Contractors who will be employed by the A-Contractors.

4c) Construction works

a) The contractors are requested to form 20 teams. Each team is headed by an A-Contractor who will employ two B-Contractors and one trainee. The trainee will be trained by assisting the contractors in building tanks.

A trainee can be promoted to be a B-Contractor and a B-Contractor can be promoted to be an A-Contractor upon producing good craftsmanship and leadership over a period of some 6 months. This arrangement will turn out good contractors without the need of more training courses. Poor contractors will be demoted or not being offered more contracts.

b) A labour contract on providing skilled labour for the construction of tanks and gutters is signed with each of the A-Contractors .

c) A set of tools and equipment is issued on a loan basis to each of the A-Contractors (Display 10).

d) The contractors are then transferred to schools where parents are ready to provide free unskilled labour and where materials are delivered.

e) The contractors are supervised weekly by the supervisors who checks that the construction work is in accordance with the standard design and instructions given during the training.

f) When a tank is completed it is handed over to the principal of the school. The principal signs a "Handing-over Certificate" which states that the work is completed in a satisfactory way and that the principal is responsible for maintenance of the tank .

g) Upon completion of a tank, the A-Contractors is paid the fees stated in the contract. Any neglect in adhering to the standard design or instructions given during the training courses is fined and deducted from the fees.

h) Thereafter the contractors are transferred to a new construction site where they sign a new contract for building another tank.

i) The supervisors meet weekly for exchange of experience and for presenting a"Weekly Work Record" to the team-leader.

j) The team-leader compiles the Supervisors' Weekly reports, with work plans, budget, etc. for his monthly reports.

COMPARABLE COSTS OF WATER TANKS

Introduction

Although rainwater can be harvested from almost any type of surface, such as roads, compounds, rocks, hills and sloping land, the most common method is to harvest rainwater from roofs of buildings.

The oldest way of harvesting rainwater from roofs, which can still be observed in rural areas of Africa, is simply to place an open calabash under a roof and let the rain fill it up.

Interestingly, about 2,000 years ago people in the Negev desert in Israel build large cisterns for storing rainwater under their houses. Although the average rainfall was only around 100 millimetres annually, the roof catchment system was sufficient to provide water for domestic use for centuries.

Today there are several types of cisterns for storing rainwater harvested from roofs all over the world.

People in Kenya can buy tanks of corrugated and galvanised iron sheets or build tanks of concrete blocks. However, since the first water tank was built of ferro-cement in 1979 (by the author) these tanks have become very popular because the tanks have proved to be stronger and cheaper than any other type of water tank. More than 3,000 tanks have been build of ferro-cement in Kenya during the last 10 years and nowadays the number is increasing with about 1000 tanks annually.

In Namibia and South Africa water tanks of plastic are being manufactured and sold with a 5-year guaranty. The biggest tank has a volume of 20,000 litres and weighs only 500 kg but the cost of installing such a tank is about US$ 3,000.

UNICEF in Namibia is starting a water tank programme at schools in the northern part of the country. The volume of these tanks is 10,000 litres. The first 20 tanks have cost US$ 1,353 per tank including all overheads, but once the training period is over a tank can be produced for about half of that amount.

Comparable costs of water tanks

Design of tank.	Volume of tank cu. m.	Cost of builders & mater-als US S	Value of community contribu-tion US $	Overheads & trans-port 50km etc. US $	Total Cost per cu. m. volume US $*
Tanks made of Ferro-cement					
Cylindrical	1.1	65	NIL	58	112
Ball-shaped	1.5	53	NIL	48	67
Cylindrical	4.3	96	NIL	66	38
"	10	550	785	689	124#
"	23	634	380	229	38
"	46	872	493	229	24
Hemi-spherical	80	1,200	539	229	18
Tanks made of Agro-plastic					
Cylindrical	0.6	250	NIL	50	500
"	2.5	483	NIL	50	213
"	5.0	700	NIL	50	150
"	10.0	1,367	NIL	50	142
"	20.0	2,667	NIL	50	136
Tanks made of galvanized iron sheet					
Cylindrical	2.0	350	NIL	50	200
Tanks made of asbestos					
Barrel-shaped	1.5	250	NIL	50	200

* Value of self-help and cost of gutters (US$ 3.56 per metre) not included in costing
# UNICEF's water tank programme in Namibia

RAINWATER HARVESTING SYSTEMS IN SOUTHERN AFRICA: Experience From Kwazulu

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INTRODUCTION

In the less developed rural areas of Southern Africa, most communities depend on local sources of water which are available naturally - river water, open wells and springs - and these are usually polluted. Often, too, water may not be easily accessible and women and children carry it for long distances in buckets or other receptacles, adding to the health hazard. This situation has not only contributed to the problems of poverty which is linked to low agricultural production, but has also escalated the problem of migration of rural people to urban areas. Moreover, inadequate and unsafe water for drinking and domestic use adversely affects the health and well-being of the rural people. Water-borne diseases and poor sanitation continue to prevail in these areas.

An adequate supply of water for agriculture, industry and people depends on human intervention in the water cycle and the development of all available water resources not only on the surface but in the ground. Providing good quality water to rural communities poses many problems. It is not merely a matter of installing pipes, pumps and other high technology equipment as it would be in an urban area, even if this can be afforded by the communities concerned, in rural areas people are often not only without the expertise to operate and maintain such equipment but they do not consider it their responsibility to do so if the system is installed "over their heads" by some outside authority without any consultation as to their particular needs. To meet these needs care must be taken generally to provide the simplest technology available, making use of whatever local resources there are, and it is essential to involve the community concerned in any decision-making regarding water supplies. The aim must be to provide technology which is not only affordable, effective and reliable, but acceptable to the people who are to use it. This paper places emphasis on the potential of simple rain water harvesting technologies to solve the water supply problem of rural households, for both domestic use and small scale agriculture.

WATER RESOURCES DEVELOPMENT PROBLEMS

As in other parts of the world, the core problem in developing water resources in the less developed rural areas of Southern Africa has been identified as that of human resource development. Some important factors inhibiting efforts by government and nongovernment organisations to improve the water supply situation have been identified by the Council for Scientific and Industrial Research as follows:

* Many rural communities are largely illiterate; those that are not lack the information and expertise to improve the situation themselves, and there is a dearth of personnel to facilitate development projects.

* Attempts by government organisations to upgrade water supplies without consulting the potential users of the water scheme do not foster a sense of community pride in the ownership of such facilities; they are seen as having been imposed upon the community and people lack the motivation to work with the authorities in operating and maintaining equipment.

* A lack of infrastructure for water schemes or ones that function properly.

* Low-income communities lack the motivation to become involved in efforts to improve their situation for fear of financial commitment beyond their means.

* If First World technologies are implemented there is a shortage of staff to maintain equipment; spare parts are not readily available; there is a lack of communication in advising the appropriate authorities about breakdowns and no transport to obtain the needed parts. People fall back on unimproved traditional water sources for survival and once again there is a threat to the health of the community.

* Because of ignorance about the health hazards associated with inadequate water supplies, rural communities may see the provision of other facilities, such as a clinic, as a more pressing need than proper water supplies, not realising that inadequate and polluted water can cause diseases like diarrhoea and typhoid as well as troublesome skin complaints.

* Efforts to provide simple technology appropriate to the circumstances are sometimes met with resistance from authorities because of the prestige attached to First World high technology.

Against this background description of the most important factors constraining water resources development in the less developed rural areas of Southern Africa, it is pertinent to examine the potential role of rain water harvesting technologies in meeting the water needs of rural people, particularly at the household level, for domestic use, agriculture and even cottage industries.

RAIN WATER HARVESTING IN SOUTHERN AFRICA

Rain water harvesting in various forms has constituted part of man's strategy for survival since before Christ and there is certainly evidence of primitive rainharvester systems being used in Southern Africa many centuries ago. In more recent times, mud and dung and ferrocement catchments have been tested. Rainharvesters have been installed in many sites, in Botswana in particular (Gould 1983) and also in Namibia where Hellwig (1968) suggested the use of rain water harvesting on a large scale; in the latter case, several techniques including bitumen sprayed onto the soil surface have been tested.

The utilisation of roof runoff is a well known phenomenon in the commercial agricultural sector in South Africa and other southern African countries, especially in the more arid areas (Alcock 1984). Water derived from roofs also constituted an important and sometimes the only potable source in arid urban areas of South Africa such as Grahamstown before reticulated supplies became available (Reynolds 1984). In such circumstances, the practice was to have two rain water tanks with the first galvanised tank acting as a settling tank draining into a second galvanised tank, from which potable and general household water was drawn. Water destined for domestic consumption was not boiled or treated in any manner. In the more arid areas of southern Africa, for example Botswana, roof runoff constitutes an important source of supply in the smaller urban centres and until recently was vital in the larger urban centres, such as Francistown, as well. In South Africa, the National Building Research Institute has designed low cost housing for use in African urban and peri-urban areas incorporating a 3 000 l rain water tank with a secondary 225 l tank for kitchen and shower use (Arrigone 1978). Each house can be fitted with a slow sand filter to purify the rain water for potable use where reticulated water is unavailable.

Thus, rain water harvesting, in one form or another, has been applied over the years in both developed and less developed areas of southern Africa. However, it is an accepted method for the procurement of water amongst only a very small proportion of the population that could potentially make use of it. In the little research that has been done on the system, emphasis has been placed on rain water harvesting as a partial solution to rural water problems in the more arid parts of the region. Undoubtedly, the technique has application in high rainfall areas as well.

RAIN WATER HARVESTING IN KWAZULU : A CASE STUDY

In recent years, Alcock and co-workers have conducted extensive surveys in two less developed rural areas of KwaZulu, located near to Pietermaritzburg, for the purpose of determining existing water supply sources and consumption patterns as well as formulating recommendations concerning the design and introduction of improved water supply systems (Alcock 1985a, 1985b; Alcock and Lea 1985).

One of these areas is the Inadi Ward, in the Vulindlela district of KwaZulu, which is situated 15 km south west of Pietermaritzburg and covers an area of 66,35 km^2; it is divided into nine sub-wards and has a population of 30 722 people of Zulu descent. The mean annual rainfall for the area is 931 mm.

Most households in the area, each with an average of 7 people in the family group, obtain their water from perennial springs (protected and unprotected). Other sources of water include streams, rivers and dams. At a limited number of protected springs, ferrocement reservoirs have been erected by the KwaZulu Department of Agriculture. A relatively small number of households and a few schools utilise roof rain water runoff and collection in tanks as a source of water. No borehole water or purified reticulated supplies are currently available in the ward. Sanitation is either non-existent or, with the exception of a few septic tank systems, confined to pit latrines.

Over one half of the households in the area consist of two or three buildings. Housing in the district is in a state of change from traditional thatched rondavels to a more westernised form consisting of rectangular wattle and daub or mud brick dwellings with corrugated iron roofs. An increasing although still rare trend is the plastering of the outside walls of houses with cement. In the few cases where gutters are present, they are made of galvanised iron in most instances. The corrugated iron roofs and gutters are not usually painted.

The water collected in the various ways referred to above is not normally boiled and very few people add disinfectant solution or chlorine tablets. As a result, water borne diseases are a major cause of ill-health and, sometimes, serious disease (for example, cholera) in the area.

Just prior to the survey work conducted in the Inadi Ward, five rainharvester units and two fog interceptors were erected in the area to evaluate optimum design materials and construction systems, and also to compare the purity of the water collected from these systems with that collected from the other water sources in the Ward. Bacteriological testing of the water from the various sources revealed that most unprotected surface sources were heavily contaminated whilst, in most instances, water collected from protected springs, roofs and from the rainharvester and fog interceptors was relatively clean. Nevertheless, if the South African Bureau of Standards bacteriological standards are strictly applied in terms of the *E. coli* content of the water, all the samples of water collected from the various sources would have to be rejected for human consumption if not boiled or treated with a disinfectant. Quite clearly, such exacting standards are not appropriate in respect of water supplies in less developed rural areas. Since the location of pit latrines is not controlled and there is widespread defecation In the open, extensive contamination of surface water is not surprising.

Where rain water is collected from roofs, a survey of households with such a collection system revealed that, on average, there is a 41% reduction in the potential water recovery from the roof due to insufficient gutter installation and inadequate storage capacity. The usual collection system consists of two uncovered 220 1 metal drums and a number of smaller plastic containers.

Water perception and source selection are important factors to be considered in any attempt to upgrade water supply systems. In the Inadi Ward, the order of preference for water sources is springwater, rain water and, last, surface water: this observation accords with that made in Lesotho by Feacham (1978). Turbidity is the single most important visible water quality parameter used by residents to assess potability. Surveys indicated that people will choose to collect water from a nearby river or stream in preference to a protected spring if the return journey to the nearest such spring is in excess of 1,5 km, particularly where steep terrain has to be traversed which is often the case in the hilly Inadl Ward.

The survey data reveals that the failure of more people to install rain water collection systems on their buildings and for their rejection of rain water as a potable source usually stems from inadequate installations; people are understandably reluctant to drink the water when the storage vessels are uncovered and rusty or unclean. Rejection, therefore, centres on poor or inadequate technology rather than the source per se. It seems that the technology deficiency derives from a lack of information concerning appropriate technology. Lack of funds or lack of knowledge concerning credit availability are of course other reasons why some households have not introduced gutters and storage tanks.

PROMOTING RAIN WATER HARVESTING (ROOF COLLECTION) IN THE INADI WARD AND ELSEWHERE

Technical considerations

The water supply potential of a given roof system will be influenced by locational factors which include topographic location, with consequent rainshadow or orographic effects, orientation of roofs with respect to the main rainbearing winds and the presence of shelter belts. Roughly 17% of the metal roofed houses in the Inadi Ward display the postulated optimum roof orientation. Clearly, new houses should be constructed with this optimum orientation in mind.

The pitch of a roof in relation to the surrounding terrain also influences the catch efficiency. The higher catch recorded by raingauges normal to the surrounding slope has been demonstrated (De Villiers 1980). Thus, houses situated on relatively steep land are likely to intercept a greater rainfall, especially under high intensity conditions, than houses situated on flat land where roof inclination does not approximate a right angle to the terrain.

Once rainfall has been intercepted by the roof, a further set of factors becomes involved in determining runoff. Depression storage on the roof surface will retain a certain amount of water and wetting of the roof surface will retain a small volume of rain water. In general, however, a runoff coefficient of 0,75 -0,95 is commonly accepted for roof surfaces (Chow 1964) and the higher value will apply to more impervious surfaces such as corrugated iron sheeting. Once runoff has been achieved, gutters which are (a) too close or too far away from the roof eaves or (b) which exhibit an excessive fall or (c) which leak can result in a considerable loss of utilisable water together with spillage down the wall and the consequent structural effects. The lack of fascia boards on most houses in the less developed rural areas results in practical difficulties when gutters are attached either to the eaves poles or the roof.

The type of material used in the manufacture of gutters is important with regard to both possible hail damage and installation difficulties, asbestos and PVC gutters are not recommended and the former material is also excluded on health grounds. Galvanised iron gutters (made from O,6 mm thick sheeting) are the best option at the present time but rusting is a problem and regular cleaning to clear blocked sections is essential. Downpipes may be made of polyethylene tubing.

A type of gutter assembly that is currently recommended in southern Africa for simple houses is one known as the Msinga Gutter Sling Bracket for use with corrugated iron roofs and galvanised iron gutters. With this system, a short galvanised angle iron is bolted directly onto the overhanging edge of the corrugated iron roof sheet and the gutter is held in place by a length of galvanised wire attached to the two ends of the angle iron and suspended below it. Two clips hold the wire in place on the gutter. The length of the wire and the positioning of the clips on the wire can be altered to regulate the slope and angle of the gutter. This system has the following advantages : low cost: simple and quick installation; no fascias required; adjustable for any roof pitch; compatible with all types of roof construction; accommodates any gutter shape and, because it is rigid, it withstands the build up of hail.

For household rain water storage, a choice of three materials is available :

* Relatively inexpensive galvanised tanks (made from o,6 mm thick sheeting) which have the important advantage of ease of installation, although their long-term durability is questionable. Some form of exterior protection against rust, such as coating with bitumen-based paint, may be necessary. If the wall of the tank has rusted, repair may be effected using bird-netting wire and cement.

* Glass fibre reinforced polyester tanks which are more expensive but also easy to install. These units have a considerable life-span but are not as readily available.

* Ferrocement tanks, also cylindrical, which are durable if properly constructed. However, the construction of such tanks requires specialised skills and the necessary building equipment is not readily available to rural householders.

In all cases, a well-fitting detachable cover for the tank is essential. This should include a short section of suitable diameter piping in the centre to facilitate connection of the downpipe. An elevated collar is especially important to prevent dust mixed with rain water from entering the tank via surface inflow. A tank overflow pipe, which must be covered with a section of gauze to prevent entry of insects, will facilitate the hygienic collection of excess runoff which may also be piped or carried to other areas of use, for example, trees or a vegetable garden near the house. The gutter outlet pipe should also be covered by a piece of gauze which will act as a primary filter. The gauze filters can be attached by means of a contact adhesive and Velcro self-gripping fastener tape.

Water tanks, no matter what material is used in their construction, should be mounted on a well-drained rock-mortar concrete or wooden framework pedestal to prevent deterioration of materials arising from ponding at the base. Several designs are available for a simple "first flush" mechanism which allows the initial roof runoff containing particulate matter to run to waste (Jenkins and Pearson 1978). In practice, however, most households will probably not bother to use such systems; they must, however, be installed on larger buildings such as schools. A standard 15 or 20 mm diameter tap with a hose union must be fitted and should be threaded into the tank rather than soldered to ensure quick replacement if necessary. A simple tap locking device is inexpensive and readily available.

Where rain water is to be collected for purely agricultural purposes, for example, to supply water to the birds in a poultry (broiler) unit, extensive use is now being made of a roof runoff collection system that consists of :

* A poultry shed with a corrugated iron roof which has a sufficiently large surface area to provide enough runoff during the wet summer months to provide water for the unit right through the dry winter months.

* An underground water tank consisting of a plastic liner supported by a stiff wire mesh structure; a plastic cover is held in place in a cone shape above the tank with a central pole and supporting wires.

* A header tank suspended below the roof of the poultry unit for supplying water by gravity feed to the bird drinkers on the floor of the unit.

* A simple hand pump for pumping the water from the underground tank to the header tank.

The installation of rainharvesters or fog interceptors, where appropriate, can be considered in those situations where efficient household rain water collection is not feasible and other sources of water are not available. An important advantage in times of drought is that rainharvesters can serve as emergency reservoirs supplied by tanker. However, such community water resource facilities can be successfully implemented only if the local community is fully involved in planning the system, erecting it and maintaining it.

Socio-economic considerations

Cost is a most important consideration in the utilisation of rain water collection systems by rural households. The present cost of installing a simple household unit (with an 11 m gutter length) with a 1 300 l storage capacity is estimated to be of the order of R800 (approximately U.S. S320)- This figure includes the guttering (galvanised iron), downpiping, tank (galvanised iron), pedestal, tap and filters.

Since the average household cash income in the less developed rural areas is of the order of R800 per month, it can be seen that finding sufficient funds to install a rain water collection system is a real prob}em, particularly because there are no widely available long term credit facilities available to rural people.

A second problem relating to the installation of rain water collection systems is that of transporting bulky tanks to the rural areas where most people do not own vehicles of any type. Neither manufacturing companies nor local hardware firms are willing to enter into hire-purchase agreements for the supply and transport of materials to households. Investigations have revealed that a lay-by System (whereby the householder deposits cash over a period of six months with the supplier for the materials to be ordered : ownership of the goods is transferred on delivery when the balance of the money owing has been paid) is acceptable and may be the answer to the problem of financing rain water collection systems. Voluntary savings clubs operated by local communities are another possibility.

The degree of acceptance of rain water collection systems by rural householders is a reflection of individual perceptions concerning their worth, in monetary and non-monetary terms. One of the problems regarding rainwater is that many householders are not aware of the annual runoff yield from their roofs. Another is that there is little understanding of the effectiveness of a safe water supply in combatting disease problems in the less developed rural areas. A rider to this, of course, is that sanitation development must not be allowed to lag behind water resources development, for both are equally important in reducing the severity and incidence of various diseases, gastro-enteritis in particular.

In those areas where some rain water collection systems exist already, rusted roofs, gutters and storage vessels as well as the presence of silt on roofs does not encourage other residents of the area to invest in such systems. It cannot be over-emphasized, therefore, that properly trained technical personnel are required to advise on the installation of systems and on their on-going maintenance. A solution frequently proposed to overcome the shortage of technical skills in the rural areas is that of training one or more residents from the area in question. Experience has shown, however, that results are often disappointing because many residents would prefer to deal with a responsible agency rather than with independent (although trained) entrepreneurs.

It seems that any accelerated upgrading programme for rain water collection systems will require the attention of an already established water agency with fully competent staff working closely, in the first instance, with the local development committee. Thus, the promotion of the desired development is the outcome of a collaborative partnership between the community and the development agency in which neither is dominant and each understands and accepts its role. This type of relationship places new demands on both parties : communities must become the focal point of decision making, and development agencies must help create or support conditions in which community-based action can occur.

CONCLUSIONS

Making more water available and more accessible to people living in the less developed rural areas of southern Africa is one of the principal goals in development work in these areas. Access to a clean water supply should be as close to the home as possible to foster the use of more water for hygiene practices. The promotion of rain water harvesting systems, particularly rain water collection from the roofs of private homes, is an excellent way of achieving the goal of improved access. Properly installed gutters will help to reduce the incidence of structural deterioration resulting from water splashing against walls. Excess roof runoff can be used to water small vegetable gardens, fruit trees, etc, with consequent upgrading of household nutrition.

Quantifying the health effects of water and sanitation development is vital in the process of motivating people to introduce rain water collection systems. Water supply and health programmes should emphasize community involvement and also hygiene education to encourage people to use more water for personal and domestic hygiene. There can be little doubt that health benefits are the major - but not the sole - justification for promoting water supply and sanitation development; such improvements also have wide economic benefits. It is important to note that behavioural changes combined with greater access to facilities are the basis for health benefits through improved water supply and sanitation.

Finally, local institution-building is the key to transferring the sustainable skills required for building appropriate rain water collection systems.

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EXPERIENCES WITH RAINWATER CATCHMENT SYSTEMS IN EAST AFRICA AND COMPARISONS WITH BOTSWANA

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The following remarks are based on experience in East Africa - the countries involved were Uganda, Kenya, Tanzania. The work was all labour intensive is fuel for machines was very often in short supply.

The rainfall in these countries does not compare with that of Botswana, and the pattern of villages and houses is not comparable with this country. The rainfall in Chobe is high, and a large portion of this very valuable source is wasted - schools have no gutters, damaged galvanised tanks or nothing at all. In many villages there is a funded water supply but this does not alter the fact that there are good openings for rainwater harvesting at such places, and clinics, customary courts etc can be added to the list. In areas such as Ngamiland and districts such as Ghanzi offer areas that rural schemes could be introduced. In Remote areas a supplementary water supply would help both people and cattle.

Stored rainwater can be a valuable supplement to other possible inadequate domestic water sources, it can also be used for gardens, or on large scale harvesting for irrigation of market gardens. It's use is particularly appropriate in parts of the world where heavy and intense storms are followed by prolonged periods of drought.

A household supply requires a catchment area, a means of collection, and a suitable storage facility.

1. Roof Catchment

Collection of roof catchment is probably the cheapest form of rainwater catchment as the additional costs are limited to the collection and storage elements.

Galvanised iron sheets and tiles are good. Thatch is a poor material, and in Uganda the banana leaf thatch would often give a yellow colour to the water. In some areas the clay would colour the water because of its composition. A plastic sheet over a thatched roof will give good results although it deteriorates during the hot dry season.

2. Ground Catchment

Another form of catchment that can be used is ground catchment, using this form of catchment can be much more expensive than roof catchment both to construct and maintain. There also may be considerable pollution problems thus restricting this form for the use of gardening or cattle.

Where I worked previously we divided the rainwater catchment into two types:

i) Large areas such as schools, hospitals and churches

ii) household or domestic

In the first instance the cost was borne by an aid agency, and the materials were purchased outside the country - this was Uganda 1986, and there was nothing available - it was not uncommon for a woman to walk 10 kilometers for 20 litres of water that the World Health Organisation would not consider potable, and a bag of cement was sometimes the equivalent to £15 sterling.

In the catchment in schools, the layout of the buildings was usually in the form of a square or a 'U'. This layout enabled the construction of central underground tank with the various buildings connected by a net work of pipes. The guttering was 6" square profile P.V.C. with a central hopper to a down pipe. A 'first flush' or sediment tank was constructed with either a mesh or well - these were fitted with lids for cleaning purposes. The collection pipes where laid with a good fall to clear any standing water to an underground brick tank. The tank was excavated by hand, and construction commenced by laying a foundation slab with reinforcement bar. The walls were double thick brick with buttresses and the inside was rendered with three layers of rendering of different thickness to make it water proof. The gap between the excavation and the walls was filled with stone and compacted soil. A sloping floor was then laid with a sediment depression at one end with wash out facilities.

The cover slabs were constructed by digging out profiles in the earth, blinding by sand and then filling with re-inforced concrete. They were constructed alongside the tank for the sake of convenience of handling. The manhole was fitted with lock and a vent on the lines of a V.I.P. latrine was also fitted. The height of the tank was usually two/three courses above ground level to stop flood water entry. A semi-rotary pump was also fitted for extraction.

The above ground tanks that constructed were of the circular variety using pre-formed interlocking blocks. These blocks were made on site by two men who would make 150 blocks in three days using a mould with a battery operated vibrator. The battery was recharged by exchanging it for the one in use in the landrover and charged by normal driving.

The tank would then be constructed in about another three days (often less) and a wood lid fitted. The tank was 2 m x 3 m giving 6 000 litres of water. Tanks up to 18 cubic metres can be constructed this way. The construction is very simple. A circular base is laid and when the blocks are hard but not dried out, they are laid to the required height, the inside is plastered, a drain and tap fitted and a lid. If possible fill with water, i.e. construct just before the rains and allow to stand, flush out and use.

In the case of one hospital these tanks were made underground, and replaced an old brick one and galvanised tanks which had been damaged by misuse or rusting.

Galvanised tanks are easy to transport, are cheap to purchase, but you only get what you pay for - i.e. a cheap, tank, that in the case of public places will be damaged by misuse (school children breaking the joint for the tap) and will need replacement. A block tank is more expensive, but will last 20 years with may be one replastering.

The cost of the vibrating mould is considerable, but:

a) it will make many blocks anywhere
b) can be used on a co-operative basis in a village or by a small trader

The domestic or 'do-it-yourself' type of rainwater harvesting is again divided into two categories.

i) The householder with a suitable roof can buy manufactured guttering and either buy or build a tank.

ii) The second group is more interesting - low income, with little buying power.

We did it locally by cutting up two sheets of galvanized iron with a panga in to strips and then bending round a pole. The ends were folded over and wire was tied across at intervals to retain its shape. The end products were hung on the rafters either to be connected to a down pipe or at a steeper incline in to a container.

A down pipe was constructed by folding a piece of sheet round a pole and folding the edges and hammering flat. Another form of guttering is two boards in the form of a 'V', and bamboo in the right area will also do very well. Bamboo also makes a very good down pipe.

The container for this water can be:

- a 200 litre drum or a similar object

or it can be a jar made with hessian sacks, filled with sand, husks and shaped into a jar, this shape is then plastered with a cement rendering. A half bag of cement will make a 250 litres jar - jars up to 1,000 litres can be constructed this way but as the jars get larger so re-inforcing in the form of wire will be required. The other way to form the jar is to weave a rough shape out of thin cane (like making a basket) - this is then covered with hession, and plastered as before.

In every case a lid must be provided, and the jars kept in a cool dark place as much as possible. The first flush is allowed to run to waste or used for cattle, before filling the jar for human consumption. Rainwater is often cleaner than collected ground water but there are pollutents caused by bird droppings etc, so simple treatment of the water by a basic two jar sand filter or by making a boiler from a drum heating it until boiling - allow to cool and use as required. Chlorination is an other way but out of reach due to cost for low income families or even iodine.

Ground collection into a sand reservoir using 'run-off' from rocky areas, or areas that have been cleared of bush and if cost allows cement rendered, can be considered.

A sand reservoir consists basically of a pit either lined with plastic, or cement rendered and filled with sand. A sediment/infiltration sump is constricted at one and connected to the 'run-off' apron. A well with a pump is fitted to the other end for 'draw-off'. An improvement on this principle is to construct a series of chambers in thepit and then fill with sand. The free water collects in these chambers having been filtered through the sand, which also reduces evaporation. A pump is provided for 'draw-off' as most of these reservoirs are constructed on flat areas where for instance a syphon would not work.

A very basic type of ground storage on this principle is to construct a mud or mud/cement lined pit in an area of natural ground or a threshing floor. The reservoir should be covered with a roof and a fence. A thorn fence - keeps out animals and stray humans.

These basic reservoirs cost nothing and will supply some bulk water mainly for animals, and I suspect humans especially when it came to home brewing time - it no doubt added something to the flavour. A number of these were constructed along with mud bamboo V.I.Ps which survived for a period.

FUTURE RESEARCH AND DEVELOPMENT NEEDS FOR RAINWATER CATCHMENT SYSTEMS IN BOTSWANA

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INTRODUCTION

Despite its low rainfall, the high value accorded to water in Botswana, especially in remote rural areas suggest that rainwater collection is both appropriate and desirable in many circumstances, especially as a supplementary and back supply in larger settlements and as the main source for domestic supply at remote and isolated rural homesteads.

POTENTIAL

There is particular potential for further developing rainwater catchment systems at schools, clinics and other government institutions with large corrugated iron roofs in rural areas, at isolated lands area homesteads and in larger settlements as a secondary source and supplementary supply. Even in the dry southwestern corner of Botswana rainwater collection has a role to play due to the extreme scarcity of water.

APPROPRIATE TECHNOLOGIES

In recent years a range of new tank and total system designs have been developed which are especially appropriate to Botswana. For example in Kenya a large 46m3 weld mesh framed ferrocement tank design is currently being constructed at hundreds of primary schools throughout Kitui district, locally made V-shaped gutters these are very cheap and are used especially designed to cope with long school roofs.

In Asia small 2m3 ferrocement rainwater jars have become extremely popular in some areas, such as Thailand where more than 12 million have been built since 1985. These too could be adapted for use at small lands area homesteads with only limited catchment areas, or reserved for drinking purposes only from small roof catchments.

CONSTRAINTS

The constraints to widespread implementation of rainwater catchment systems in Botswana are considerable. Apart from the physical problems encountered when trying to transport materials and workers to remote rural areas, the main problem is poor workmanship often based on inadequate designs. Lack of supervision and second rate materials are also frequently to blame for sub-standard tank construction. Another major constraint is that government agencies and others charged with supplying water have in the past simply not taken either the technology or the water needs of those in remoter areas seriously enough.

IMPLEMENTATION STRATEGIES

Any rainwater catchment tank implementation strategy in Botswana, must have at its core a significant training element. This could possibly be centred on existing institutions such as the brigades. As a first initial step towards widespread implementation of some of the new improved rainwater tank designs a major programme to build large ferrocement roof tanks at primary schools and clinics in rural Botswana should be considered. Between 100 and 300 schools and clinics might be included in this programme which would need to be developed incrementally over a number of years to ensure the effective training of the builders employed. The total cost of the project would run to several million pula at current prices and would depend on the scale of the project. A cost of at least P12,000 per 46m3 tank for construction costs alone should be expected.

FUNDING

A number of potential sources of funding already exist, these include the ALDEP water tank package which provides a subsidy of up to 85% for farmers in lands areas. The district councils supported by the Ministry of Local Government, Lands and Housing (MLGLH) are also providing funding for the implementation of both brick and corrugated iron tanks at schools, clinics and other government buildings. At present relatively small 5-10m3 brick and corrugated iron tanks are being implemented, these are under designed for the purpose and lack durability. With the same funding far greater storage volume could be purchased using some of the ferrocement designs.

The Department of Water Affairs is now paying more interest to rainwater catchment systems as these will undoubtedly play an important role in remote rural locations when the Lands Area Water Supply Project is eventually implemented.

RESEARCH NEEDS

For successful implementation throughout the country several aspects of rainwater catchment strategies need to be further considered. These include

- A detailed study of ALDEP's water tank programme including past, present and future perspectives.
- An assessment of the potential for developing rock catchment technology in Botswana.
- A study of the applicability, feasibility and potential of rainwater catchment systems technologies in the Lands Areas
- Cost-Benefit Analysis of Using RWCS in Urban Areas.
- The development of PC compatible software for assisting decision making regarding appropriate design specifications for rainwater catchment tanks.

RECENT STUDIES AND FUTURE DEVELOPMENT

The findings of a recent study conducted by BTC revealed both a considerable untapped potential and desire in both rural and some urban areas for increased development of rainwater catchment systems. Part of this study included a survey of primary schools and the possibility of rainwater collection from residential roof catchments in Gaborone the results of which are summarized below.

Clearly there is considerable potential for the expansion of rainwater catchment systems technology in Botswana, both in rural and urban areas.

SUMMARY OF RESULTS OF SCHOOLS POSTAL TANK SURVEY

No. of Schools Surveyed	250
No. which Responded	127
No. of Schools with Tanks	60
Schools with Galv. Iron Tanks	46
Schools Reporting Tank Leakage	46
Schools depending on Bowsers	3

	Total	Mean	Min.	Max.
No. of Students/Staff	62635	498	67	1120
Roof Area in m2	153055	1320	188	4242
No. of Tanks	277	2.2	0	16
Mean Annual Rainfall		469	220	680

ANALYSIS OF RESULTS

	Mean	Per Capita
Mean Roof Area of Schools Surveyed	1320m2	2.7m2
Mean Annual Roof Runoff	495m3	0.995m3
Mean Tank Storage Volume Requirement	198m3	0.4m3
Mean Annual Potential Rainwater Supply	347m3	0.7m3
Mean Potential Supply per School Day	1735 l.	3.5 litres

SUMMARY OF GABORONE RESIDENTIAL ROOF SUPPLY SURVEY

Total Housing Stock (March 1991)	16,034 units
Estimated Total Roof Area	1,483,932 m2
Estimated Total Roof Runoff	481,035 m3
Potential Supply (2m3 Tank/Household)	220,115 m3
Annual Value of Water Saved	P521,672
Total Potential Saving- over 20y Tank-life	P10,433,440
Total Saving per Household over 20 years	P625

RECOMMENDATIONS

1. Large ferrocement rainwater catchment tanks should be constructed at schools, clinics and other government buildings throughout Botswana to replace the current galvanized iron and brick designs, due to their poor durability.

2. The Kenyan KIDP/ASAL 23m3 and 46m3 tank design should be used as a model on which a ferrocement tank design for use in Botswana can be based and appropriate training courses organized.

3. An in-depth feasibility study should be conducted to examine the viability of producing small 2, 4 and 6 m3 ferrocement tanks at central locations for transportation and sale to householders. Investigations into the possibilities of including these as standard requirements for all SHHA and BHC housing should be undertaken.

4. A number of areas of further research into rainwater catchment systems in Botswana need to be pursued, including studies on those topics listed above:

   - the ALDEP water Tank Programme.
   - the potential for using rock catchment systems.
   - the feasibility of using RWCS technology in Lands Areas.
   - cost-benefit analysis of using RWCS in urban areas.
   - developing PC software for use as a RWCS design tool.

5. Inclusion of a rainwater catchment systems as part of the Lands Area Water Supply Project, should be promoted and appropriate designs investigated.

6. A major programme of rehabilitation of existing systems needs to be urgently considered. Leaking metal tanks can be repaired by applying ferrocement technology.

7. The existing ferrocement working group should be strengthened.

8. The ongoing pilot project on rainwater collection from pans being undertaken by RIIC should be supported and the possibilities of replication of this technique as a means of providing small scale water supplies in western Botswana investigated.

9. The current ALDEP rainwater catchment system design requires an in depth review. The use of combined roof and ground catchment systems should be investigated.
   The package should be promoted by producing a manual showing how the roof catchment can be used in combination with excavated material (from tank construction) to produce a simple dwelling.

REFERENCES

Botswana Technology Centre (1991) Rainwater Catchment Systems Development in Botswana, P/Bag 0082, Gaborone, 76p.

CLOSING ADDRESS

MR. J. B. S. DIPHAHA
Managing Director of Botswana Technology Centre

Mr. Chairman, members of the organising committee, foreign participants, ladies and gentlemen. It is indeed with great pleasure that I have been able to join you after your deliberations of the last two and a half days. Looking through your programme, it is quite obvious that you have had a busy schedule and an in-depth look at all aspects of Rainwater Catchment systems and their applications. The range of papers you have considered and the inputs you have had from participants from Kenya, Namibia, Tanzania, Zimbabwe and south Africa was from all accounts impressive.

I do not need to emphasise the seriousness with which we view the option of Rainwater catchment. You have already had occasion to visit the BTC and you have heard from my staff regarding our involvement in this regard. Indeed rainwater catchment is not new to us. Ever since the inception of the BTC in 1979, we have implemented and promoted this option for water supply. The BTC headquarters is but one example of the possibilities of what can be achieved in an urban setting. A paper presented during your deliberations has already outlined out intentions in this regard for the new BTC headquarters. This is indeed an expression of our commitment to strengthening our inputs in rainwater water catchment (RWC).

Only last year we commissioned a study on rainwater catchment in schools, when 250 schools were contacted by way of a questionnaire with over half replying. This revealed both a considerable untapped potential and desire both in the rural and some urban areas for increased development of rainwater catchment systems. I am glad to note that not only do you have schools represented at this workshop but that you were also able to see for yourself the potential for rwc in schools during your field trip yesterday morning, particularly as the continued depletion of our ground water resources is of major concern and the provision of water to the remote areas of our country cannot be undertaken in the conventional manner due to the significant costs involved in supplying small scattered settlements and the high salinity of groundwater in many areas.

It may be worth reminding ourselves at this juncture that Batswana have a unique settlement pattern which has a bearing on water provisions. Many Batswana have 3 homes, intermittently living in the Town/Village, in the Lands Areas and at the Cattle Post. While we have a well developed policy for water supply in the Towns and Villages, no such policy exists on the Lands Areas or Cattle Posts where anything up to 35% of our population resides for a significant part of the year. Water supply to these remote areas is a challenge to all of us and rainwater catchment can provide an economical and acceptable means of supplying potable water. The BTC has been intimately involved with the Department of Water Affairs in a Study addressing this very issue and in consultation with other interested parties will be shortly drawing up a workable policy for the supply of potable water to the scattered settlements of Botswana. It is inevitable that rwc with figure highly as one of the several options for the supply of potable water in these areas. The recent work by RIIC in Zutswa which you had occasion to discuss yesterday involving rainwater collection from pans is a further example of the exciting possibilities for rainwater harvesting in a remote setting in Botswana. Indeed the relevance of this kind of applied research cannot be overemphasised.

In conclusion Mr. Chairman, I am glad that the BTC was able to facilitate and support this workshop which has stimulated renewed interest in rwc in this country and drawn such a wide spectrum of participants. I would also like to thank the organising committee for a job well done and many other individuals and organisations which have contributed to the success of this workshop. These inputs are well appreciated. I sincerely trust that you will take the message of the infinite possibilities for rwc to your districts and begin identifying possibilities for an implementation strategy in your areas.

Finally, I would like to express my appreciation to the foreign delegates who have taken time off from their own schedules to share with us their valuable experiences. Until we meet again. Thank you.

ANNEXES

ANNEX 1

Workshop Programme

Monday 1st March 1993 - Botswana Polytechnic, East Campus Machel Drive

0800 - 0915	Registration, Poster Display, Tea/Coffee
0915 - 0945	Opening Address - Mr. B. Khupe - Director of Water Affairs
Session 1	**Chaired By: Dr. Krib Gurusamy and Mr. D.G Rutashobya**
1000 - 1030	An Overview of Rainwater Catchment Systems in Botswana Mr. John Gould/Mr. Baraedi Jay
1030 - 1100	Rainwater Catchment Systems in Namibia Mr. Pita Ngiphandulwa
1100 - 1130	Lands Area Water Supply: The ALDEP Rainwater Catchment Tank Programme - Mr. G.P.N. Chilume
1130 - 1200	Review of Rainwater Catchment Systems in Kenya Mr. John Mbugua
1200 - 1230	Rainwater Catchment Applications: The Botswana Technology Centre Experience - Mr. Stanley Chishimba
	Announcements
1230 - 1400	LUNCH (Rolands Rendevouz)
Session 2	**Chaired by: Mr. Colin Grant and Mr. John Mbugua**
1400 - 1430	The Economics of Rainwater Collection - Dr. B. K. Acquah
1430 - 1500	Rainwater Catchment in Zimbabwe - Mr C. Mukandi
1500 - 1530	Rainwater Harvesting for Agriculture and Horticulture - Dr. G. Nilsson
1530 - 1550	TEA BREAK
1550 - 1700	Visit Botswana Technology Centre (BTC) Rainwater Catchment System
1700 hours	Leave for Kanye
1710 - 1730	Brief stop at Gabane to see microcatchment for fruit tree production
1930 hours	DINNER AT RIIC, Kanye

Tuesday 2nd March 1993 - Kanye, RIIC Conference Centre

0800 - 1200	Field Trip in Kanye
1200 - 1400	LUNCH

Paper Presentations and Discussion

Session 3	**Chaired by: John Gould and Mr Pita Ngiphandulwa**
1400 - 1430	Gound based Rainwater Catchment utilising Salt Pans - Mr. Steven Petersen
1430 - 1500	Rainwater Catchment Systems Application and Technology Tanzania Country Report - Mr. D.G. Rutashobya
1500 - 1530	Planning and Rainwater Management - Mr. Mark Vlasic
1530 - 1545	TEA BREAK
1545 - 1615	Sand and Geotextiles in Rain Harvesting - Mr. Felipe Solsona
1615 - 1645	How to Plan and Implement a Water Tank Programme - Mr.Erik Nissen- Petersen
1645 - 1715	Rainwater Harvesting Systems in Southern Africa: The Kwazulu Experience - Prof. John Erskine
1715 - 1745	Experiences with Rainwater Catchment Systems in East Africa and comparisons with Botswana - Ted Berth-Jones
1930 hours	DINNER/DRINKS

Wednesday 3rd March 1993 - Kanye RIIC Conference Centre

Session 4	**Chaired by: Bjorn Rydtun and Prof. John Erskine**
0800 - 8.30	Future Research and Developments Needs for RWCS in Botswana - Mr. John Gould/Dr. Krib Gurusamy
0830 - 1000	Working Group Discussion
1000 - 1030	TEA BREAK
FINAL SESSION	**Chaired by: John Gould/Krib Gurusamy/John Mbugua**
1030 - 1200	Working Group Summary Presentation, Recommendations
1200 - 1230	Closing Ceremony - Mr. J.B.S. Diphaha Director - BTC
1230 - 1400	LUNCH AND DISPERSING

25/02/93

ANNEX 2

Summary of discussions during workshop presentations

Paper by J. Gould and B. Jay on "An overview of Rainwater Catchment Systems in Botswana"

Question: How to avoid dirt, dust, leaves and similar to be drawn into the catchment tank?

J. Gould; For roof systems this is a question of interest. The dirt, dust etc, settle through sedimentation and are not a major problem if the water itself is not exposed to sunlight, as well as tapping from the tank bottom at a minimum level of 10cm above the base helps to ensure its purity.

G. Hallam; Are there any guidelines concerning cost vs size to be used related to expected rainfall?

J. Gould; This requires a paper in its own right perhaps the paper on " Economics of RWCS" will answer this question.

Paper by Pita Ngiphandulwa on "RWCS in Namibia"
and
E. Nissen-Petersen presented poster showing the ongoing project of training unskilled persons in constructing ferrocement tanks in Northwest Namibia.

M. Hagos; What group are the targets of the referred technologies in Namibia?

P. Ngiphandulwa; Larger communities and groups of people.

Paper by G.N.P. Chilume on " Land Area Water Supply: The ALDEP Rainwater Catchment Tank Programme".

J. Gould; The ALDEP programme has found some difficulties making its water tank designs attractive to local farmers. The scheme is therefore under-subscribed. Could it be possible to make this package more interesting/ attractive?

G. Chilume; The subsidy to the farmers will not be reduced. A credit system could be introduced. We hope our tanks will be more attractive using our modified design, [with a raised 40m3 roof catchment included].

F. Mhuriro; The ALDEP program suffer from the lack of experienced district officers taking decisions. How or when can this be overcome?

G. Chilume; We have a network of skilled officers, in a position to make the final decisions. We will however further educate our staff at a workshop to be held in May 1993.

J. Erskine; Problems in construction and maintenance, could they be based in the lack of a propriate extension service advising and monitoring on the installations.

G. Chilume; This program is implemented without a permanent extension service.

Paper by John Mbugua on " Review of RWCS in Kenya".

M. Hagos; Regarding areas of high intensity of rainfall, how is the implementation of collection areas for larger systems?

J. Mbugua; There are difficulties in relation to conserving collection areas for large systems. The lesson we have learnt is that the collection area is as important as the dam itself. Erosion and sedimentation can be mentioned here. The emphasis on the whole system, not only the collecting system is important.

P. Alexander In relation to recharge, what system is expected to be appropriate, as for instant dry aquifers?

J. Mbugua; The multi-purpose of a catchment system and therein recharge area is important to utilise. Channels having plants along their sides as filters, the channel shape to enable silt and sediment removal, further for larger collecting areas as dams/ pans with wells downside the system.

Paper by S. Chishimba on " Rainwater Catchment Applications: The BTC experience."

G. Nilsson; What is the cost of a ferrocement tank?

S. Chishimba; A 5 m^3 tank is about P1500 included materials and labour.

Paper by Dr. B. K. Acquah on " The Economics of Rainwater Collection".

Comments/ Corrections;
Table 2a regarding cost of tanks was clarified.
Need to separate cost and labour. Maintenance costs not included ?

Paper by Mr. C. Mukandi on " RWCS in Zimbabwe".

Question; Why no rainwater collection in the dry areas of Zimbabwe?

C. Mukandi; Little knowledge of the technology.

Paper by Dr. Gus Nilsson on " Rainwater Harvesting for Agriculture".

Comments; Drip irrigation should be combined with rainwater catchment systems.

G. Nilsson; Agree, we use drip irrigation in the stage system at our cabbages nursery as an example.

Comment; Planting in stories could cause problems in high rainfall areas - can it be used in such areas?

G. Nilsson; Planting large numbers of plants in the thin sand layer over cultivated soil, i.e. including no strips, and table excess water out of the area for other purposes.

Comment; How do You maintain the strips?

G. Nilsson; We maintain the sand every Year. In Kalahari we create a hard dome under a thin sand layer.
Paper by presented by Colin Grant on behalf of Steven Petersen on " Ground based Rainwater Catchment of Salt Pans".

Mrs. Mpuisang; Are there evaporation losses from this system?

C. Grant; The tanks have roofs so evaporation losses should be minimal.

Comment; Why was the middle wall in the first tank as low regarding the overflow to the second tank being higher?

C. Grant; We started on trial and error basis. This wall could be higher to increase settling in the first chamber.

J. Gould; What is the runoff coefficient and what is the collecting area?

C. Grant; Area approximately 200x80m, the drawing estimate the sizes. The total collection area is wider than the fenced area.

K. Gurusamy; Have You tested the water quality?

C. Grant; Tests have been taken and lab. result are awaited.

J. Gould; Have you considered using Moringa Olifera seeds as a natural coagulant? [See Waterlines April 1990].

Paper by Mr. D.G. Rutashobya on " RWCS in Tanzania.

F. Mhuriro; How does one encouraged institutions to finance the RWCS?

D. Rutashobya; Most of the people now employing this technology are individuals with resources. The institutional projects are government funded.

J. Gould; How about the wooden tanks reported in Tanzania?

D. Rutashobya; This (bamboo) project now financed by the NGOs are not mainly used for storing rain water but more directly storing water from other sources.

Paper by Marc Vlasic on " The role of RWCS in erosion Reduction".

F. Solsona; How do you hope to implement strategies for the topics you have discussed?

M.Vlasic; There is no strategy at present, however the importance to agree upon strategies in the GOs are obvious. The present problems will only increase in the future.

J. Erskine; Is there a policy that will back up the proposals?

M. Vlasic; No there is not. We are taking an initiative to establish this.

N. Lwin; The future development in MMamokhasi area, does this include groundwater monitoring ?

M. Vlasic; There are no monitoring systems.

Paper by Felipe Solsona on " Sand Geotextiles in Rain Harvesting".

D. Rutashobya; Why was turbidity requested to be checked as shown in the slide projections?

F. Solsona; All catchments have high turbidity levels. Diverters don't work very well and therefore it is necessary to check turbidity levels in catchments.

J. Erskine; Is it possible to remove turbidity by using a coagulating agent? Are you not creating more bacteria?

F. Solsona; Yes, you reduce turbidity by using a coagulating agents. However, the corresponding bacteria growth is a problem. Using chemicals as the problem solution is neither recommendable or may even be a worse solution regarding the low skills and knowledge in remote areas.

Paper by Erik Nissen-Petersen on " How to Plan and Implement a Water Tank Programme".

L. Linde; How do You select the sites for building Your dams?

E. Nissen-Petersen; Making use of traditional methods well known among the local people and also including the locals in the siting process, is valuable for a successfull implementation. Examples could be observing the vegetation growth to estimate the location of water sources.

F. Solsona; How do you successfully manage to build so many dams and tanks being a single person responsible for all phases of the projects ?

E. Nissen-Petersen; You have to select Your construction team carefully. Making the best builders supervisors, and introducing a A and a B level of constructers. The bad workers has to be laid off. If a builder does a good job he is retained.

B. Jay; What is Your trick in making crack-free tanks?

E. Nissen-Petersen; One has learnt to make crack-free tanks from experience. I have been in the business for about 16 years. Initially whenever there was a crack in a tank I tried to find out the problem by breaking the tank up and finding out the weaknesses or the faults. Cracks in tanks are usually die to lack of reinforcement or poor curing especially in ferrocement tanks. It is also good to mention that 15% of the value of the contract is only paid to the contractor when the tank built is free of cracks. Otherwise that money is used to repair any cracks in the tank if they occur.

K. Gurusamy; How do You ensure that good construction work is done?

E. Nissen-Petersen; Contracts has been given only to A contractors to ensure good products. A good contractor is categorised as A, a subcontractor as B. Every contractor has to employ a trainee to work on the contract and possibly becoming a B and A level contractor.

Mrs. Mpuisang; How do You decide on the height of dams?

E. Nissen-Petersen; If the river bed at the point selected to build the dam has a lot of coarse sand one can go ahead and build the dam with a reasonable height. However, if the sand upstream contains a lot of fine sand the settled sand, which should be the coarse sand able to store the most water, will have to be collected in more steps resulting in smaller step is taken at a time.

M. Sebina; What motivates community participation in a project because it seems to be such a difficult task to motivate a community to participate in a project in Botswana?

E. Nissen-Petersen; In Kenya it is easy because water projects are needed badly by the community and women are willing to carry sand and stones to help the construction of tanks, etc. In Namibia it is easy to request the help of students and parents through the school headmasters.

Paper by Prof. John Erskine on " Rainwater Harvesting in Southern Africa".

F. Mhuriro; The mentioning of "thatched roofs" and collection of water from them was in due time. This is the major construction form You find in any rural area. Could you outline some more on the described options for this type of roof construction?

J. Erskine; The thatched roofs can not collect as pure water as other construction materials, because bits and debris get into the water and the water have a distinct colour and taste.

J. Mbugua; Use of polyethylene bags on the roof of such houses will minimise the unwanted taste and colour.

J. Gould; A survey of rural Botswana in 1983 revealed people did not like the taste of water from thatch roofs. The water could be used for other purposes but not for drinking.

B. Rydtun; What is the reaction of beneficiaries of water projects if they are told they would pay for them?

J. Erskine; They can see the results for themselves and so it is not difficult to convince them to pay if necessary.

Paper by T. Berth-Jones on "Experiences with Rainwater Catchment Systems in East Africa and comparisons to Botswana".

M. Sebina; What vision do you have for the situation in Botswana compared to East Africa?

T. Berth-Jones; It will depend on the local materials available, and applications of the East Africa experience to Botswana including the Thai jars, etc.

D. Rutashobya; If women have to walk more than 20 km to and from their homes to where they fetch the water, then water quantity matters more than water quality.

ANNEX 3

Discussion Group Findings and Recommendations

On the final day workshop participants divided into six discussion groups on:

- Rainwater Catchment Systems for Schools/Housing Projects and other Institutions
- ALDEP Tanks / Rainwater Harvesting for Agriculture
- Rainwater Quality / Health Related Issues
- Rainwater Collection from Pans, Rocks and for Ground Recharge
- Rainwater Catchment Systems Design, Construction and Training
- Community Participation / Implementation Strategies/Planning and Funding Projects.

The main findings and recommendations from each group are summarized below.

Group 1

Rainwater Catchment Systems for Schools/Housing Projects and other Institutions

It was noted that schools are the largest consumers of water in many communities, as primary schools have staff and pupil roles totalling almost 500 on average. Water is used for cooking, washing as well as drinking.

Since many schools experience periodic shortages of water it was proposed that all schools and clinics in Botswana should be provided with rainwater catchment tanks as standard by the responsible bodies i.e...

Primary Schools by M.L.G.L.H.
Secondary Schools by Ministry of Education/ D.A.B.'s
Clinics/Health Centres by M.L.G.L.H.

This should become government policy, be included in the designs of these facilities and carry a maintenance vote.

The group proposed a new appropriate design should be investigated and pilot trials carried out on a few selected schools which might help to convince policy makers of their viability. The end users should be involved in the maintenance of the systems.

Problem areas with severe water problems should be targeted to receive the first assistance resulting from such a project.

Group 2

ALDEP Tanks / Rainwater Harvesting for Agriculture

It was suggested that the present ALDEP designs were not satisfactory in a number of respects and a review of existing designs and pilot testing of any potential improvements was urgently needed.

The use of roof and ground catchments in combination was also recommended. It was also suggested that material excavated during tank construction could be used to build walls beneath the raised roof catchment structure to provide a simple dwelling.

It was proposed that a manual for farmers, A.D.'s and other extension workers needs to be produced giving more information about the effective installation, operation and maintenance of the ALDEP water tanks and refresher courses periodically provided. The Botswana College of Agriculture, the University and ALDEP agreed to work together to produce such a manual.

The current ALDEP package requires more promotion and a manual could substantially assist in this process.

With regard to Rainwater Harvesting for Agriculture it was felt that more research and dissemination of information on this topic was needed and any efforts in this direction should be supported.

Group 3

Rainwater Quality / Health Related Issues

It was suggested that there was a need to identify the type of health related problems derived from the use of rainwater and to determine the quality of water derived from different types of catchments (ground, rock, roof etc..) at a national level by carrying out physical, chemical and bacteriological analysis.

Using this information national standards could be set for rainwater intended for human consumption and other uses. Methods of meeting these national standards could then be investigated by relevant institutions who should be invited to develop these through incremental improvements.

Health extension workers etc.. should educate people in rural areas about ways to improve the quality of their drinking water.

Group 4

Rainwater Collection from Pans, Rocks and for Recharge

Pans:

The group agreed that the recent development regarding rainwater collection from pans was indeed very interesting and deserved more attention. Problems of water turbidity currently being experienced were considered as possible to solve using the application of an appropriate technique.

Rock Catchments:

The group concluded that while rock catchments have only a limited role to play in overall water provision in the country there are some areas of E. Botswana where suitable sites are available and where they could be of local importance.

Groundwater Recharge:

The use of using surface runoff for groundwater recharge has potential in Botswana but care needs to be taken to avoid contamination of aquifers resulting from surface pollution.

Group 5

Rainwater Catchment Systems Design, Construction and Training

Large ferrocement surface tank designs were considered as the most appropriate for construction at schools. Hundreds of 46m3 tanks of this design have recently been successfully built in Kenya and a similar programme is now starting in Namibia.

The design is both durable and cost effective and large storage volumes are needed in Botswana due to the nature of the rainfall.

It was proposed that 2-3 week courses should be held for builders at various brigades around Botswana. A number of Ministries should be encouraged to support and become involved with the implementation of these designs including:-

- M.L.G.L.H. through the district councils
- Ministry of Education
- Dept. of Architecture and Building Services

Rainwater Tanks should be included as standard on the design of public buildings, especially in rural areas.

Group 6

Community Participation / Implementation Strategies /Planning and Funding Projects.

It was noted that Community Participation was important in both project identification and the whole project cycle.

Implementation involves assembling the key actors local community groups, N.G.O.'s and Government and agreeing on all project related responsibilities.

- Provision of appropriate technologies
- Funding
- Training
- Extension
- Maintenance

The benefits to the community need to be confirmed.

There is also a need for a public awareness/training campaign.

ANNEX 4

Sites Visited during the Field Excursion on 2nd March 1993

Mmakgodumo Dam

The dam was constructed as early as 1937/38. However, there are some indications of a dam structure as early as 1913. The construction of the dam was done through an agreement with the local tribe for developing the area for horticulture. The construction was undertaken by labour intensive methods, only using oxen and some excavation tools in addition to hand digging for reaching the rock basement. To prevent the water from leaking eastward a wall consisting of iron beams a and concrete "lining" was erected on this side of the dam. Further, the collection area was improved by directing streams leading down towards the dam area, by implementing barriers and channels.

Makaba Primary School, Kanye

Although connected to the village water supply system, rooftop rainwater catchment systems have been incorporated onto most buildings, since the water supply is undependable. The catchment systems consist of several examples of corrugated iron above-ground tanks installed in 1982 and 2 cement tanks installed in 1991. None of the corrugated tanks are in operation due to rusting problems and the lack of rain gutters leading to the tanks. The cement tanks are in operation and provide a useful supplementary supply for drinking and cooking purposes.

Check dams along stream bed in Nyrosi-East Ward, Kanye

Several stone check dams were installed along the length of the stream in 1986. The dams were designed by an engineer and constructed by unskilled labourers as part of a drought relief project.

Mmamokhasi Dam

Farmers channelled a request through the Regional Agricultural Office to the Water Development Section. The dam was designed and constructed (1988) by the Min. of Agriculture. The Irrigation section of the Agricultural Office designed a downstream irrigation system to be served by the dam. The dam capacity is 8.21×10^5 m^3. The intention was also to water livestock. At present the main purpose is livestock watering and irrigation of a small vegetable garden project.

Pelotsetlha

This site has been a pilot area for the ALDEP (Arable Lands Development Program). This programme was originally intended for providing water for draught animals in the lands areas to allow early ploughing at the start of the rainy season. The ground catchment systems used traditional mud/dung threshing floors as catchment areas and with most ground catchment systems the quality of the water was very poor due to contamination of the catchment area by excrement from small children and animals. In response to this problem the Ministry of Agriculture developed the new design involving a raised corrugated iron sheet catchment area and a plastic polyethylene tank. The new ALDEP Water Tank design was observed at Pelotsetla. This has a purpose built $40m^2$ roof catchment area and a $10m^3$ ferrocement sub-surface catchment tank.

Twsidi

Two ALDEP Tanks were visited at households in the field, one using the traditional threshing floor catchment apron, the other the new purpose built $40m^2$ roof catchment. At both sites the tanks were full following the recent rains. A number of members of the excursion drank water from these tanks and no ill effects were reported!

ANNEX 5

Workshop Participants

Name	Organisation	Designation	Town/Area
Alexander P C.	Centr. Distr. Council	Architect	Serowe
Berth - Jones T.	Chobe Sub - District	Head of Water Dept.	Kasane
De Haan H.	Kgalagadi Distr. Council	Head of Water Dept.	Tsabong
Sebina M	Mahalapye Sub District		Mahalapye
Dihitso O	S/Phikwe Town Cuncil	Chief Architect	S/Phikwe
Mcinwa	SE Distr. Council	Chief Architect	Ramotswa
Masie P	Serowe/Palapye Sub District	Serowe	
Massic P	Southern Distr. Council		Kanye
Jakyoino W	Kanye Brigades Dev. Trust	Coordinator	Kanye
Rehnpen B.	Serowe Brigade	Business Manager	Serowe
Alıwah J.	BAC, Sebele	Lecturer	Gaborone
Mmolawa K.	BAC, Sebele	Lecturer	Gaborone
Mpuısang T	BAC, Sebele	Lecturer	Gaborone
Mhurıro F	MMphapula CJSS	Headmaster	Palapye
Mokgwetse T	Nata Primary School	Staff Member	Nata
Mazonde M	NIR,UB	Researcher	Gaborone
Acquah B.K	NIR, UB	Research Fellow	Gaborone
Showa A	Polytechnic	Lecturer	Gaborone
Dubbey J. M.	Polytechnic	Principal	Gaborone
Phale J	Polytechnic	Lecturer	Gaborone
Sinha P.K.	Polytechnic	Lecturer	Gaborone
Vaishnav T	Polytechnic	Snr. Lecturer	Gaborone
Letshwenic M	Polytechnic	Student	Gaborone
Motshidi M	Polytechnic	Student	Gaborone
Mphathiwa P	Polytechnic	Student	Gaborone
M Chapusa	Polytechnic	Student	Gaborone
Mashagane B	Polytechnic	Student	Gaborone
Odipile P	Polytechnic	Student	Gaborone
Donkor M.	Sebele	Senior Lecturer	Gaborone
Gould J.	UB	Lecturer	Gaborone
Linde L	Dept of Water Affairs	Systems Energy Advisor	Gaborone
Khupe B.	Dept of Water Affairs	Director	Gaborone
Jay B.	Dept of Water Affairs	Senior Water Engineer	Gaborone
Narang S B	MLGLH (Technical)	Chief Architect	Gaborone
Hagos M.	MLGLH, Water Unit	Chief Engineer	Gaborone
Hallam G	MLGLH	Training officer	Gaborone
Lwin N	MOA	Well Specialist	Gaborone
Mphathi M.	MOA	Senior Engineer	Gaborone
Kostov L	MOA	Chief Technical Advisor	Gaborone
Reetsang B. L. B	MOA	Head of Legumes	Gaborone
Chilume G.	MOA	Head of Agronomy	Gaborone
Semetsa S	MoA	Technical Officer	Gaborone
Kgwarape S.O.	MoA, Water Unit.	Chief Technical Assistant	Gaborone
Grant C	RIIC	Technical Director	Kanye

Rydtun B.	RIIC	Chief Water Engineer	Kanye
Moelenyane M.	RIIC	Technical Officer	Kanye
Mbewe M.	Thusano Lefatsheng	Research Coordinator	Gaborone
Kyin Wah	UNDP (FAO, MoA)	Civil Engineer	Gaborone
Nilsson G.	Sanitas	Director	Gaborone
Taylor F.	Veld Products	Director	Gaborone
Diphaha J. B.S.	Botswana Technology Centre	Managing Director	Gaborone
Gurusamy K.	BTC	Prinicipal Civil Engineer / Unit Head	Gaborone
Chishimba S.	BTC	Civil Engineer	Gaborone
Hunt G.	BTC	Senior Architect	Gaborone
Mookodi S.	BTC	Architect	Gaborone
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