HANDBOOK ON RAINWATER HARVESTING STORAGE OPTIONS

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LIST OF ACRONYMS

ATC	Appropriate Technology Centre
CBOs	Community Based Organisations
cm	Centimeters
BOQs	Bills of Quantities
DRWH	Domestic Rainwater Harvesting
EMAS	Escuela Movil de Agua y Saneamiento
GI	Galvanised Iron
GOU	Government of Uganda
IWSSCD	Interantional Water Supply and Sanitation Decade
Kg	Kilogram
m	Meters
mm	Millimeter
MWE	Ministry of Water and Environment
NETWAS	Network for Water and Sanitation
NGO	Non Government Organisation
No	Numbers
PC	Piece
PVC	Poly vinyl Chloride
RCC	Reinforced Cement Concrete
RWH	Rainwater Harvesting
Ton	Tonne
URWA	Uganda Rainwater Association
WHO	World Health Organisation

FOREWORD

The survival and development of human beings depend on water–its quality and quantity. Access to clean and safe water in Uganda is still low and this remains one of the developmental challenges. According to the sector performance report (2015) access to clean and safe water is 65% in rural areas and 73% in urban areas.

The current level of investment in water supply systems by Government and Development Partners is not sufficient to cope with the high population growth rate of 3.4 per annum and a result the coverage has stagnated over the years. New strategies are required if the National Development Plan (NDP2) and Uganda Vision 2040 targets are to be met.

Uganda is well endowed with high bimodal rainfall in most parts of the country. However, this resource has not been adequately exploited to improve water coverage. One way to address the challenge is by encouraging investment by the families, schools and health centres in rainwater harvesting storage facilities. The Water Sector has been promoting rainwater harvesting at household and institutional level as part of the self-supply strategy. However, the uptake of rainwater harvesting is still lower partly because of inadequate knowledge on available storage technologies.

This handbook is intended to be a practical reference guide on rainwater harvesting storage options for technical personnel, skilled masons and social workers involved in promoting the collection of rainwater at household, community and institutional levels. The Handbook provides step by step procedures in construction and installation of ferro-cement tanks, rainwater jars, underground masonry tanks, rock catchment and Escuela Movil de Agua y Saneamiento (EMAS) Tank. The Handbook also provides the installation procedures for catchment tanks, stainless tanks, corrugated iron tanks, and Bob rainwater bags. The Handbook provide a guide to maintaining the water quality as well as operation and maintenance of the water facilities.

It is hoped that the application of this Handbook will increase the uptake of rainwater harvesting in districts and ultimately increase the clean and safe water coverage in rural and urban areas hence contributing to the NDP2 and Vision 2014 targets.

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Hon. Ephraim Kamuntu

Minister of Water and Environment

1 INTRODUCTION AND BACKGROUND

1.1 Introduction

This handbook is prepared as a tool for promoting rainwater harvesting (RWH). The Handbook is intended to be a practical reference guide for technical personnel, skilled masons and social workers involved in promoting the collection of rainwater at household, community and institutional levels. Specifically, the handbook targets:

- Ministry of Water and Environment (MWE) Staff involved in promotion of RWH.
- District water officers and Extension workers.
- Private sector entrepreneurs, artisans and masons.
- Non-governmental Organisations/Community Based Organisations (NGOs/CBOs) staff involved in rainwater harvesting.

The proceedures in this Handbook have been presented as clearly and easily as possible so that even artisans with a basic knowledge and skill of masonry can follow them and master the techniques.

1.2 Objective of the handbook

The objective of the handbook is

- To transfer and instill construction skills on water storage structures within the beneficiary communities/individuals or institutions.
- To promote and improve on construction techniques, tank design and maintenance of the already known / existing rainwater storage tanks within the beneficiary communities.
- To act as a reference book for extension staff and artisans in using low cost technology methods during construction of rainwater harvesting storage systems
- To act as a reference book for the promotion of available rainwater storage options

1.3 Background

The survival and development of human beings depend on water; its quality and quantity. For ages, many people have been under the illusion that water is abundant, taking for granted that it is a gift from nature and is an inexhaustible resource that is there for the taking.

Safe water and sanitation coverage in Uganda is still low and this remains one of the biggest developmental challenges. It has been estimated that access to safe water within 1 km distance is 65% in rural areas (MWE, 2015). Access to safe water and sanitation services has not been equitably distributed to communities in Uganda due to lack of adequate surface and groundwater potentials in water stressed areas.

The goal of "Safe Water and Sanitation for All" set by the International Water Supply and Sanitation Decade (IWSSD) in the 1980s and now extended to the year 2030 may only be a distant dream at best if there is no increased investment in water supply.

One way to address this formidable challenge is to encourage investment by the families, schools and health centres. In the past this has been possible as families and some institutions would invest in traditional rainwater harvesting technologies that would range from pots to jars to tanks, to provide convenient water supplies that they manage and maintain themselves. Many rural people value these water sources for their convenience, taste, productive use and most importantly, the actual ownership and control bestowed. Relatively small investments by families could thus add up to the massive investment needed to reach the national target on safe water access.

Rainwater harvesting through roof catchments is being promoted in the Water sector because it is an optimal method, affordable and manageable by communities in the water stressed areas both at household and institutional levels through construction of rainwater harvesting tanks, mobilization of communities, sensitization and advocacy and training of the private sector to enhance and boost on their skills in RWH tank construction and its management.

The uptake of rainwater harvesting in all Districts in Uganda is still very slow. Very few families or even schools and health centres have been able to take up the technology as a viable option for provision of water. Moreover, Uganda is endowed with high levels of rainfall in most parts. According to the Uganda Bureau of Statistics, National household survey (2009/2010), at least 62% of houses in Uganda had an iron roofs and hence can harvest rainwater. Rainwater harvesting particularly through roof catchment, is being promoted because it is an optimal method, affordable and manageable by the low-income community members both at household and institutional levels.

The MWE would like to promote rainwater harvesting in every family and institution through provision of this Handbook. The objective of the Handbook is to provide communities and Institutions a range of rainwater storage options that can be promoted in various parts of Uganda. Under each technology option technical details on design, materials, tools required, construction guidelines/steps, and estimated costs, among others, are provided.

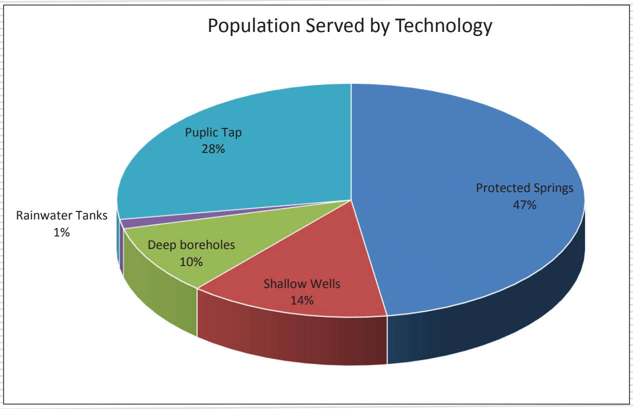
1.4 History of Rainwater Harvesting in Uganda

Traditionally, communities and private individuals have owned and managed water sources with minimal government support. Rain water harvesting technologies which included banana stems and collection in containers like saucepans and pots were very common. During the colonial period large water storage systems were particularly constructed at administrative buildings.

The year 1997 witnessed the unsuccessful re-introduction of institutional rainwater harvesting collection. The limitations in managing these facilities led to the shift to household collection and storage (Domestic Roof water Harvesting). In the same year, the Uganda Rain Water Harvesting Association (URWA) was established in the sector to promote Domestic Roof water Harvesting technology and has done much to raise awareness and identify potential and technical solutions.

The years 2003 – 2004 the GoU prepared a strategy for rainwater in Uganda, centering on promotion and capacity building of communities and the development of enterprise to provide facilities. It divided the promotion of the technologies into an NGO delivery mode, involving promotion and capacity building of communities and a private sector mode, which is based on the development of enterprises to provide facilities. Domestic Roof water Harvesting started to be included in the activities of other NGOs throughout the country. Most of these organisations were building facilities for water users. Some were training masons and women's groups to construct facilities. The usual concept was to support the masons to construct demonstration facilities to trigger other households to invest their own financial resources in them. Traditional savings groups, with revolving loans were among the strategies used by households to finance construction. In 2004 MWE further supported the piloting of Domestic Roof Water Harvesting, through NGO delivery mode, sending a signal of growing government support of technology.

From 2006 to date, District Local Governments were allowed to construct demonstration Domestic Roof water Harvesting facilities and train masons from their Water and Sanitation Conditional Grant (funding transferred from central to local government specifically for water and sanitation project implementation by District Local Governments). Domestic Roof water Harvesting was first included in national safe water coverage estimates in 2006. District local governments have continued to construct Domestic Roof Water Harvesting facilities from 2199 in 2007/8; to over 41,000 in 2014/15.



In the Financial Year 2010/11 a comprehensive self-supply guiding framework was developed and is currently being operationalised. One of the strategies in the framework include production of a set of guidelines on options for water source improvements for Domestic Roof Water Harvesting technologies.

1.4.1 Description of Rainwater Harvesting

Rainwater harvesting is the collection, storage and use of rainwater. It refers to the act of collecting rainwater together from catchment surfaces such as iron sheets (hard roofs), grass thatched roofs, polythene papers/tarpaulins, trees, rocks, and artificial paved surfaces.

The storage refers to putting the collected rainwater into containers where it can safely remain for some time until when it is required. Common storage facilities include drums, jerrycans, pots, saucepans, basins, tanks, polythene sheets, ground surface/ditches, troughs, ponds, and rocks (Figure 1).

There are various uses of rainwater including domestic chores (drinking, washing, cooking, bathing), industrial (construction), and farming (Figure 2).

igure 1: Common storage facilities of rainwater in households

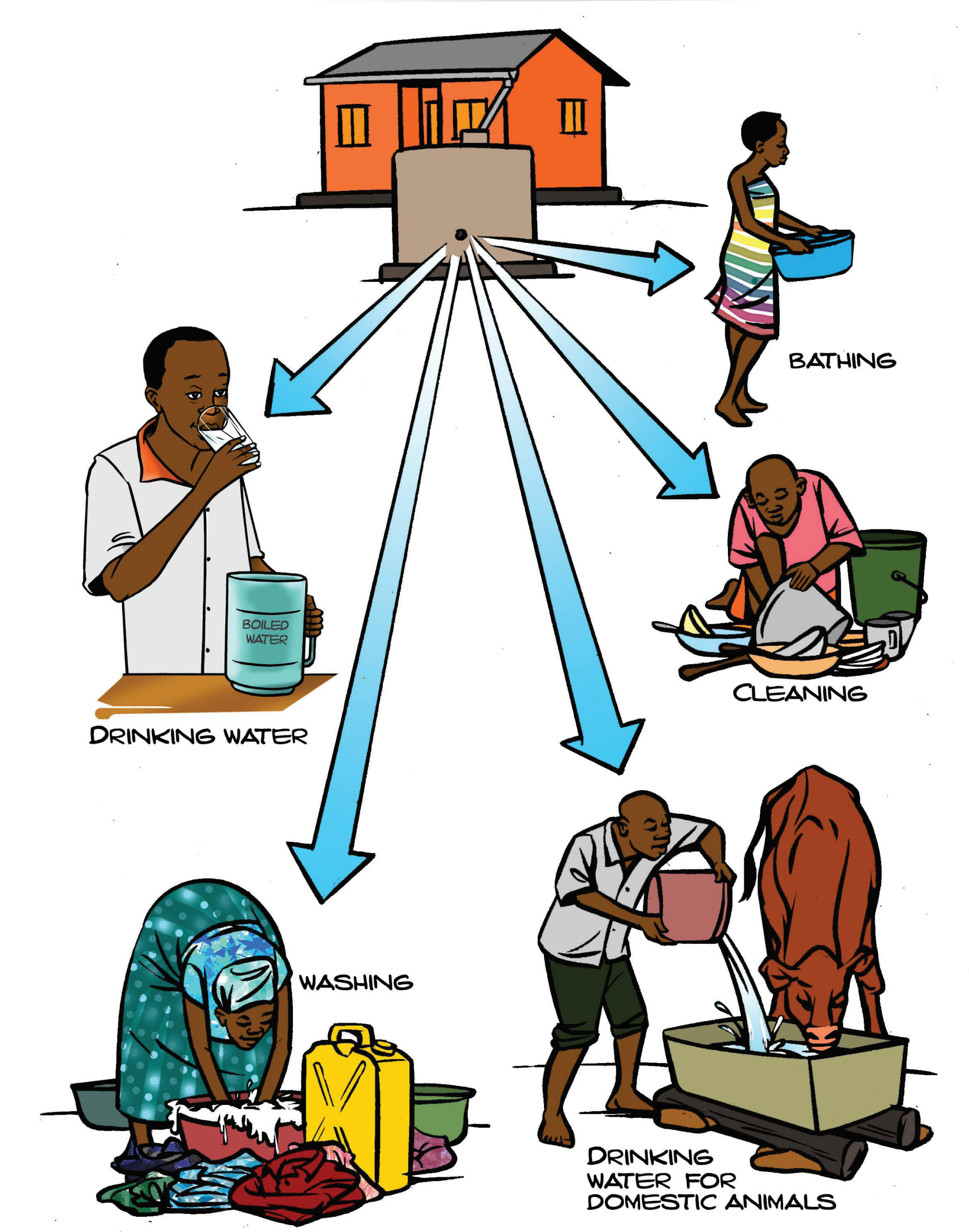


Figure 2: Uses of Rainwater

1.5 Advantages and Disadvantages of Rainwater Harvesting

1.5.1 Advantages

There are a number of advantages from rainwater harvesting as a low-cost technology for household and institutional water supply.

I. It is affordable for low-income communities.

II. Beneficiaries have improved water security, better quality of water and majority of the technologies are user friendly and have a long life span of over 10 years (URWA Bulletin August 2005).

III. Time is saved from collection of water from other conventional sources (springs, boreholes, shallow wells). This is a key benefit for women and children especially the girl-child who bear the burden of collecting water for the family.

IV. Localizing water facilities at household and institutional levels provides a better opportunity for proper operation and maintenance and utilisation of water facilities by users themselves.

V. During the wet seasons, the presence of rainwater storage within the compound would encourage the household and institutions to use more litres per person per day with the corresponding associated health benefits.

VI. Opportunity for skill development and income generation among individuals such as masons (Figure 3)

VII. There are associated health benefits as a result of access to safe water.

VIII. Promotes agriculture production hence generating income for many households

IX. Water from Domestic Rainwater Harvesting (DRWH) tanks is comparable in cleanliness to that fetched from protected rural point sources, averaging faecal coliform counts of around 10 per 100 ml (just about WHO 'low risk'). Chemical quality and laundry-softness is superior and taste generally is superior to water from rival sources. Affordable techniques are known by which quality can be further improved if required (URWA, 2006).

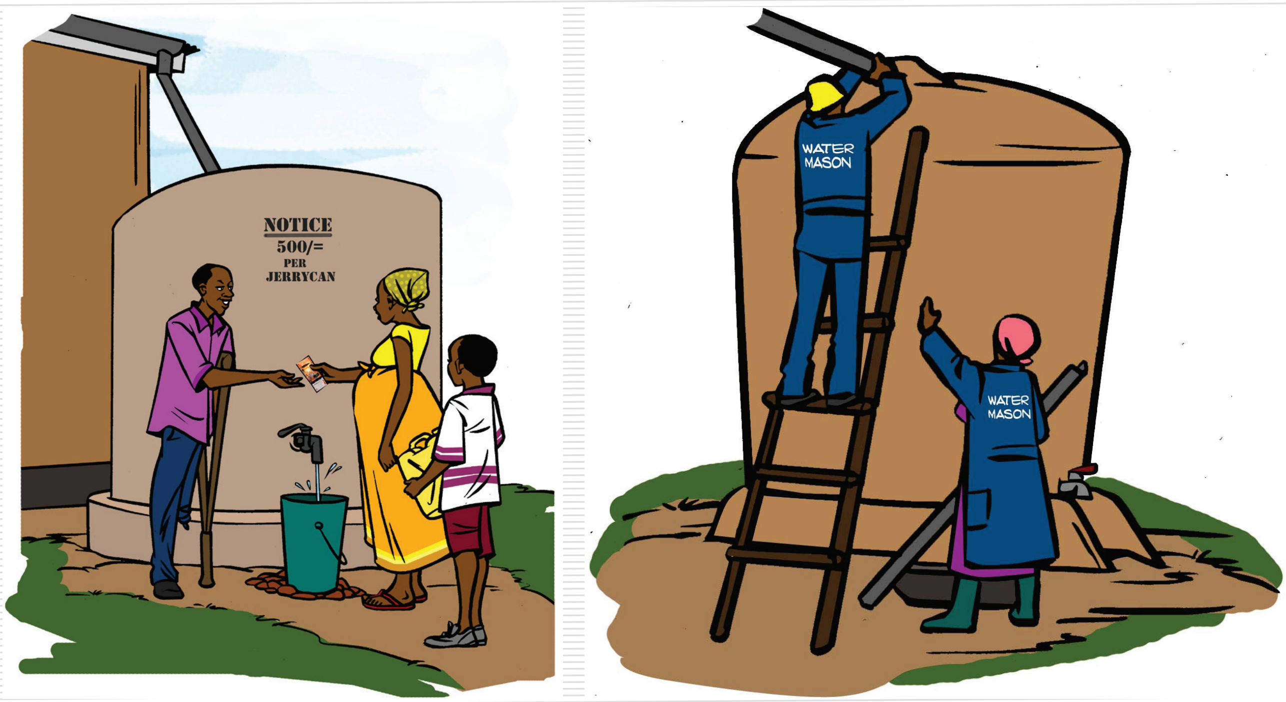


Figure 3: Rainwater harvesting creates income as well as jobs for masons

1.5.2 Disadvantages

(i) Storage systems are expensive and not affordable by many households.

(i) Depends on seasons – may not provide water throughout the year.

(ii) The quality of rainwater is affected by cleanliness of the catchment surface.

(iii) Domestic roof water harvesting is a house-by-house technology compared to communal sources and therefore benefits only a household.

(iv) Communal rainwater harvesting is not easily feasible because communal roofs are grossly inadequate nor desirable (primary advantage of convenience is lost).

1.6 Rainwater Patterns in Uganda

Uganda, which is astride the equator in the hinterland of Tropical Africa, is endowed with plenty of rainfall (Figure 4). The annual rainfall ranges from about 650mm in the northeastern region to about 2,200mm over Lake Victoria basin in the central region. Uganda has two wet seasons commonly referred to as bimodal. The rainy season is from March till May and October till November. Light rain season falls in November and December. Dry seasons are from December to February and June to August.

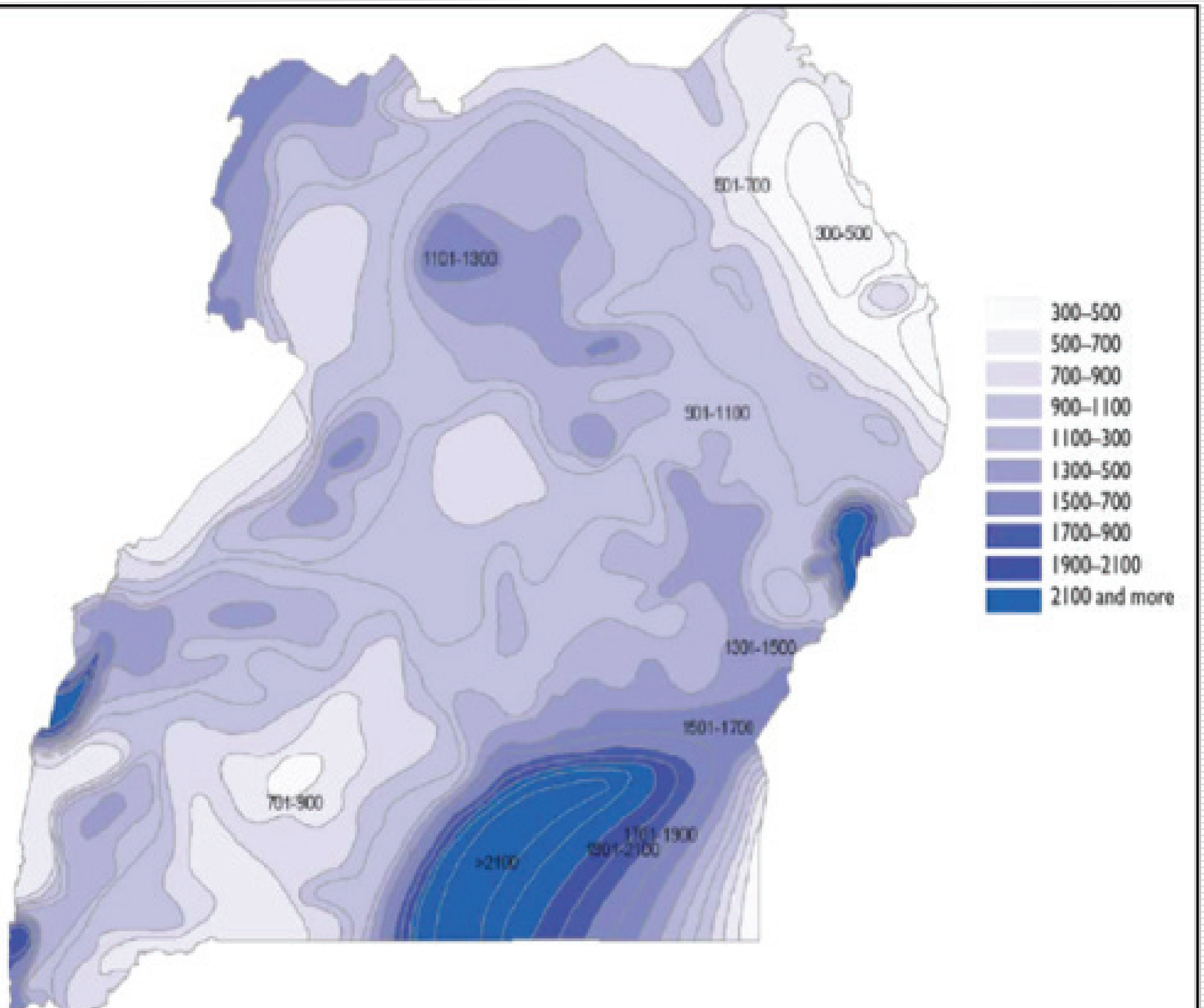


Figure 4: Average Annual Precipitation in Uganda, (mm/Year) (Source: USAID 2013)

2 CONSIDERATIONS WHEN SELECTING RAINWATER STORAGE SYSTEMS

2.1 Selection of Storage Options

The selection of a particular tank depends on the following parameters (NETWAS, 2008);

(i) Cost (affordability) of the tank (Figure 5)

(ii) Tank capacity

(iii) Purpose of which the tank will be used (Domestic, Institutional or production).

(iv) Location in relation to the plot of land – hence can be either above ground or underground.

(v) Availability of materials for construction of the tank

(vi) Availability of technology and skilled manpower in the village

(vii) Appearance (design of the tank)

(v) Catchment i.e. size of catchment area or artificial paved catchment

(vi) Type of soils bearing capacity

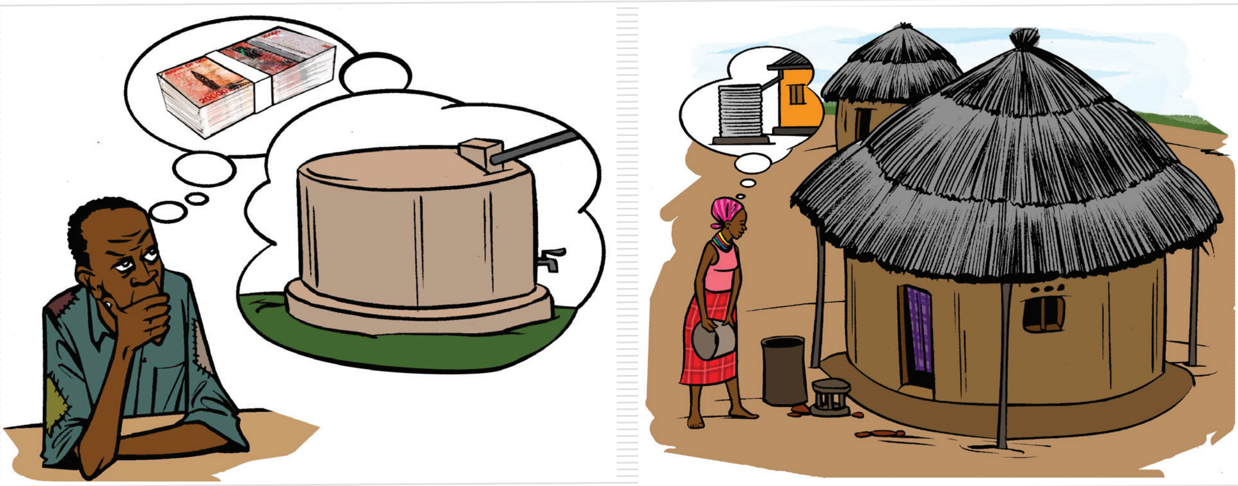


Figure 5: Cost of the tank and catchment system determines choice of facilities

2.2 Siting of Storage Systems (tanks)

When siting or locating the position of a tank, the following should be put into consideration:

(i) Leave a distance of 1.5m from the existing building (Figure 6). This enables plenty of working space during construction and the stability of the house not to be tampered with. This distance can however be reduced in areas with very firm/rocky soils or if the tank capacity is small i.e. less than 4,000 litres.

(ii) The slope of the roof of the building. When built on the upper side of the slope, gutters will not be able to capture all the water from the roof efficiently.

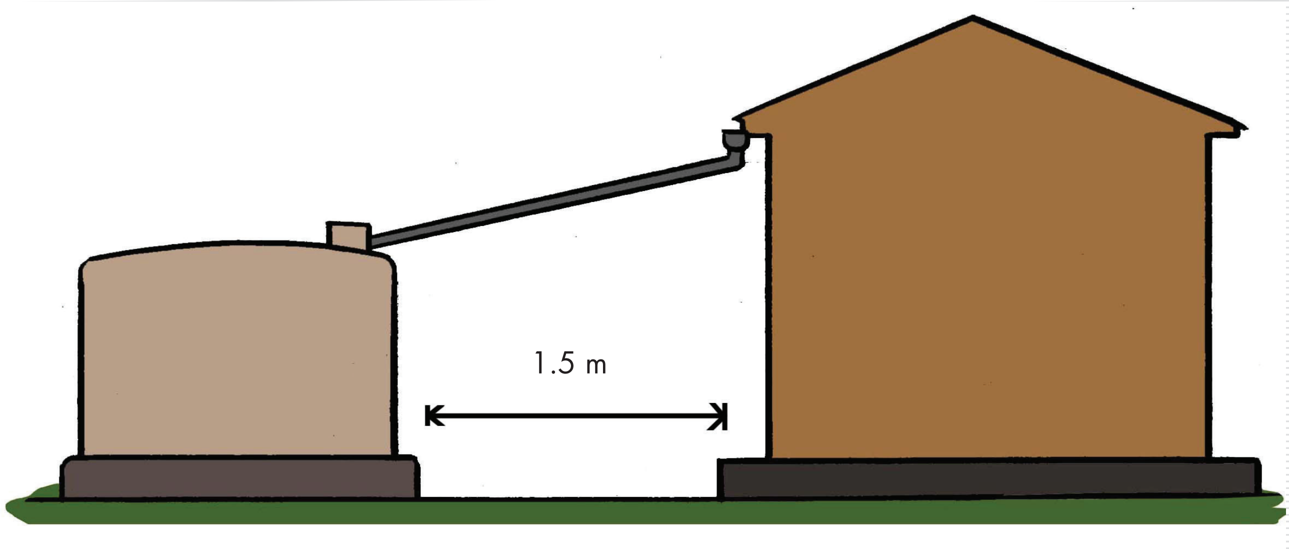


Figure 6: A distance of at least 1.5m should be left from the existing building

(iii) Height of the tank. This is limited by the following:

- The type of tank used e.g. for Ferro-cement tank, heights more than 2.0m require more reinforcements thereby increasing the cost of construction.
- The roofs of most buildings are 2.5 – 3.0m high and when the height of the tank exceeds 2.0m, it will be too difficult to install gutters for easier flow of water into the tank.

2.3 Sizing the Tank

Tank sizing is important in determining the optimum capacity of a tank for a particular water demand, catchment area and amount of rainfall available.

When a tank is sized correctly, it avoids wastage of materials in building a tank that is too large and will never fill, or building a tank that is too small and always overflows. A right size capacity of tank should provide enough water throughout the dry season (3 months).

The critical design parameters for tanks are:

- Rainfall data (mm).
- Catchment area (m^2).
- Daily water demand (number of people using tank x daily per capita consumption).
- Length of dry spell.

Below is the example giving calculations of water requirement per day per household size

Example:

Assume 5people in a family, each using 20 litres per each day,

Amount of water required daily	=	5 x 20
Amount required for the three months (90 days)	=	5 x 20 x 90 days
	=	9,000 litres

The volume of the tank required to store water should be 10% larger to provide allowance 'dead' storage at the bottom where rubbish collects and a free board on top for air circulation,

Additional storage capacity is therefore	=	10% x 9,000 litres
	=	900 litres
Total tank volume is therefore	=	9,000+900 litres
	=	9,900 litres
	=	approx. 10,000 litres

Roof Catchment Area (hard roof):

Most single unit residential houses in Uganda are built with the roof covering 7m x 12m of land area.

The area of roof catchment is therefore	=	7m x 12m
	=	$84m^2$

When 1mm of rain falls on a hard roof of 1m x1m, the total volume of runoff = 1 litre. Therefore for an average annual rainfall of 1.000mm (for Uganda), the amount of water that can be collected from the 7m x 12m in a year would be:

Amount of water per year	=	7m x 12m x 1,000mm
	=	$84m^2$ x 1,000mm
	=	84,000 litres

Note: Average annual rainfall ranges from approximately 500 – 1,200mm in Uganda. The average length of the wet season is about 5 months meaning you can collect 84,000 litres over the (5 month) wet season or 16,800 litres each month of the wet seasons. Over the dry period (3 months), a family of five would need about 9,000 litres of water. If, in the last month of the wet season, the family had managed to collect all the water, it would mean they have 16,800 litres of water , which is more than needed through the dry period.

It should also be noted that in regions where the average rainfall very low i.e. less than 600mm, the family of 5 would require a larger tank capacity to store more than one month of wet season rainfall to meet the dry season demand. Alternatively a larger roof size would be required to collect the amount of water needed in the dry season. ***See Annex: 1***

As stated above, the key factor in determining the capacity of tank is the need to have the amount of water required to meet the dry season demand in storage at the end of the rainy season. For a given number of beneficiaries, this factor is affected by the amount of rainfall and the size of the catchment area.

2.4 Guttering

The installation of gutters on roofs should take into consideration of the following:

(i) Gutters should be of either square or half-circular section made from PVC or galvanized iron sheet metal (Figure 7).

(ii) Gutters should be put in position using gutter brackets, made from PVC or metal stripes fixed to the fascia board of the building.

(iii) The slope of the gutter towards the water tank should be such that there is a drop of about 10cm for every 10m run (i.e. 1% slope). For very long gutters (>15m) fixed on fascia boards, the slope can be varied such that the first half of the gutters is laid at 0.5% slope and the rest at 1% slope to maintain reasonable gap between the gutter and the edge of the roof.

(iv) Starting from the end nearest the tank, gutters should be laid into the brackets so that the next gutter sits inside a previous one with a 20cm overlap. The overlap shall be made stable by applying a bituminous paint between the two overlapping gutters. The brackets should be positioned such that it falls in the centre of the overlap. Plastic gutters have customised, water tight connectors that doesn't not require overlap.

(v) The end of the gutters toward the tank should be provided with a down pipe and a purpose made first-flush system.

(vi) The ends of the gutter should be blocked with stoppers to reduce water loss.

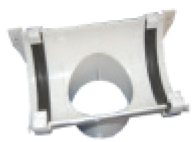
 Stop end outlet	 Gutter support bracket	 Gutter down pipe clips	 PVC gutter
 Gutter fittings Clamp	 Gutter Joint Bracket (Connector)	 Gutter Short Stop End	 Gutter Running Outlet

Figure 7: Different forms of uPVC roof gutter and fittings (grey type) found on local markets in Uganda

2.5 Provision of first flush system

- Many contaminants find their way into the tank from the roof. Waste from birds, rats, cats, lizards, leaves and other debris wash into the tank. This introduces harmful bacteria into storage water system, which can cause serious illness.

- In order to avoid this, routinely sweeping of the roof and removal of debris from gutters is required. The first flush system removes the first 50 to 100 litres of rainwater and directs it away from the storage tank. As a rough guide, the minimum storage capacity of a first flush device should be equivalent to 1mm of rainfall over the catchment area developed i.e. 1 litre of storage per square metre of catchment.

- Simple first flush diverters require active management, by draining the first flush water volume following each rainstorm. First flush diverters may be the preferred pre-treatment method if the water is to be used for domestic purposes.

- The different forms of down pipe designs to avoid inflow of debris, sand, leaves and bird droppings during first rainfall are shown in (Figure 8).

Figure 8: Different forms of first flush designs used in rooftop catchment to avoid the 1st dirty water of the rain (Photos from ATC)

- Other forms of first flush system include a small vessel installed before the main storage tank to store up to 1,000 litres of first flush water depending on the size of the catchment area (Figure 9). The first flush water is used for non-potable purposes like washing, cleaning, and gardening.

Figure 9: Large capacity first flush device with washout valve for easy operation

2.6 Water Quality Management

The requirements for the management of rainwater quality are as follows:

- Fitting the tank with first flush system to improve the bacteriological and physical quality.
- Cover the tank and provide filtration screens to prevent debris, leaves, insects, and rodents from getting into the tank.
- Regular cleaning of catchment surface and gutter (Figure 10).
- Tree branches hanging over the roof should be trimmed to reduce dry leaves, bird's droppings falling onto the roof.
- Correct installation of gutters to avoid water pooling and collection debris.
- Prevent or minimize light penetration into the tank to avoid growth of algae and other biological activity.
- Testing/monitoring water quality informs users of risks of contamination.
- Cleaning the tank from inside at least twice a year or every start of the rainy season (Figure 11).
- Do not allow children to climb onto the tank.
- Water disinfection with chlorine to make water safe for drinking (**Figure 12**).

Where first flush devices are not installed or operated properly, the storage tanks and jars should be cleaned regularly e.g. once every 3 months or at least at the beginning of every rainy season. Gutters and covers should be cleaned periodically after leaf fall; and soak pits dredged at least once a year.

Figure 10: Gutters and covers should be cleaned periodically after leaf fall

Figure 11: Jars and other storage containers need regular cleaning inside

Figure 12: Water disinfection with chlorine to make water safe for drinking.

- The down pipe should point away from the tank/ first flush device during the dry season and during the first downpour of the wet season, which will flush debris off the roof. After that, the down pipe should be set to fill the tank from the second and subsequent downpour.
- The tank wall should always be observed closely and when small cracks are identified the rest of the community should be notified (for a communal tank). Some cement should be obtained to fill up the cracks. When this is not done, cracks will become bigger and one time the tank break and the water supply will collapse.
- The access hatch for the tank should be well secured/sealed to control access into the tank, which should only be granted for repairs or maintenance.

2.7 Conserving Rainwater

It is very important to use rainwater sparingly to avoid wastage and drying up of the tank. Installing well-calibrated depth gauge on the tank helps to monitor water availability and prioritising use for critical needs in times of scarcity.

A number of reasons contribute to fast emptying of tanks:

(i) Unregulated usage of water that can lead to wastage.

(vii) Inadequate monitoring of water level in the tank before the rains stop and during the dry seasons (Figure 13)

(viii) Water being used for non-priority needs during the dry season instead of for critical demand like drinking and cooking.

(ix) Inaccurate estimation of water demand.

(x) More water being used than what the tank is designed for – people being unaware of how much they should be using.

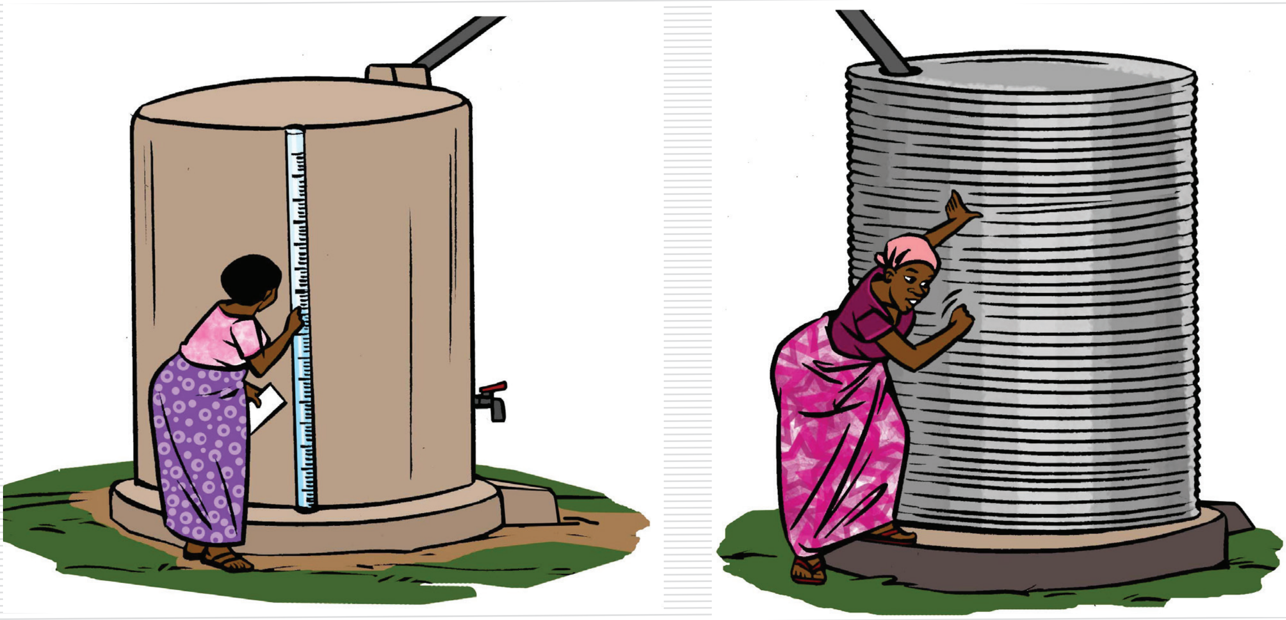


Figure 13: Ways on how to know the level of water in the tank

Table 1. Gives a usage pattern that can be used to ensure that the water in the tank remains up to 2 months in the dry season.

Table 1: Best Practices for conserving rainwater

Period	Amount to Draw	Good Practices
Feb to May & Sept to Dec	Up to 6 jerry cans	Use first rains to flush and clean the tank, roof and gutters. Place padlock on tap, collect overspill, ensure gutters are fitted properly, save money to increase gutters.
May to June (when rains begin to reduce)	Up to 4½ jerry cans	Regularly check level of water in tank. Try to ensure tank remains at a high level for the beginning of the dry season. Do this by: conserving water where possible, ensuring whole roof is guttered, collecting and using overspill/overflow. Make sure tank is clean before storing water for the dry season.
June/July/ Aug (Months will vary yearly)	Up to 3 jerry cans	If tank is full at the beginning of the dry season and only 3 x 20 litres water is used every day, the tank can provide potable water for two complete dry months or more if less is abstracted. Ensure tank is scrubbed clean before next rains arrive.

NOTE: A piezometer (Transparent horse pipe) would also be used to determine the water levels in the tank. This is effected by fixing the horse pipe at the tap, holding it upright as you open the tap and superimpose it on the tank wall that is calibrated with figures of water volumes in the tank (in form of jerrycans).

Additional guidelines:

- Lock and fence tank
- Ensure the tank is full or at a high level at the beginning of the dry season
- Users should ensure that gutters are fitted properly including being higher than the bottom of the roof to catch spillage, no leakages and lie on a slope of 1 in 100 so that maximum rain is caught
- Users should be encouraged to save for an extra guttering if their roof can take it as tank is more efficient with more roof area especially towards the end of the wet season when rains are less frequent and there is a need to catch as much water as you can so that the tank is full at the beginning of the dry season.
- Users should get into the habit of checking the level of the tank. They should be managing their water abstraction according to the level of the tank, not the month when they think the rains will stop to avoid empty tanks in years when the dry season starts early.

Replacement of parts:

Maintenance of parts like taps, basin (cover) washout, down pipe and gutters is essential. In instances when they break down, they need replacement most especially it would be better to replace in dry season.

3 RAINWATER STORAGE TECHNOLOGIES

3.1 Ferro-Cement Tank

3.1.1 Description

Ferro-cement (Figure14) is essentially an extension of conventional reinforced cement concrete (RCC) technology. However, there are advantages that make ferro-cement a preferred choice. It is a thin-walled construction consisting of rich cement mortar with uniformly distributed and closely spaced layers of continuous and relatively small diameter mesh (metallic or other suitable material).

Compared to other cement concrete structures, those made of ferro-cement are lightweight, tough, durable, crack resistance and can be made into virtually any shape. It is a low technology construction in that it does not necessarily require highly skilled labour and complex construction methods, sophisticated or heavy equipment or manufacturing in a plant, and yet a good performance in construction can be achieved. It is cheaper than other concrete or masonry constructions and can easily be repaired, if necessary.

3.1.2 Drawings

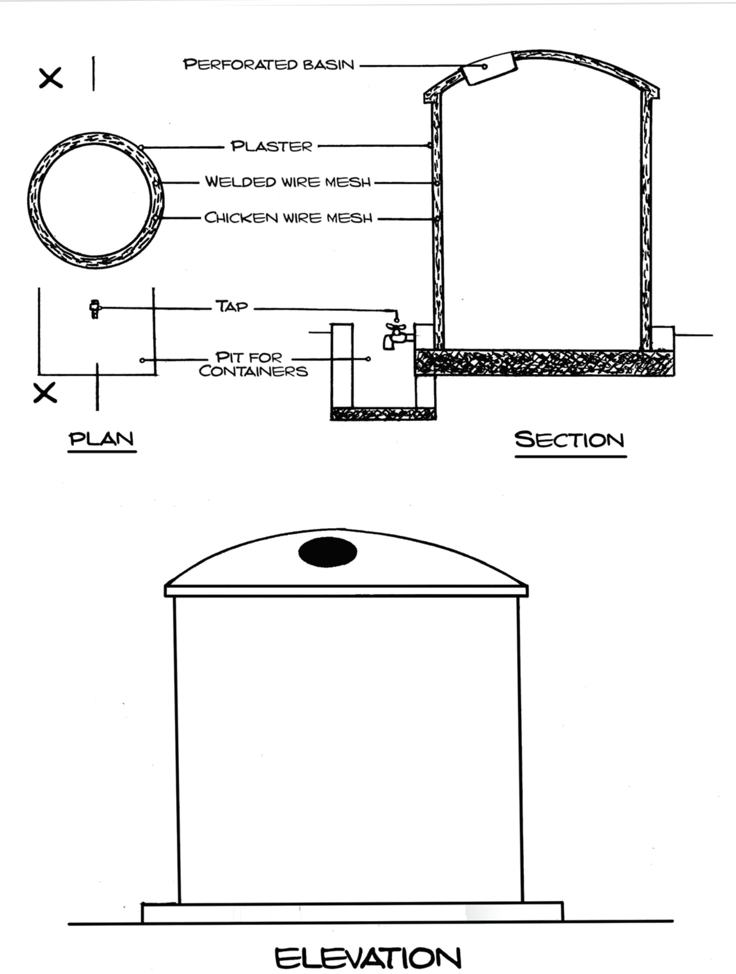


Figure 14: Ferro-cement tank drawings

3.1.3 Construction materials

The key materials required for constructing a ferro-cement tank are:

- Cement
- Chicken
- Wire mesh
- Medium grain
- Sand (0.15 – 2.5mm)
- Aggregate (3/4")
- GI pipes and fittings
- Tap
- Hard core
- Bricks and
- Water.

The quantities for the tanks ranging from 2 to 50m^3 are shown in Table 2.

Table 2: Construction materials required for Ferro-Cement Tanks

Item	Unit	2 m³	5 m³	10 m³	20 m³	30 m³	40 m³	50 m³
Portland Cement (50 kg)	Bag	6	10	15	23	32	40	50
Water proof (leak seal) cement	Kg	3	6	7	12	16	20	23
Lake sand	Ton	2	3	4	6	8	10	12
Fine sand	Ton	2	3	4	6	8	10	12
Bricks (well burnt)	Pc	60	80	100	140	200	280	350
Hardcore	Ton	2	3	4	6	8	10	12
Aggregates	Ton	2	2	3	4	4	5	5
Chicken Mesh (3/4″; 3′ wide)	M	15	20	25	35	45	55	60
Expanded mesh (2′ x 6′)	Pc	0	0	6	11	16	22	28
BRC mesh (2.1m wide)	M	6	8	12	19	27	36	46
Binding Wire	Kg	3	5	7	12	12	14	14
Coffee Mesh	M	2	2	2	2	2	2	2
GI pipe (3/4″)	M	1	1	1	1	1	1	1
GI Elbow (3/4″)	Pc	1	1	1	1	1	1	1
GI Reducing Socket (3/4-1/2″)	Pc	1	1	1	1	1	1	1
Lockable Tap (1/2″)	Pc	1	1	1	1	1	1	1
GI pipe 1 ¼″	M	1	1	1	1	1	1	1
GI Socket 1 ¼″	no.	1	1	1	1	1	1	1
GI Plug 1 ¼″	no.	1	1	1	1	1	1	1
GI Elbow 1 ¼″	no.	1	1	1	1	1	1	1
Manhole covers	no.	2	2	2	2	2	2	2
Polythene	M	7	8	12	20	28	37	45
Poles (6m)	Pc	4	4	10	14	20	24	30
Papyrus (6x4ft)	Pc	2	2	3	4	5	6	7
Water	Litre	500	800	1,200	2,000	3,000	3,500	4,000
Skilled labour	Man day	4	6	8	12	12	14	14
Unskilled labour	Man day	4	6	8	12	12	14	14

3.1.4 Equipment and Tools

The tools required to construct Ferro-cement tank are show in Table 3 below

Table 3: Tools required in construction of Ferro-cement tank

Tool	Quantity
Wheel barrow	1
Spade	1
Hoe	1
Trowel	2
Spirit levels	1
Measuring tape	1
Batching box	1
Mortar pans	2
Wooden floats	2
Steel float	1
Metal float	1
Building line string	1
Pliers	1
Wire cutter	1
Hack saw	1
Hammer	1
Hand saw	1

3.1.5 Construction steps of Ferro-cement tanks

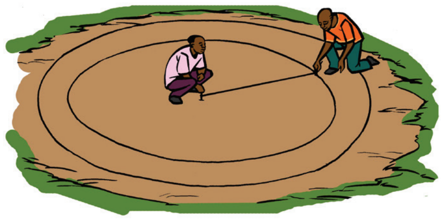
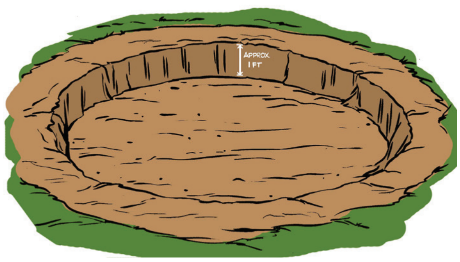
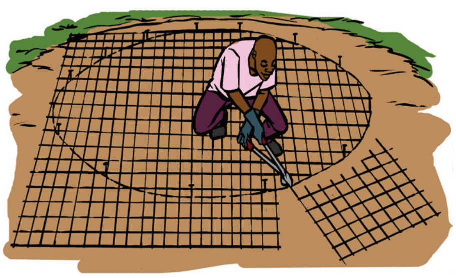
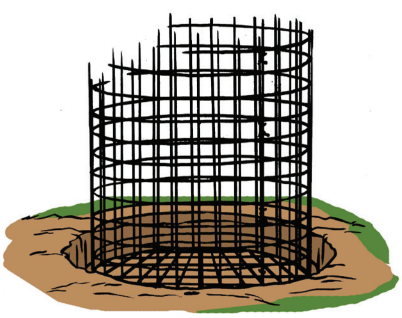
Ferro-cement tanks are usually set to stand at ground level or on elevated base depending on site conditions or preference of the beneficiary. The construction methods are principally the same but additional features like soak pit would be mandatory for the ground level tank to dispose of waste-water. The construction steps described below are for tanks installed at ground level.

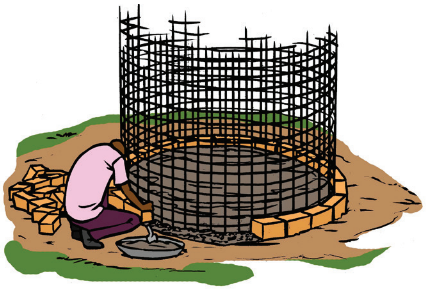
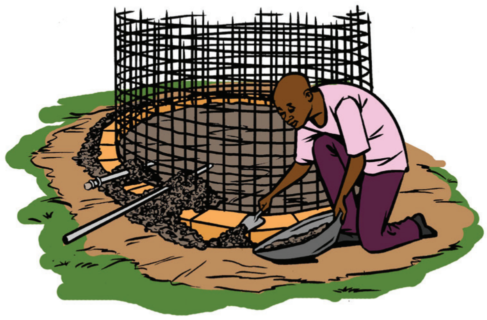
Step 1: Site preparation

- Clear the site of vegetation, tree stumps etc.
- Level the ground to make even

Step 2: Construction of Tank Foundation

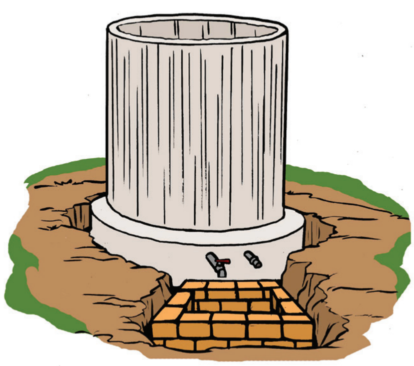
The following are the steps in constructing ferro-cement tanks:

 **(i) Setting out the tank base as per design** **(ii) Excavation of the foundation** 	• Drive a peg into the ground in the middle of the selected site; • Tie a string on the peg; • Measure the distance from the peg to the wall (radius) as per the drawings and add 15cm to mark the radius of the base; • Tie a 5" nail on the string at the point of the base radius and draw a circle around the peg. • Excavate the area inside the circle at least 30cm deep up to firm soil; and ensure that the bottom is well levelled.
 **(iii) Preparing the floor mesh**	• On a levelled ground, draw a circle as in (i) above with a radius 10cm longer than that of the tank wall to determine the size of the floor mesh; • Lay the wire (BRC) mesh over the circle drawn on the ground; • Cut out the round shape of the base mesh.
(iv) Erecting wall mesh 	• With the peg at the centre of the excavated area, draw a circle as in (i) above with the radius of the tank wall; • Put nails around the circle at 30cm interval; • Place the floor mesh in the excavated area and position it over the marked circle; • Erect pieces of welded (BRC) mesh vertically along the wall circle marked by nails in the excavated area; • Use binding wire to tie the wall mesh onto the floor mesh.
(xi) Concrete works 	• Place compacted hardcore base in the excavated area up to about 15cm from the top; • Prepare concrete of mix 1:2:4 (by volume); • Pour the concrete onto the hardcore bed up to about 5cm thick and level it; • Place the weld mesh cage prepared in (iv) above on the concrete layer; and • Pour the concrete over the floor mesh and fill it up to ground level.

 (vi) **Brickworks**	• Construct one course of brick wall around the the cage about 5cm from the wall cage.
 (vii) **Installing washout tap pipes**	• Pour some concrete on top the brick wall; • Place the washout pipe and the delivery pipe on the concrete; • Pour concrete on the inside and outside the cage to cover the pipes and compact well.

Step 3: Construction of Tank Walls

(i) Wrapping the chicken wire mesh 	• Wrap the chicken wire mesh tightly around the wall cage with the sides and ends overlapping at least 15cm; • Wrap the galvanised wire continuously and tightly over the chicken mesh ensuring that the spacing between the wires corresponds to the design; • Secure the galvanised wire on the wall cage using binding wire at intervals to maintain the tightness and spacing.
 **(ii) Wrapping the sack/mat**	• Wrap the wall cage with a sack or mat to support the mortar during plastering; • Fasten the mat tightly on the cage with strong wire or string; • Check the wall mesh for verticality and correct where necessary by pulling with binding wires tied on pegs driven into the ground around the tank.

(iii)Plastering works 	• Prepare mortar of ratio cement : sand : water = 1:3:0.5(by volume) using clean, sieved sand adding water proof cement as specified; • Start plastering from the inside pressing1.5cm thick mortar into the wall mesh against the mat; • Let the mortar set for 24 hours then apply the second layer (1.5cm thick) pressing hard on the first layer; • Apply 2.5cm mortar screed on the floor and smoothen; • Apply 5mm cement screed on the floor and wall to finish on the inside; • Remove the sack/mat and cut off excess mortar to leave even surface.
(iv) 	• Prepare mortar (as above) and press about 1 cm thick layer on the outside; • Apply the second layer (1cm) on the outside after 24 hours and trowel smooth to finish; • Constantly pour water on the mortar and screed for at least 7 days to keep damp at all time for proper curing.
(v) Water draw-off box 	• Construct a box to accommodate a 20 litre jerrycan drawing water from the tank; • The box should also be large enough to allow for future maintenance and repair works on the tap.

Step 4: Constructing Tank Cover/Roof

Two methods can be used to construct the tank roof (Figure 15):

- Constructed directly on the tank using expanded mesh placed on weld mesh. This is suitable for large capacity tanks (i.e. >8,000 litres).
- For smaller capacity tanks, the cover can be pre-cast on the ground and then lifted onto the tank where it is then finished.

The method described below is for the precast tank cover used in small to medium size tanks.

(i) **Preparing mould for tank cover**

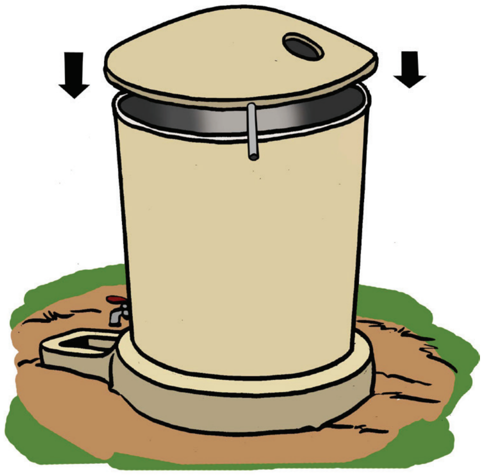
	Mark out a circle of diameter equal to the central diameter of tank wall on a levelled ground
	Heap and compact soil inside the circle to form a uniform dome about 22 – 25cm high at the centre (depending on the size of the tank).
	Cut and place chicken mesh on the curve joining the pieces by hooking with the cut wires on the edges to make it lie flat on the curve.
	Then cut, shape, and tie galvanised wire as reinforcement for the roof over the chicken mesh pressing it down with binding wire hooks driven into the ground; the access hole should be marked out with a ring (50cm diameter) made of galvanized wire.

Figure 15: Dome made of compacted soil for cover mould (left) and reinforcement wires placed over chicken mesh.

(ii) Plastering the Cover

Apply about 2cm of well compacted mortar (cement: sand ratio of 1:2 by volume) all over the surface excluding the access hole and cure as specified.

Note *that the tank cover should be made during the first days of construction to give enough time for it to dry/set adequately for lifting.*

(iii) Covering the Tank

- Lift the dry cover (after at least 5 days), wash it, and place it on top of the tank wall (Figure 16).
- Trim off excess mortar and mesh on the edge of the cover and join the protruding wires and mesh together with that of the wall.
- Seal the joint between cover and wall and apply mortar finish inside and outside as specified.

Figure 16: Tank cover in position ready for finishing coats

Roof construction for larger capacity ferro-cement tanks i.e. larger than 8m^3 is done directly on the tank wall. Roof reinforcement mesh (Figure 17) is attached to the protruding wall mesh and propped with wooden poles. A thin layer of mortar is then gently applied to cover the mesh lightly before the thick layer is applied on top of the tank and rendered smooth to finish. The wooden props are then removed after at least five days and a finishing layer of plaster is applied on the underside and rendered smooth. A central roof support (usually of reinforced concrete would be needed for tanks of 20m^3 and above.

Very large capacity ferro-cement tanks (larger than 35m^3) are constructed with additional layers of reinforcement wires on the wall. Also additional roof support (usually reinforced concrete column) placed along the tank wall would be required to protect the tank wall from the weight of the roof.

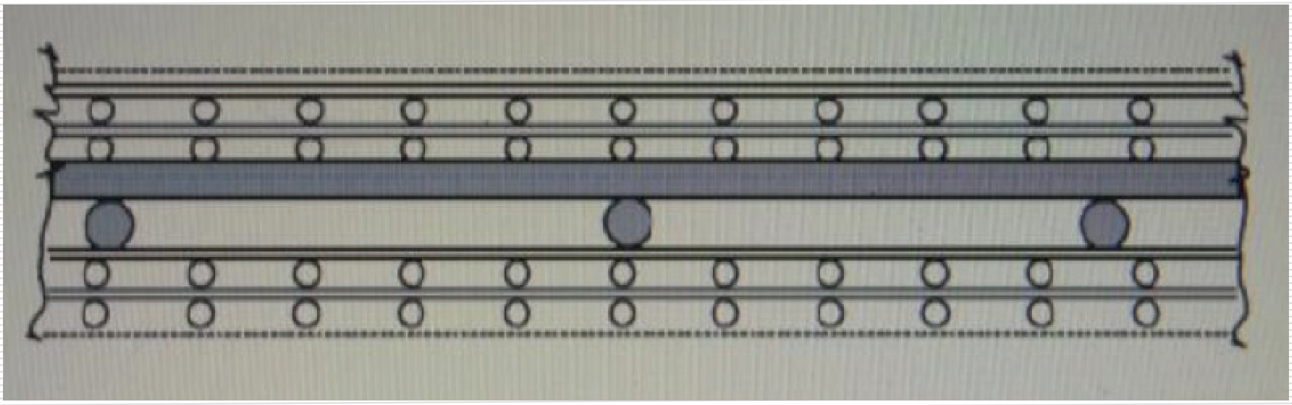


Figure 17: Cross-section of tank wall showing additional layers of mesh reinforcement for large capacity ferro-cement tanks..

3.1.7 Advantages and Disadvantages of Ferro-cement Tanks

Advantages
- They are constructed on site using common building materials.
- There are many examples of ferro-cement tanks in the country hence skills and knowledge transfer is quite easy
- They can be constructed in any sizes according to the capacity required or available money.
- They are very strong and therefore difficult to vandalise.
- They can be easily repaired when damaged or vandalised.
- They are durable.
- They can be constructed by locally trained artisans.
- They are relatively cheap compared with other manufactured tanks on the market.

Disadvantages
- They require good quality sand and wire mesh that may not be locally available.
- For new tanks, chemicals in cement dissolve in stored water thereby affecting the quality.

It is easy to make mistakes during construction; poorly constructed tanks can allow water to seep through thereby causing algal growth on the wall and also corroding the wire reinforcement.
- Technique of constructing these tanks depends on availability of welded reinforcement mesh and wire mesh. Since this ese cannot be found in all Districts, other methods cannot be substituted
- Transporting materials to the site especially in hard to reach areas, increases the costs

Operation and Maintenance of Ferro-cement Tanks
- Check for any leakage in the tank wall and repair immediately to avoid water loss.
- For leakage through the bottom, monitor any significant drop in water level to detect leakages in the tank.
- Regularly check for any cracks in the wall of the tank and seal them immediately.
- To seal a crack in the wall; cut through the plaster about 2.5cm on both sides of the crack up to the wire mesh and plaster with a strong mortar of 1:2 cement to sand ratio.
- Wash the wall of the tank and clean out any rubbish from the bottom of the tank at least once a year (i.e. at the start of the rainy season.
- Regularly check the tap for any leakage or damage and repair or replace immediately to avoid water loss.

3.2 Rainwater Jar

3.2. 1 Description

Water jars are relatively small capacity storage vessels shaped like pots or bottles with volumes usually ranging from less than 100 litres to 2,000 litres but the sizes commonly used in rainwater harvesting range from about 300 to 2,000 litres. They are made from different materials including sheet metal, earthenware, and ferro-cement. The common types used in Uganda are made from ferro-cement materials but with much lighter wire reinforcement.

Jars can be constructed to sit at ground level or on a raised base depending on site conditions or preference of the beneficiary. The construction methods are principally the same but jars sitting at ground level would require soak pits for disposing of wastewater. The Bill of Quantity and the construction methods described below are for jars sitting at ground level.

3.2.2 Drawing

The drawings below show the dimensions of iron moulds for the jar body (Figure 18) and rim moulds for the jar mouth(Figure 19)

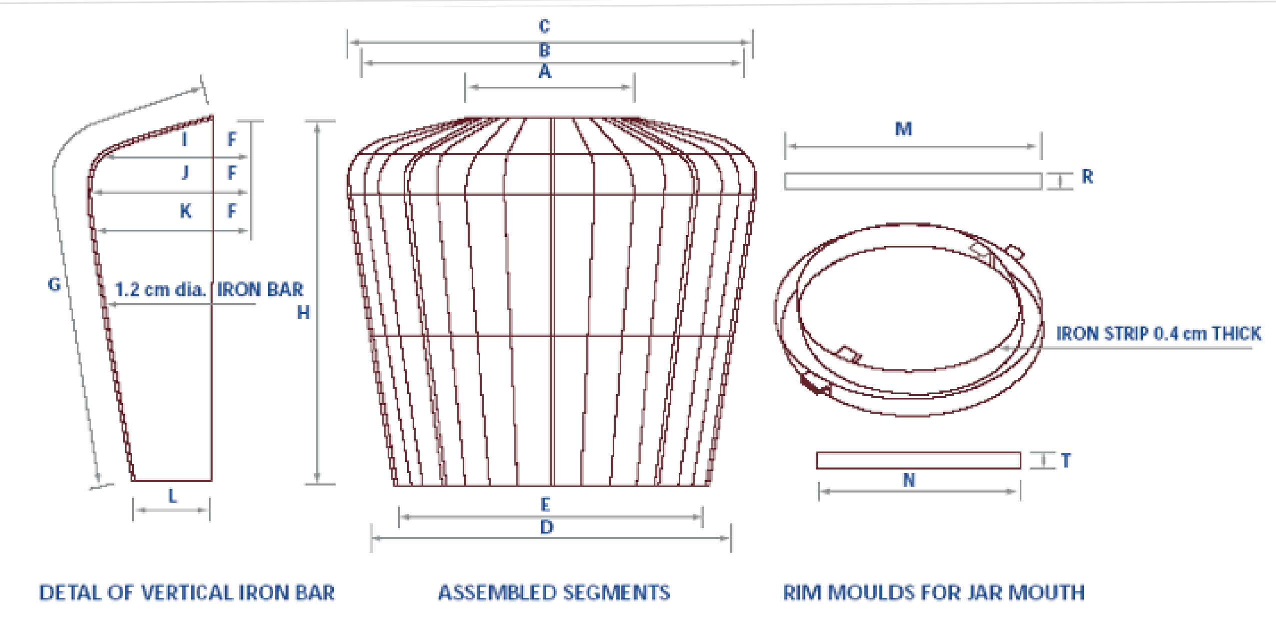


Figure 18: Dimensions of iron moulds

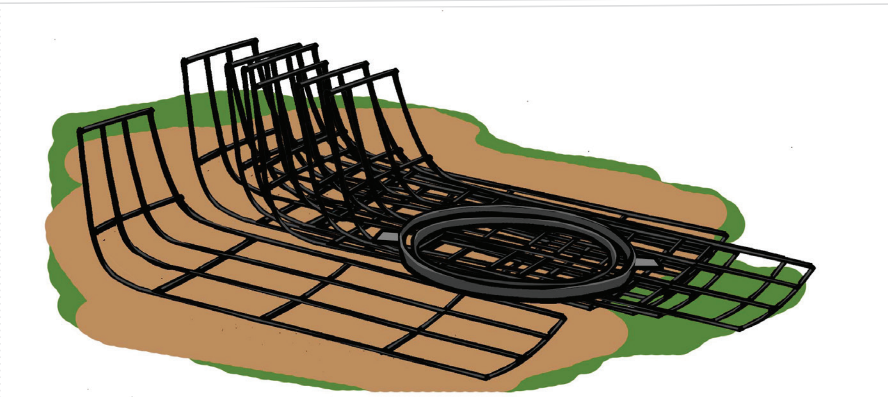


Figure 19: Iron mould segments ready for jar construction

3.2.2 Construction Materials

The materials required are summarized in the Table 4 below

Table 4: Materials required for rainwater jars

Description	Unit	300L	500L	1,000L	2,000L
Cement (50kg bag)	Bag	1.5	2	3	4
Sand	Ton	1	1	2	3
Aggregate	Ton	0.2	0.2	0.3	0.3
Galvanised wire (1.5mm □)	Kg	3	4	6	8
Galvanised wire (3mm □)	Kg	1	1.5	2	2
GI Pipe (3/4")	M	1	1	1	1
Lockable tap (3/4")	Pc	1	1	1	1
GI socket (3/4")	Pc	2	2	2	2
GI plug (3/4")	Pc	1	1	1	1
Nylon net	Sq.m	1	1	1	1
Jute (Hessian) cloth	Sq.m	2	3	4	6
Big iron sewing needle	Pc	1	1	1	1
Wooden or aluminium cover	Pc	1	1	1	1
Skilled mason	Man day	2	2	2	2
Unskilled labourer	Man day	2	2	2	2

3.2.3 Iron moulds for rainwater jar construction

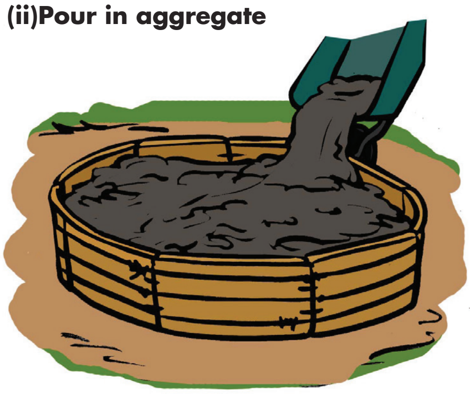
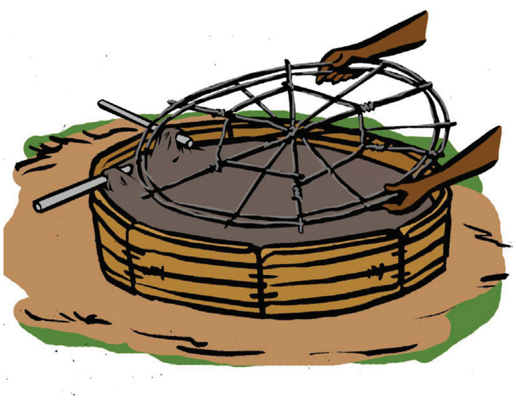
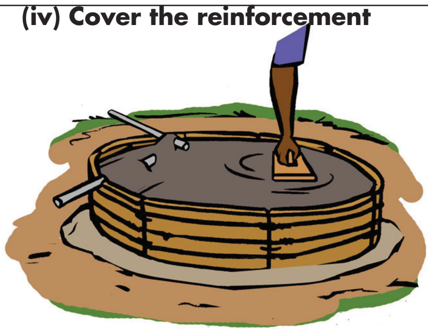
Moulds for making jars can be made from different materials including sawn fabrics filled with soil or dry leaves/husks; shaped wooden or concrete blocks; timber frames; or shaped and welded iron bars. The welded iron bars moulds are easier to transport, store, and assemble and usually maintain the desired shape thereby producing high quality jars. Below is the description of the welded metal bars mould that is used in the subsequent construction methods.

The iron moulds are for the body of the jar and for the jar mouth. The body mould is made from 12mm iron bars and the rim mould for the jar mouth is made from 4mm thick and 5cm and 7cm wide metal strips (Figure 18). The body mould is made in segments that are assembled to form the complete mould.

The drawings below show the dimensions of iron moulds for the jar body and rim moulds for the jar mouth (Figure 19).

3.2.4 Construction steps of Rainwater Jar

Step 1: Construction of the jar foundation

(i)Preparing the base 	• Clean and level the ground surface. • Set the circular pre-cast mortar segments to form the foundation wall (8 segments make 1.3m for 1,000 litres and 10 segments make 1.6m for 2,000 litres). • Join the pre-cast cement segments with binding wire. • Mark the centre point of the circle with a piece of wire. • Fill the foundation with well-compacted sand, up to 6 centimetres deep.
(ii)Pour in aggregate 	• Pour in aggregate about 5cm deep on top of the sand and pack it down tight. • Reinforce the cement segment circle binding wire wound around the mould (as shown) to maintain the shape. • Pour about 2cm of mortar 1:3 mix over the aggregate and compact to level.
(iii) Make base reinforcement 	• Make base reinforcement using 3mm galvanised wire as shown. • Place the GI washout pipe (with an elbow at the end for be anchor) on top of the concrete layer. • Place GI delivery pipe (with an elbow and pipe extension at the end for be anchor) on top of the concrete layer. • Place the wire reinforcement on top of the aggregate (and the washout and delivery pipes)..
(iv) Cover the reinforcement 	• Cover the reinforcement wire with 4cm thick mortar of 1:3 mix. • Place the drainpipe in the mortar and plaster the top with mortar of 1:2 mix. • Smooth the surface of the floor to slope toward the drain pipe.

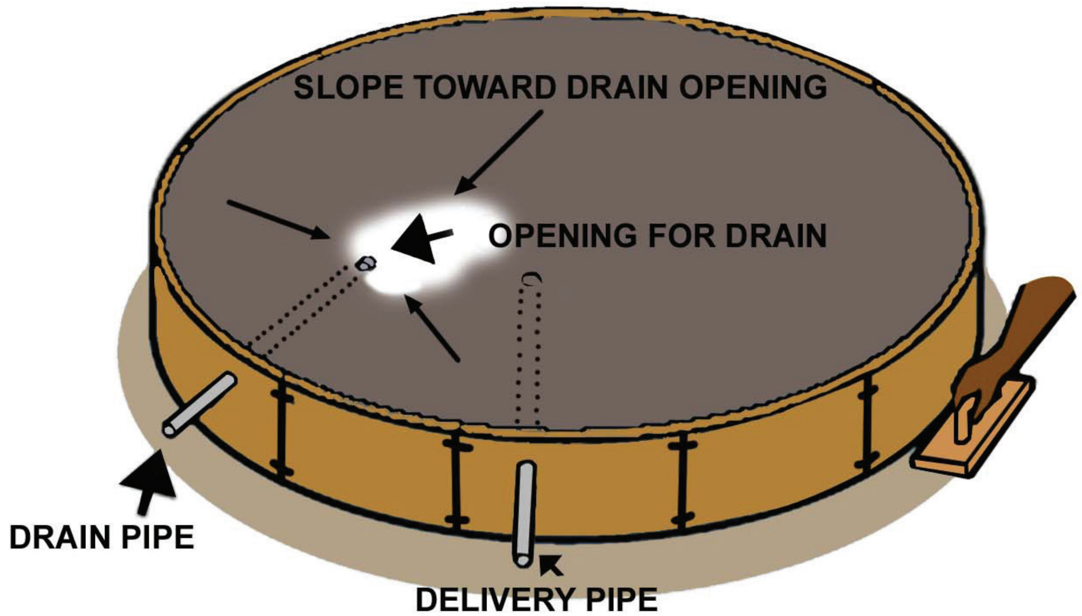
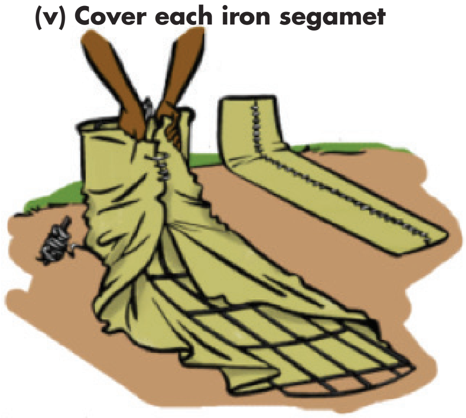
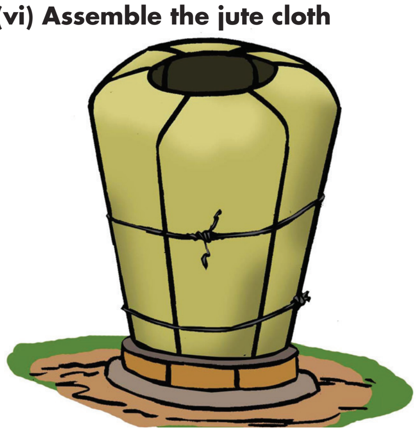


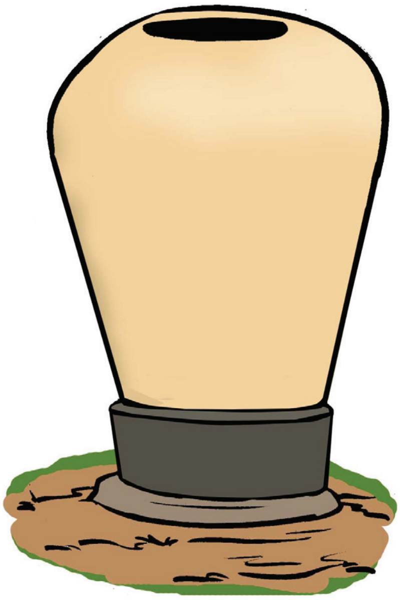
Figure 20: Completed jar base with floor sloping into the drain pipe

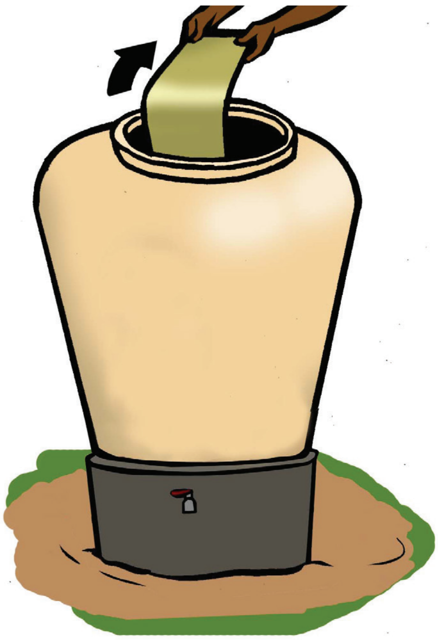
Step 2: Preparation of moulds for jar construction

(v) Cover each iron segamet 	Cover each iron segment mould with jute cloth and sew it tightly onto the mould with a big iron needle.
(vi) Assemble the jute cloth 	Assemble the jute cloth-covered mould segments and tie together with binding wire. Place the assembled jute cloth-covered jar mould onto the jar foundation/base.

Step 3: Construction of jar wall

(vii) Apply first layer of mortar 	• Smear the jute cloth with a thin layer of mud slurry made by mixing mud and water. • Smooth the surface and leave for about 30 minute to dry slightly.
(viii) Apply second layer of mortar 	• Apply 1.2cm thick mortar of 1:2 ratio on the outside of the mud covered jute cloth. • Wait about 30 minutes and then apply the second 1.2cm coat of 1:2 mix cement mortar. • Take care not to make the mortar wet or too thick to prevent it from falling off.
(ix) Fasten the galvanised wire 	• Fasten the 1.5mm galvanised wire tightly horizontally around the jar over the cement mortar layers as reinforcement. • The space between the reinforcing wires should vary from 3cm to 6cm from the bottom to the top.

(x) Apply third layer of mortar 	• Apply the third layer of 1:2 ratio mortar 1.2cm thick over the galvanised wire. • After about 30 minutes, apply the fourth and last layer of mortar 1.2cm thick and leave to set.
(xi) Fill spaces with mortar 	• Place the two rim moulds on the jar mouth and fill the space between with mortar. • Remove the moulds before the cement mortar is set.
(xii) Smothening of the outside 	• Trowel the jar surface smooth to finish on the out-side. • Plaster the foundation wall and trowel smooth to finish.

(xiii) Remove the mould segments	
	• Remove the mould segments from inside the jar after at least 12 hours of applying finishing layer on the outside. • Clean the inside wall of the jar using hard brush and water. • Apply 5mm thick cement screed on the inside and smoothen to provide waterproof layer easy to clean.

3.2.5 Advantages and Disadvantages of Rainwater Jars

Advantages

- They are constructed on site using common building materials.
- They are very strong and therefore difficult to vandalise.
- They can be easily repaired when damaged or vandalised.
- They are durable.
- They can be constructed by locally trained artisans.
- They are relatively cheap compared with other storage technologies.

Disadvantages

- They require good quality sand and wire mesh that may not be locally available.
- They require moulds for good quality construction.
- For new jars, chemicals in cement dissolve in stored water thereby affecting the quality.
- The sizes are usually predetermined by the size of the mould used.

3.2.6 Operation and Maintenance of Water Jars

- Check for any leakage in the jar wall and repair immediately to avoid water loss.
- For leakage through the bottom, monitor any significant drop in water level to detect leakages in the jar.
- Regularly check for any cracks in the wall of the jar and seal them immediately.
- To seal a crack in the wall; cut through the plaster about 2.5cm on both sides of the crack up to the wire mesh and plaster with a strong mortar of 1:2 cement to sand ratio.
- Wash the wall of the jar and clean out any rubbish from the bottom of the jar at the start of the rainy season.

- Regularly check the tap for any leakage or damage and repair or replace immediately to avoid water loss.

3.3 Masonry Tank

3.3.1 Description

Masonry tanks are constructed using different types of materials including: burnt clay bricks; concrete blocks/bricks; cement mortar blocks/bricks; (dressed) stone blocks; and interlocking stabilised soil blocks. The most commonly used material for masonry tanks construction is the locally fired clay bricks because of the ready availability and relatively low costs.

Masonry tanks are constructed above or below ground and in capacities ranging from less than 3,000 litres to over 100,000 litres. The larger capacity tanks require more metal reinforcements than the smaller capacity ones. The depths of tanks are usually limited to between 2 – 3 metres to minimise the amount of water pressure that increases with the depth. The depths of tanks constructed below ground can however be increased up to 4.5m because the soil backfill support the tank wall therefore countering the action of water pressure on the wall.

Masonry tanks rely on strong cement mortar plaster applied to the inside of the wall to prevent leakage. Tanks constructed above ground using stabilised soil blocks must also be plastered on the outside to prevent rainfall eroding the wall.

3.3.2 Construction materials

The main construction materials required are: bricks or blocks; cement; aggregate; river sand; lake sand; reinforcement bars, binding wire, mesh, and water. The bill of quantities for the commonly used locally fired clay bricks are shown below.

Construction materials for brick masonry water tank are shown in Table 5 below.

Table 5: Construction materials for four metre deep underground brick tank

Item	Description	Unit	15 m^3	20 m^3	30 m^3	40 m^3	50 m^3	65 m^3
1	Excavation	m^3	38	45	64	82	103	128
2	Fired clay bricks	No.	2160	2550	3300	3960	4560	5460
3	Cement	Bag	25	28	40	48	55	63
4	Water proof cement	Kg	6	7	9	11	12	15
5	Lake sand	Ton	4.5	5	6.5	8	9	11
6	Clean plaster sand	Ton	2	2.5	3	4	4.5	5
9	Aggregate (3/4”)	Ton	3	5	8	12	16	20
10	Y10 rebar (12m)	Pc.	15	20	27	38	46	60

Item	Description	Unit	15 m^3	20 m^3	30 m^3	40 m^3	50 m^3	65 m^3
11	R8 stirrups (12m)	Pc.	16	20	26	34	44	56
12	Binding wire	Kg	5	6	8	10	12	14
13	Wooden poles (14’)	No.	8	8	8	10	10	12
14	Timber shutters (12”x1”)	Pc.	4	4	4	5	5	6
15	Timber planks (3”x2”)	Pc.	4	4	4	5	5	6
16	Wire nails (assorted)	Kg	3	3	3	4	4	5
20	Construction water	Litres	2580	3000	3000	3000	3000	3500
	Labour							
17	Masons	MD	20	24	28	32	36	40
18	Casual labourers	MD	20	24	28	40	48	56
19	Technical supervision	MD	5	6	7	8	10	12

Note: For above ground tank, excavation is required for strip foundation only.

3.3.3 Equipment and Tools

The equipment and tools required for constructing masonry tanks are the common construction ones used in building construction; the key ones are shown in the Table 6 below.

Table 6: Equipment and Tools for constructing soil stabilized block tank

Tool	Quantity
Wheel barrow	1
Spade	2
Trowel	2
Wooden float	2
Steel float	1
Spirit level	2
Plumb bob	2
Wooden template	1
Measuring tape	1
Mortar pan	2
Building line string	1
Wire cutter/pliers	1
Hack saw	1
Bow saw	1
Claw hammer	1
Line bar	1

3.3.4 Construction Steps for Masonry Tank

Construction steps for below or above ground masonry tanks are similar the only major difference being in the amount of excavation and the need to do proper backfilling when constructing underground tanks. The steps below describe the construction of underground brick masonry tanks.

Step 1: Setting the site

Clear the vegetation and level the ground where the tank will be constructed. The size to be cleared depends on the site of the tank and the working area. The cleared area should be at least two metres wider than the diameter of the tank to be constructed in order to provide adequate working space.

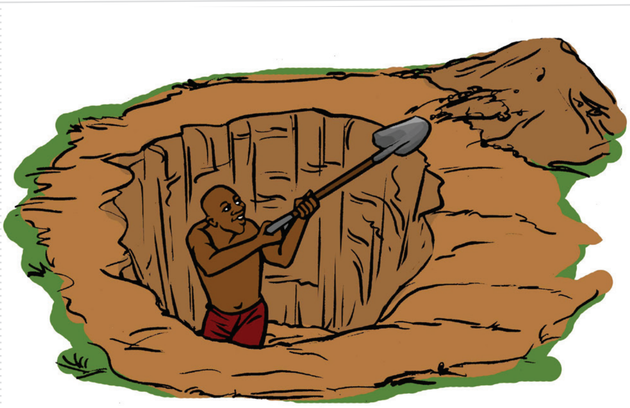
Drive a peg (with a hammer) into the ground in the middle of site cleared;

a) Tie a string on the peg

b) Measure the distance from the centre to the outside of the tank wall (radius) as per the drawings.

c) Add at least 25cm to the outside radius of the wall measured and tie the string on a 5-inch nail; and

d) Then draw the circle around the peg; the added area around the tank provides working space and backfill to strengthen the tank.



a) Excavate the area marked out. The depth of the tank should not exceed 4.5 metres to avoid excess water pressure when the tank is full of water.

b) Trim the wall of the excavation to make even and level the bottom of the pit.

Step 2: Construction of Tank Foundation

a) Cut the 10mm reinforcement bars and tie using binding wire spacing the bars 15cm apart to form a mat with the diameter equal to that of the tank.

b) Prepare the concrete of cement: sand: aggregate ratio of 1:3:6 (by volume measured using a batching box) and cast 50mm thick layer at the base of the excavation and level.

c) Place the base reinforcement mat over the levelled concrete; and

d) Pour 150mm thick concrete layer over the floor reinforcement compacting and levelling the concrete using a bar line. Smoothen the top of the concrete using wooden trowel (Figure 21).

Figure 21: Tank foundation construction

Step 3: Wall Construction

Allow the foundation to cure for 24 hours before starting to construct the tank walls.

Use a nail and string to mark the inside of the tank wall; this circle will guide the mason to correctly lay the first course of the bricks (Figure 22).

Figure 22: Wall construction

a) Prepare the mortar with cement: sand ratio of 1:3 (by volume). Build the first course of the blocks with 2 inches of mortar between the blocks.

b) Use spirit level (Figure 23)on every block and every course to ensure accurate vertical and horizontal levels.

c) After the first course plumb-bob should be used to ensure that each course is vertically aligned perpendicular to the base.

Figure 23: Use of a spirit level ensures accurate vertical and horizontal levels

a) Fill the vertical interlocks with mortar using a trowel and smooth wooden float on both sides. The mortar to fill in the vertical interlocks should fairly be fluid so that it can be inserted into the interlock space.

b) From the second course onwards, only 5 mm of mortar should be used in the horizontal interlock. Ensure each course is offset to the centre of the one below in form a "T" joint. When each course finished check all sides to ensure that they were mortared and smooth.

c) After the wall is built up to the required height, backfill the outside of the wall with well compacted gravel/murram up to the ground level. Leave the wall to cure for 24 hours.

Step 4: Plastering and Waterproofing

a) Prepare the cement mortar of ratio 1:3 (by volume) adding an equivalent of 1 kilogram of waterproof cement for every 50kg of cement. Plaster the wall from inside (Figure 24). Level the plaster using a bar line. Smooth and press the plaster with wooden float over the plaster in a circular motion.

Figure 24: Plastering the inside of the tank

b) After plastering the wall, plaster the floor of the tank. The walls of the tank should arch down the centre, allowing sediments to collect to the bottom of the tank.

c) Prepare cement mortar of ratio 1:3 (by volume) adding the equivalent of 1 kg of waterproof cement in 50kg of cement. Apply another layer plaster to the walls and floor of the tank using a float. Cover the mouth of tank with plastic sheet or tarpaulin to protect the inside of the tank from direct sun rays, which may cause cracking. In the morning after plastering, pour some water in the tank for it to cure properly.

Step 5: Construction of Concrete Cover

a) After the tank has properly cured (5 days), start the construction of the tank cover. Lay horizontal pieces of timber at the spacing of 1 m parallel across the mouth of the tank (Figure 25). This framework should be supported by poles underneath. Nail horizontal planks of timber at right angles on top of the laid timber. Leave a space for manhole access cover (0.6m x 0.3 m). Cut the timber planks to shape at the internal wall of the tank.

b) Secure plywood around the edge of the tank to act as a framework when concrete is poured. Put the manhole access cover in place on top of the framework.

Figure 25: Lay horizontal pieces of timber at the spacing of 1 m parallel the mouth of the tank

c) Lay BRC mesh over the top of the framework on the tank. Lay 12 mm of bar at the spacing of 300mm between them. Lay another set of 12 mm bar spacing of 300 mm at right angles to the first set. Tie up the two sets of bars with binding wire at the point where they intersect. Lay the steel works beams (150mm x 150 mm) using 16 mm bars and 8 mm links. The links should be placed at a spacing of 200 mm and secured with binding wire. Place the beams in parallel at a spacing of 1.2m (Figure 26).

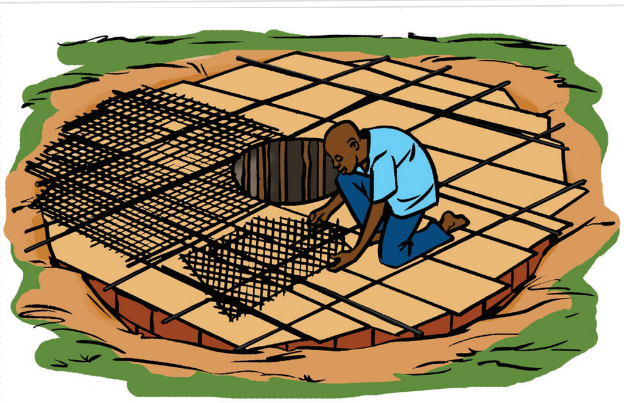


Figure 26: Binding wire on the tank

d) Prepare concrete mix of ratio 1:2:4 (by volume). Apply on the framework to a thickness of 200mm. Spread and level the concrete (Figure 27).

Using a chisel, carefully work out a round opening for the overflow of the tank. Fix a short 3 or 4” diameter pipe into the hole. Cover this hole with a mosquito screen. After 24 hours apply a cement sand screen and plaster the cover of the tank and the portion of the wall which is above the ground.

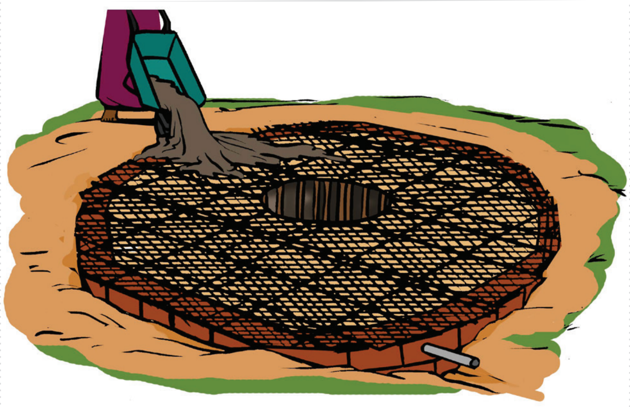


Figure 27: Applying a cement sand screen on the cover of the tank

Step 6: Removing the shutters

After 7 days remove the all the timber and poles (Figure 28) from the tank. Clean the tank and connect to piping and guttering from the roof, ready to receive water into the tank (Figure 29).

Figure 28: Removing the shutters

Figure 29: Completed underground tank with a bucket for drawing water

3.3.5 Advantages and Disadvantages of Masonry Tanks

Advantages

- They are constructed on site and can use variety of readily available common building materials; burnt bricks can be made by the households, hence cheaper.
- They can be constructed in any sizes according to the capacity required or available money.
- They can be constructed entirely below ground or above ground.
- They are very strong and therefore difficult to vandalise.
- They can be easily repaired when damaged or vandalised.
- They are durable.

Disadvantages

- They require good quality bricks or other manufactured bricks/blocks that may not be locally available.
- For new tanks, chemicals in cement dissolve in stored water thereby affecting the quality.
- It requires skilled masons for good quality tank construction.
- Underground tanks require a pump to hygienically extract water for consumption thereby adding to capital investment and O&M costs.
- It is difficult to detect leakage in underground tanks.

3.3.6 Operation and Maintenance of masonry tanks

- Check for any leakage in the tank wall and repair immediately to avoid water loss.
- For underground tanks (or for leakage through the bottom), monitor any significant drop in water level to detect leakages in the tank.
- Regularly check for any cracks in the wall of the tank and seal them immediately.
- To seal a crack in the wall; cut through the plaster about 2.5cm on both sides of the crack and plaster with a strong mortar of 1:2 cement to sand ratio.
- Wash the wall of the tank and clean out any rubbish from the bottom of the tank at least once a year (i.e. at the start of the rainy season.
- For above ground tank, regularly check the tap for any leakage or damage and repair or

3.4 Plastic Tanks

3.4.1 Description

Plastic tanks are factory made rainwater storage systems. In Uganda there are two major manufacturers of plastic tanks; Crestank Limited and Poly Fibre (Uganda) Limited. They mainly manufacture above the ground tanks (Figure 30), however underground tanks can be manufactured on special order.

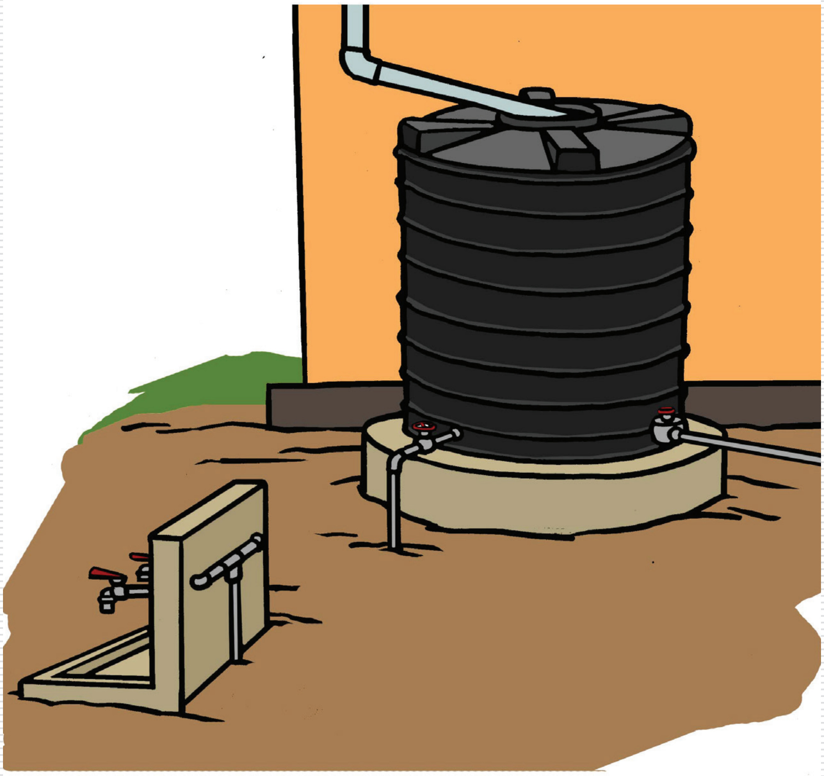


Figure 30: Above the ground plastic tank

3.4.2 Drawing

The materials used are food grade polyethylene that has been effectively stabilized against the harmful effects of sunlight.

The tanks are produced in various capacities ranging from 100 litres to 24,000 litres. The larger tanks, suitable for RWH, are usually cylindrical in shape.

Plastic tanks are lightweight and easily transported and easy to install, service and maintain.

3.4.3 Advantages of Plastic Tanks

- Last more than 30 years if well maintained
- Does not rust; maintains water quality
- Easy to clean
- Easy to install
- Water taste or colour does not change
- Little maintenance costs
- No joints leakage
- Readily available in the market

3.4.3 Dimensions of plastic tanks

The table below shows the dimensions of medium and large capacity tanks suitable for rainwater harvesting.

Table 7: Dimensions and average prices of medium and large capacity tanks suitable for RWH

Capacity (Litres)	Diameter (cm)	Height (cm)	Average Price (UGX – Aug. 2015)
4,000	176	210	1,380,000/=
5,000	186	205	1,600,000/=
6,000	198	223	2,150,000/=
6,000	252	146	2,150,000/=
8,000	219	243	3,200,000/=
10,000	285	189	3,800,000/=
10,000	239	271	3,800,000/=
16,000	290	280	7,200,000/=
24,000	356	280	12,000,000/=

3.4.4 Construction Instructions for Installation and Care of a plastic Tank

1. Ensure strong flat/even base with diameter larger than that of the tank
2. Drill inlet and outlet at specified points (indicated on the tanks) only
3. Channel the overflow water away from the tank to reduce erosion around the base
4. Use flexible pipe for interconnection when required
5. Always support pipe work with stand frames or in concrete to prevent excess strain on tank wall.
6. Check tank before installation. It may have been damaged in transit or storage.
7. Ensure all pipes enter the tank at 90 degrees to the tank wall (Figure 31)
8. Ensure overflow pipe has larger flow capacity than the inlet or down pipe
9. Always support tank wall while drilling

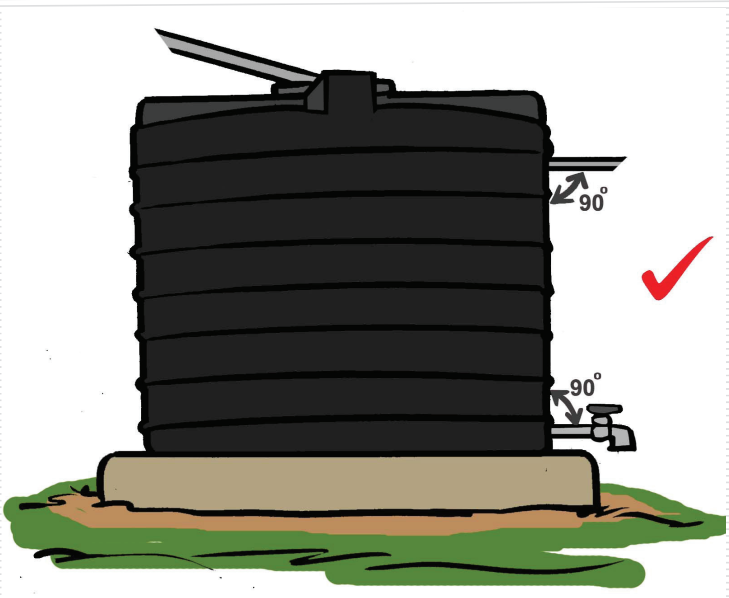


Figure 31: Pipes at 90^0 to the tank wall

3.4.5 Plastic Tank Care Instructions

Dos and Don'ts of Plastic Tanks

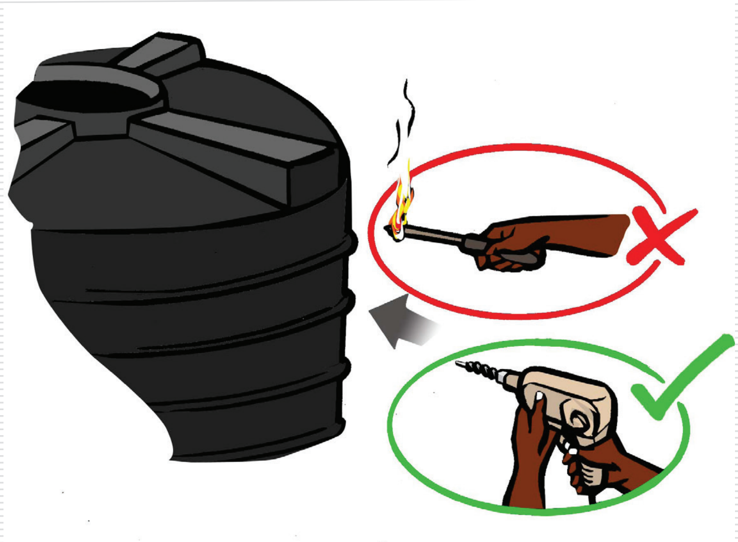


Figure 32: Do not use fire, use only a drill bit to make a hole in the tank

1. Don't make a hole with heated metal. Use only drill bit (Figure 32)
2. Don't leave gaps between support planks in the base
3. Don't put any object e.g. stone, wood etc. under the tank
4. Don't allow pipe work to hang from the tank unsupported
5. Don't over tighten the back nut on pipe connections
6. Don't use outlet/inlet greater than 1 Inch for tanks of 100 – 1000 litres capacity and not greater than 21/2 inches for tanks of 1,500 – 10,000 litres.
7. Don't throw tank down. Always lift and place it gently on ground (Figure 33)
8. Don't exert access weight on pipe connections. Tank will be damaged.
9. Keep tank away from heat or heat generating objectives. Tank may melt or catch fire
10. Always ensure tank does not sit on sharp objects
11. Don't exert excess weight on top of the tank. It may damage tank top

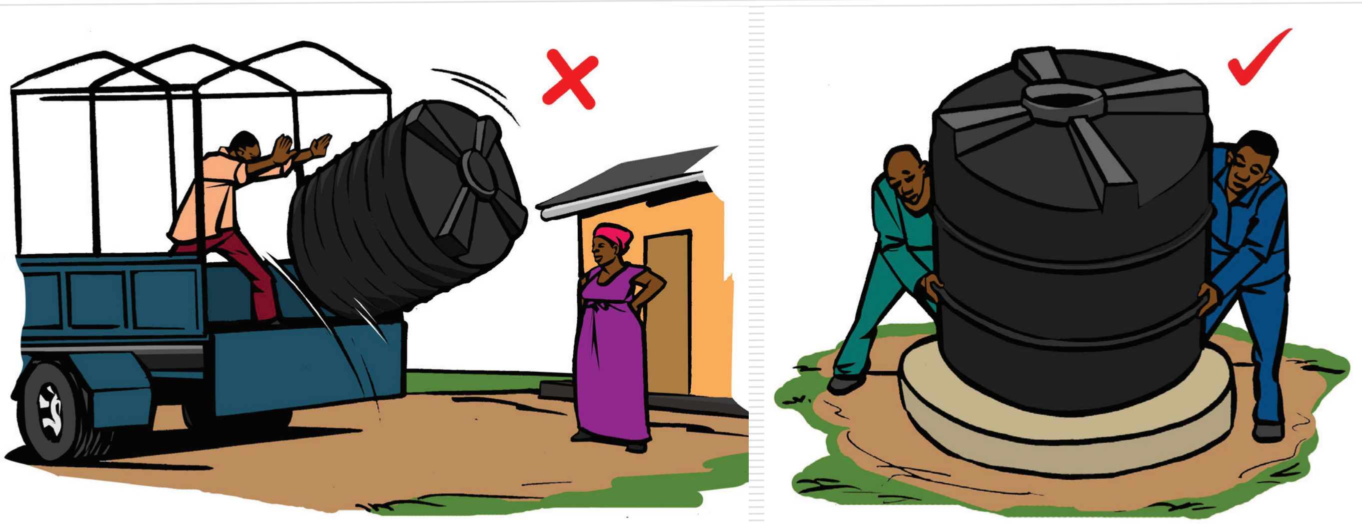


Figure 33: Don't throw tank down, just lift it up

Figure 34: Exerting excess weight on top of the tank may damage the tank top

3.4.6 Advantages and Disadvantages of Plastic Tanks

Advantages

- Last more than 30 years if well installed and maintained
- Does not rust; maintains water quality
- Water taste or colour does not change
- Easy to clean
- Easy to install
- Little maintenance costs
- No joints leakage
- Readily available in the market

Disadvantages

- Are easily vandalised by the community
- Very difficult to repair when damaged/vandalised
- Difficult to access inside for cleaning and maintenance.
- Expensive to acquire
- Difficult to deliver to sites in difficult to reach places.
- Limited storage capacity especially for high water demand installations.
- They can be easily stolen causing big loss of investment.

3.4.7 Operation and Maintenance of Plastic Tanks

- Check for leakages around pipe connections and carefully tighten; two artisans, one on the inside, are needed to tighten the connections.
- Using a long broom, scrub the bottom of the tank from the top and flush out the water at least once a year i.e. at the start of the rainy season; climbing on top of the tank risks damaging the roof.
- Check for any leakage or damage to the tap and reapir or replace immediately to avoid water loss.

3.5 Stainless Steel Rainwater Tank

3.5.1 Description

Stainless steel rainwater tanks (Figure 35) are factory made. It is new on the market but the demand from households, businesses and institutions is growing rapidly. It is preferred for being high resistance to corrosion, staining and bacteria.

The tanks have threaded provisions for pipes connections and customised stands for easy installation. Tanks capacities vary from 250 to 7,000 litres with options for stand up or horizontal installations.

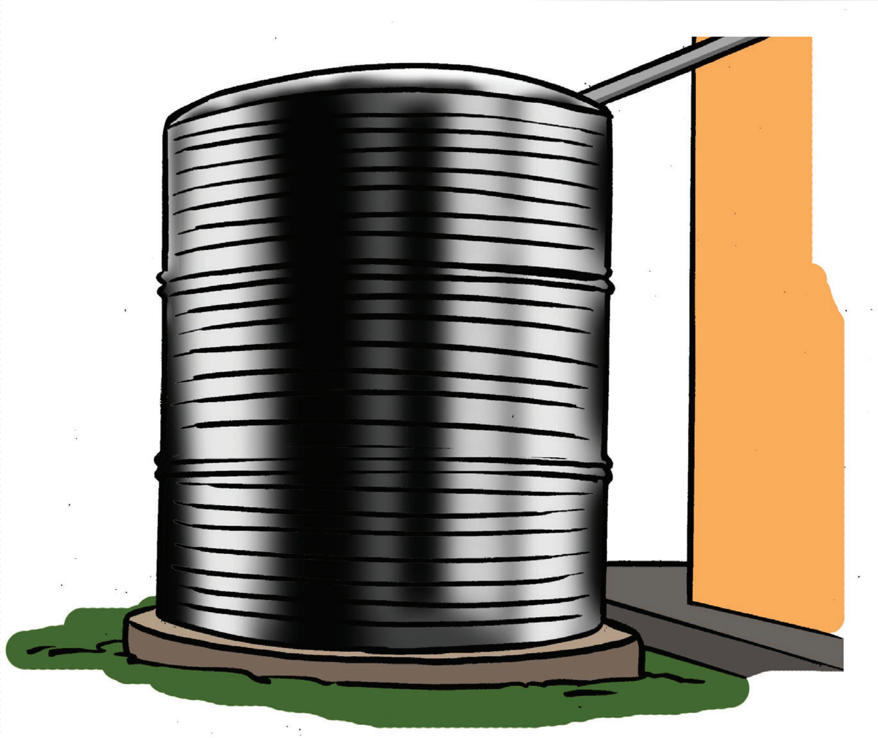


Figure 35: Stainless steel tank

3.5.2 Dimensions of the Stainless steel Tank

Table 8: Sizes of the Stainless steel Tanks

Capacity (L)	Height(mm)	Width(mm)	Weight(kg)	Stand Height(mm)
250	610	700	7.38	440
500	500	850	21.40	440
1,000	1,400	970	28.80	440
1,250	1,400	1,050	36.00	440
1,500	1,800	1,050	41.40	440
3,500	2,100	1,620	77.50	440
5,000	2,900	1,620	102.12	440
7,050	3,500	1,620	129.00	440

3.5.3 Dos and Don'ts of Stainless Steel Tank

(i) The tank must be installed on a strong, flat, and even surface.

(ii) Water outlet and discharge point should use BSPT 304 pipe fitting and other non-ferrous and non-poisonous product (ABS, PVC & Poly pipe).

(iii) Stop-cock should be fitted on outlet pipe to facilitate repair works.

(iv) Overflow point should have tracked-connecter; water hose shall be added if necessary.

(v) Outlet point shall be fixed with tracked-connector.

(vi) Discharge point at the centre location of the bottom of tank shall be fixed with tracked-connector.

(vii) Any extra water outlet should be requested before fabrication. No alteration or additional pipe connections should be provided after purchase.

(viii) All the water pipes connected to the tank openings must be firmly fitted to avoid any vibration that may damage the threads and cause leakage.

(ix) Discharge point should have a valve to ease washout of dirty water or sediment from the tank that should be done regularly.

(x) The location for tank installation must be far away from chemical materials or liquids.

(xi) Do not use underground source water or contaminated water or chemical for storage.

(xii) Ensure all pipes connected to the tank are well supported and properly aligned as specified by manufacturer.

Dos	Don'ts
Place water tank on a flat and even surface with strong support.	Avoid uneven or unstable surface that would affect stability of tank.
The tank location must be located far away from chemical, air-conditioner, flammable materials and cooling tower.	Do not place water tank near chemical, air-conditioner, flammable materials and cooling tower to prevent any vapour or heat that could affected the properties of the tank.
Always use non-ferrous and non-poisonous fittings for tank connection	Never use any ferrous pipe fittings to avoid rusting and corrosion.
Overflow point must be connected with pipe or hose.	Do not purposely leave overflow without pipe connection to avoid water running over the tank.
Connect discharge point with valve to ease discharge of sediment or dirt from the water tank.	Avoid using plug of capon discharge point since they are hard to operate (require spanner) when discharging sediment or dirt from tank.
Always make sure all connections to the tank are firmly installed, well-supported and properly aligned.	Don't leave pipes that are not properly aligned and well-supported to avoid leakage or damage to the tank.
It is recommended to place water tank in well-ventilated area with easy access.	Do not install water tank in stuffy and tiny area to avoid corrosion and limited access for maintenance.

3.5.4 Advantages and Disadvantages of Stainless steel tanks

Advantages

- Rust free, fire-resistant and solid body.
- Free from fungus, algae, insect and water contamination
- Base discharge point makes it easy to drain sludge and residue
- Strong and durable pipe connection points minimising damage to tanks
- Light weight; easy to transport and install; customised tank stand
- 50-year design life span – worthwhile long term investment

Disadvantages

- Initial capital investments may be too high for average households
- Thin wall can be easily punctured by vandals and repairs may be difficult for communities.
- Very difficult to repair when damaged/vandalised.
- Difficult to deliver to sites in hard to reach places.
- Limited storage capacity especially for high water demand installations.
- They can be easily stolen causing big loss of investment.

3.5.5 Operation and Maintenance of Stainless Steel Tanks

- Scrub the inside of the tank with a long broom and flush out the water at least once a year at the start of the rainy season.
- Check the tap for any leakage or damage and repair or replace immediately to avoid loss of water.

3.6 Corrugated Iron Tanks

3.6.1 Description

Corrugated iron tanks are widely used in Uganda. They are fabricated by informal manufacturers using galvanised or pre-painted corrugated roofing sheets manufactured locally or imported. Depending on the materials used, the tanks can be affected by rusting which creates weaknesses and eventually leakage.

The tanks are usually fabricated in capacities ranging from 1,000 to 15,000 litres. They are easy to install and maintain. Initial corrosion of galvanized steel normally creates a thin adherent film that coats the interior surface of the tank and provides protection against further corrosion; cleaning should not disturb this film. Avoid copper or copper alloy fittings(brass and bronze) connected directly to steel tanks as this causes corrosion.

3.6.2 Construction Materials

The materials for the 10,000litre corrugated iron rainwater tank are shown in the Table 9 below

Table 9: Construction materials for 10,000 litres corrugated iron tank

Item	Unit	Quantity
Corrugated iron sheet (walls) – 10′ length; G24 or 26	Piece	7
Galvanised iron sheet (floor) – 10′ length; G24 or 26	Piece	2
Galvanised iron sheet (floor) – 10′ length; G24 or 26	Piece	2
Aluminium rivet (100 pieces)	Pkt.	3
Bituminous paint	Lt.	1
Soldering wire	Kg	0.5
GI socket (outlet, washout, inlet, overflow)	Pieces	4
Skilled labour	Man day	6

Price List

The average prices of the different capacity corrugated iron tanks as of July 2015 are as follows.

Tank size Litres	Amount (UGX)
1,000	300,000
5,000	750,000
10,000	1,200,000
15,000	1,700,000

3.6.3 Corrugated Iron Tanks Tank Care Instructions

- Avoid salty materials/ liquid poured on the tank. These accelerate the process of corrosion
- Prevent children from playing on the tank
- Avoid heat near the tank
- Tanks used for corrosive water should be repainted at least every five years

3.6.4 Advantages and Disadvantages of corrugated Iron tanks

Advantages

- They are cheaper than most locally manufactured or constructed tanks
- They are readily available in large urban areas where there are many small scale metal fabricators.
- They can be installed very fast.

Disadvantages:

- They are not fabricated to any established standards – some are made from substandard materials.
- Transport aspect of the tanks increases costs substantially since they are not readily available in most parts of the country.
- It has a limited lifetime
- It can be easily vandalised.
- It can be difficult to repair when damaged or vandalised.
- It is difficult to access the inside for cleaning or maintenance.
- They can be easily stolen causing big loss of investment.

3.6.5 Operation and Maintenance of Corrugated Iron Tanks

- Check for any leakages along the joints of the wall panels and seal with bituminous 'paint' (commonly referred to as 'bondex').
- Scrub the bottom of the tank with long broom from the top and flush out the water at least once a year i.e. at the start of the rainy season.
- Check the water tap for any damage or leakage and repair or replace immediately to avoid loss of water.

3.7 Dammed Storage

3.7.1 Description

Dammed storage is usually used in rock catchment systems that can potentially produce large quantities of water. Large capacity catchment systems rely on large dammed storage from where water can be channelled to treatment facilities for potable supply used directly for productive purposes.

The dammed storage is created by constructing a retaining wall or compacted soil embankment across a valley usually formed between two sloping rock faces. The retaining wall can be constructed from any of the common building materials like stones, concrete blocks, bricks, or reinforced concrete.

Figure 36: Large dammed storage for a rock catchment system

3.7.2 Design of Dammed Storage

Design Considerations

- Determine the gradient of the rock surface and the approximate runoff flow pattern.
- Determine appropriate location of the retaining wall to minimise the length of the wall and maximise the depth to achieve the necessary storage. A valley between steep sloping faces of the rock towards the lower end of the catchment area would be desirable.
- Design an overflow weir on top of the retaining wall long enough to allow all the runoff from the catchment area to flow through when the dam is full.
- Design the outlet facility to include a filter box and outlet pipe, a sediment storage, and wash-out pipe with valve/plug.

3.7.3 Construction materials

The materials required for constructing dammed storage on rock catchment system include:blocks/bricks, cement, medium grainsand(0.15 – 2.5mm), aggregate, reinforcement bars, pipes (GI), and water. The quantities of the materials depend on the length and height of the retaining wall.

3.7.4 Equipment and Tools

The tools required to construct rock catchment

Table 10: Equipment tools for construction

Tool	Quantity
Wheel barrow	1
Spade	2
Measuring tape	1
Building line/string	1
Spirit (or water) level	1
Batching box	1
Mortar pans	2
Wooden floats	2
Club hammer	1
Cold chisel (for stone masonry)	2
Line bar	1

3.7.5 Construction Steps for construction of Rock Catchment

Step 1: Site Clearance

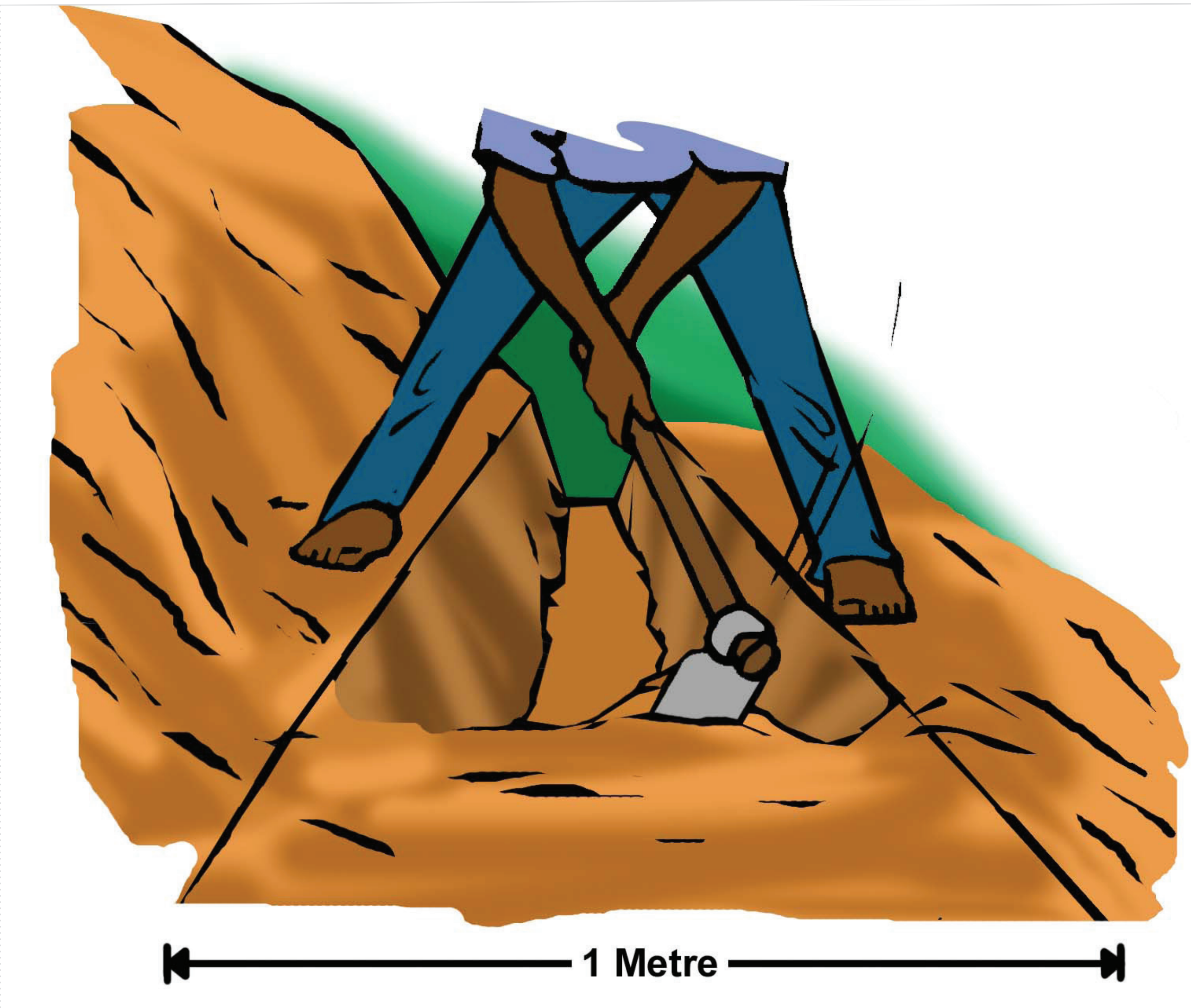
Clear and clean the storage area of vegetationand loose soil materials.

Step 2: Site Clearance

Mark out the site where the retaining wall will be constructed.

Step 3:

Excavate a strip about 1m wide for the wall foundation up to the firm rock surface. The actual width of the wall foundation depends on the height and, therefore, the depth of water in the storage.



Step 4:

Cast reinforced concrete strip foundation for the retaining wall making efforts to level the top to receive the masonry wall.

Step 5:

Construct the retaining wall inserting the washout and delivery pipes at appropriate levels. The washout pipe would start from the lowest point of the storage, which can be right against the retaining wall but the inlet to the delivery pipe would be at a slightly higher above the lowest point of the storage and can be up to 20m or more away from the retaining wall.

Step 6:

Construct the filtration box around the inlet to the delivery pipe and fill it up with clean gravel and aggregate.

Step 7:

Complete the retaining wall ensuring that the blocks/bricks are well jointed to reduce leakage. Finish the rear face of the wall with 25mm cement mortar plaster of ratio 1:3(by volume) mixed with waterproof cement. The plaster should be pressed hard and rendered for a smooth finish.

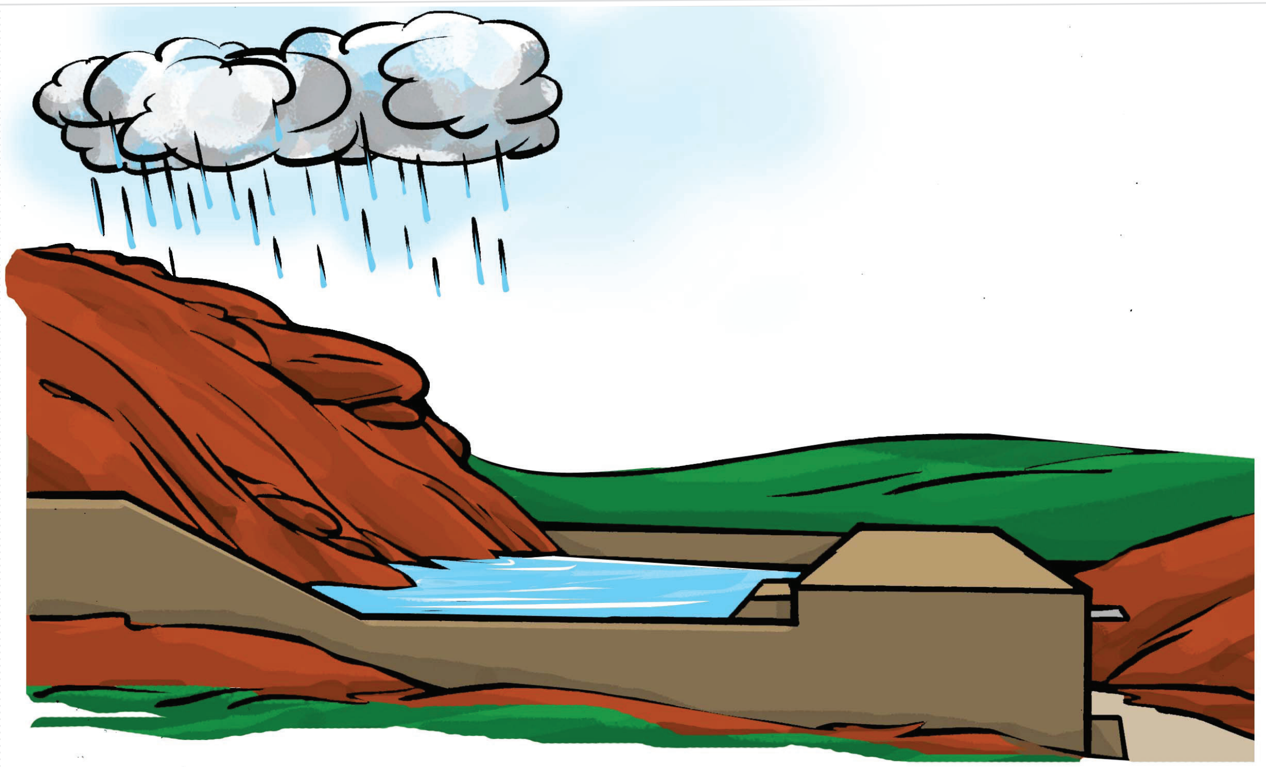


Figure 38: The dammed storage outlet system with sediment storage, filter box, outlet pipe, and washout pipe

The advantages of dammed storage include the followings:

They are economical and reliable source of water in arid, semi-arid and desert areas where the groundwater is saline, surface water unavailable and rainfall is low. The potentially large storage capacity can supply water to large communities for multiple uses. The maintenance of dammed storage system is simple and cheap and mainly involves cleaning the storage space before rainy seasons, repairing cracks that may form in the retaining wall, cleaning the filter medium in the outlet box, and repair or replacement of water fittings (valves and taps).

3.7.6 Advantages and Disadvantages of Dammed storage

Advantages

- They are economical and reliable source of water in arid, semi-arid and desert areas where the groundwater is saline, surface water unavailable and rainfall is low.
- The potentially large storage capacity can supply water to large communities for multiple uses.
- The maintenance of dammed storage system is simple and cheap and mainly involves cleaning the storage space before rainy seasons, repairing cracks that may form in the retaining wall, cleaning the filter medium in the outlet box, and repair or replacement of water fittings (valves and taps).

The disadvantages of dammed storage include:

- Open to contamination by animals and birds.
- Very high water losses due to evaporation, which could be as high as 50% especially in arid and semi-arid areas.
- Mosquito breeding can be a problem in the low lying warm conditions; and
- Algal growth affects the quality of water collected in open storage.
- Designs vary from site to site and usually requires an expert to carry out.
- The initial capital investment is huge and may not be afforded locally.

3.7.7 Operation and maintenance of Dammed storage

- Clean the storage space at least once every two years before the start of the rainy season.
- Regularly check for cracks or leakage in the retaining wall and repair the cracks immediately to reduce water loss and avoid the risk of wall collapse.
- Clean the filter medium in the outlet box at least once every year i.e. just before the start of the rainy season.
- Repair or replace any damaged of water fittings (valves and taps) to avoid water loss.

3.8 EMAS Tank

3.8.1 Description

EMAS (Escuela Movil de Aguay Saneamiento) is a low cost underground rainwater harvesting tank the tank has a narrow neck of 0.8m with a wider stem of 1.4 – 1.8 m and bowl shaped bottom (Figure 39: Fully functional EMAS tank). It can store up to 8000 litres. The depth is usually 3 m though it is possible to go deeper. Several tanks can be built in series interconnected with pipes to increase storage. The reduced diameter of the neck of the tank is designed to save cost of the cover. The tank depth of an EMAS tank has no limit but the average depth should be 3 – 4 m. The excavation of the bottom should be in bowl shape to enable sediments settle in one place for ease of cleaning.

Figure 39: Fully functional EMAS tank

Table 11: BoQ for EMAS Tanks (August 2015 Rates)

Item	Unit	Rate(UGX)	3m³	5m³	8m³	10m³
Excavation	M³	10,000/=	4	6	9	11
Portland Cement (50 kg)	Bag	30,000/=	4	5	6	7
Water proof (leak seal) cement	Kg	3,000/=	3	4	5	6
Lake sand	Ton	30,000/=	0.5	0.75	1	1
Fine sand	Ton	30,000/=	0.5	0.75	1	1
Bricks (well burnt)	Pc	250/=	250	250	250	250
Poles (for ladder)	Pc	7,000/=	3	3	4	4
Wire nails (assorted)	Kg	5,000/=	1	1	1	1
Water	Litre	20/=	200	250	300	350
EMAS pump (optional)	Pc	100,000/=	1	1	1	1
Skilled labour	Man day	30,000/=	4	4	5	5
Unskilled labour	Man day	15,000/=	4	4	5	5

Equipment and Tools for EMAS Tank Construction

The tools required to construct EMAS tank are show in Table 12 below

Table 12: Tools required in construction of EMAS tank

Tool	Quantity
Wheel barrow	1
Spade	2
Pick axe	2
Hoe	1
Trowel	2
Wooden float	2
Steel float	1
Spirit level	1

Tool	Quantity
Measuring tape	1
Batching box	1
Mortar pans	2
Building line string	1
Claw hammer	1
Bow saw	1

3.8.2 Steps for construction for EMAS

Step 1: Excavation

Start excavation with a narrow mouth of 0.8m up to the depth of 1 m (Figure 40: Excavate up to 1m below the ground).

Increase the size of excavation diameter to 1.4 – 1.8 m to the required depth of 3 – 4 m.

It is recommended to excavate in stable soils. If the soils are stony, there will be holes where stones are removed; cover them with mud.

Figure 40: Excavate up to 1m below the ground

Step 1: Excavation

Start excavation with a narrow mouth of 0.8m up to the depth of 1 m (Figure 40: Excavate up to 1m below the ground).

Increase the size of excavation diameter to 1.4 – 1.8 m to the required depth of 3 – 4 m.

It is recommended to excavate in stable soils. If the soils are stony, there will be holes where stones are removed; cover them with mud.

Step 2: Construction of the curbstone

Begin constructing the curbstone from the foundation around the tank hole for about 30cm deep (Figure 41).

On the foundation, a curbstone is setup of another 30 cm using stone and mud or only mud.

Set up the intake and overflow piping. For a roof of about 50 m^2 a pipe of $1^{1/2''}$ pipe is adequate. Tie a plastic millimetre screen to the overflow pipe to prevent insects getting into the tank.

On the moistened mud you set up set up the cement layer of about 3 cm to make it solid and waterproof

Figure 41: Construction of the curbstone

Step 3: Wall Construction

- Set up mud cakes to provide a solid layer on which to lay the cement white wash (use water proof cement). The thickness of the mud cake should be about 2.5 cm. Use slightly dry mud
- Prepare a cement motor with fine sand. The ratio should be 1:4 and 1:5 depending on the sand texture.
- Plaster the first layer directly on the moistened earth. Its thickness should be approximately 1.5 cm.
- After the mortar has aerated, render the second layer with a ratio of 1: 3(cement to sand)

- The second layer should be thinner than the first one. The plastering should be continuous and not interrupted for days. Polish the wall using slipper. You can also use trowel, rubber or oilcloth gloves and set the mortar manually.

- At the end of plastering, the case pipe is arranged for the pump with its plug (Figure 42)

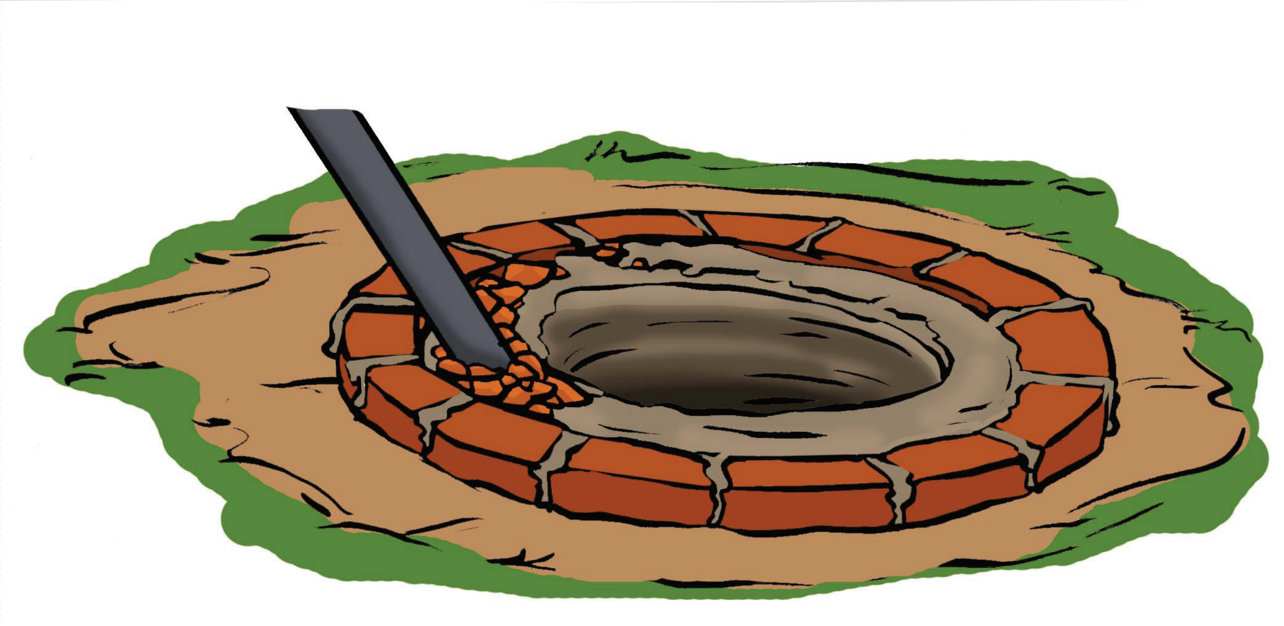


Figure 42: Plaster and arrange case pipe with its plug

Step 4: Applying waterproof cement

- After plastering, after 12 hours, apply the first layer of waterproof cement (Figure 43). Cover the mouth of the tank such that the cement does not dry too fast. Waterproof cement (white wash) is laid on the wall with a brush or a thin broom. Apply two coats of white wash.

- Perforate the inlet hole with a knife at the floor after the tank has cured.

- Construct a deeper pit at the end of the tank help in draining the tank

- Fill the tank with water after 5 days.

Figure 43: Applying water proof cement

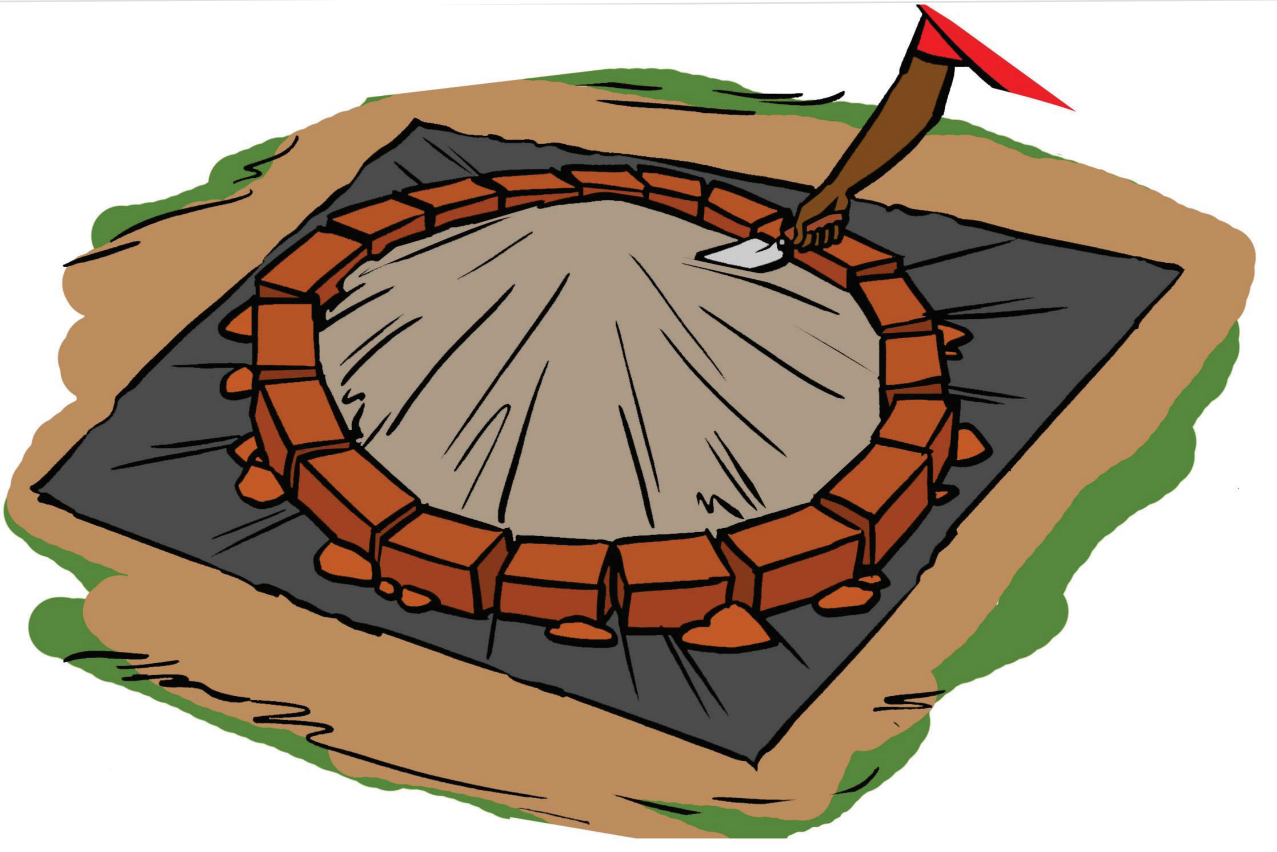


Figure 44: Constructing the tank cover

Step 5: Constructing the tank cover

EMAS casts its covers arched vaulted. For its mould a small hillock made of earth and covered with plastic or paper. The height of the arch is a ¼ of its diameter. No iron bars are used except a ¼ ″ ring near its outward edge.

To be able to pick up this heavy cover, two holders are cast tied to a ¼ ″ iron bar ring

For 1 meter diameter cover, cement must be 5 cm thick. The larger the diameter, the more thickness.

As its outward mould, a ¼″ x 2″ galvanised iron or simply stones, earth on its edge.

At the center of the arch or vault a short 11/4″ pipe is cast of about 20 cm length. This pipe is used to control the level and volume of water and must be always plugged with a stopper made of the same PVC pipe.

3.8.3 Advantages and Disadvantages of EMAS tanks

Advantages

- They are cheap to build requiring very little manufactured materials i.e. cement.
- The can be easily constructed in different sizes depending on the need and available resources of the beneficiaries.
- They cannot be easily vandalised.

- They are durable.
- They can be constructed by locally trained artisans.
- Repairs to minor damages can be easily carried out by any trained artisan.

Disadvantages

- They can only be constructed in firm and non-rocky soils.
- Being underground, they require a pump to hygienically extract water for consumption thereby adding to capital investment and O&M costs.
- For new tanks, chemicals in cement dissolve in stored water thereby affecting the quality.
- They require a lot of experience and skills to excavate the pit to the required accuracy.
- They rely entirely on the stability of the soil for their strength; any collapse of the excavation can damage the tank permanently.
- Being underground, it would be difficult to detect leakages that can lead to high water losses.

3.8.4 Operation and Maintenance of EMAS tanks

- Monitor any significant drop in water level to detect leakages in the tank.
- Regularly check for any cracks in the wall of the tank and seal them immediately.
- To seal a crack in the wall; cut through the plaster about 2.5cm on both sides of the crack and plaster with a strong mortar of 1:2 cement to sand ratio.
- Clean out any rubbish from the bottom of the tank at least once a year (i.e. at the end of the long dry season.

For More Information

Appropriate Technology Centre for Water and Sanitation - Upper Kauga, Prison Road, Mukono P.O. Box 748 Mukono, Uganda Telephone: +256-(0)-414-690806 E-mail: atc.mwe@gmail.com: http://www.atc.washuganda.net

3.9 BOB RAINWATER BAG (TANK)

3.9.1 Description

The *bob* rainwater bag is a low-cost, innovative domestic rainwater harvesting device. It is essentially a bag with a storage capacity of up to 1,400 litres. It is easy to transport and weighs 8 pounds (3.6kg) when empty. This tank was developed by Enterprise Works, a division of Relief International. The bag is manufactured in China and imported in Uganda ready for installation. It can be installed using local materials cement and bricks or mud and bricks. The bags cost USD 45 – 50. These tanks were successfully piloted in Kabale, Kamwenge, Isingiro and Mbarara districts (Naugle et al, 2011).

Construction Materials – BOB Tank

The materials required are summarized in the Table 13 below:

Table 13: Construction Materials required for BOB tank

Description	Unit	Rate (UGX)	1,000L	1,500L
Cement (50kg bag)	Bag	30,000/=	1.5	1.5
Burnt clay brick	Pc	250/=	300	300
Sand	Ton	30,000/=	0.25	0.25
Hardcore	Ton	30,000/=	0.5	0.5
Treated wooden poles (for support)	Pc	10,000/=	4	4
Wire nails (assorted)	Kg	5,000/=	1	1
BOB tank bag (1,000 L)	Pc	100,000/=	1	0
BOB tank bag (1,500L)	Pc	120,000/=	0	1
Skilled mason	Man day	30,000/=	1	1
Unskilled labour	Man day	15,000/=	1	1

Equipment and Tools for BOB Tank Installation

The tools required to construct BOB tank are show in Table 14 below

Table 14: Tools required in construction of BOB tank

Tool	Quantity
Wheel barrow	1
Spade	1
Hoe	1
Trowel	1
Wooden float	1
Steel float	1
Spirit level	1
Measuring tape	1
Batching box	1
Mortar pans	1
Building line string	1
Claw hammer	1
Bow saw	1

3.9.2 Installation Steps

Step 1: Construction of Raised Platform

Site the location of the platform, which the rainwater bag will be installed.

Mark the area with a radius of the platform should be 0.5m Lay the first line of bricks around the area marked .You may use mud mortar or cement mortar in laying the bricks (Figure 45)

Then lay the subsequent line of bricks up to 1 meter high.

Figure 45: Lay line of bricks up to 1m and compact the earth

Leave the mortar cure for a day before filling platform with earth or stone aggregate.

Compact the earth to ensure there are no voids. For aggregate, use a mix ratio of 1:6:6 for cement sand and aggregate to make the mortar for filling the platform. Plaster the wall of the platform with mud or cement mortal (Figure 46).

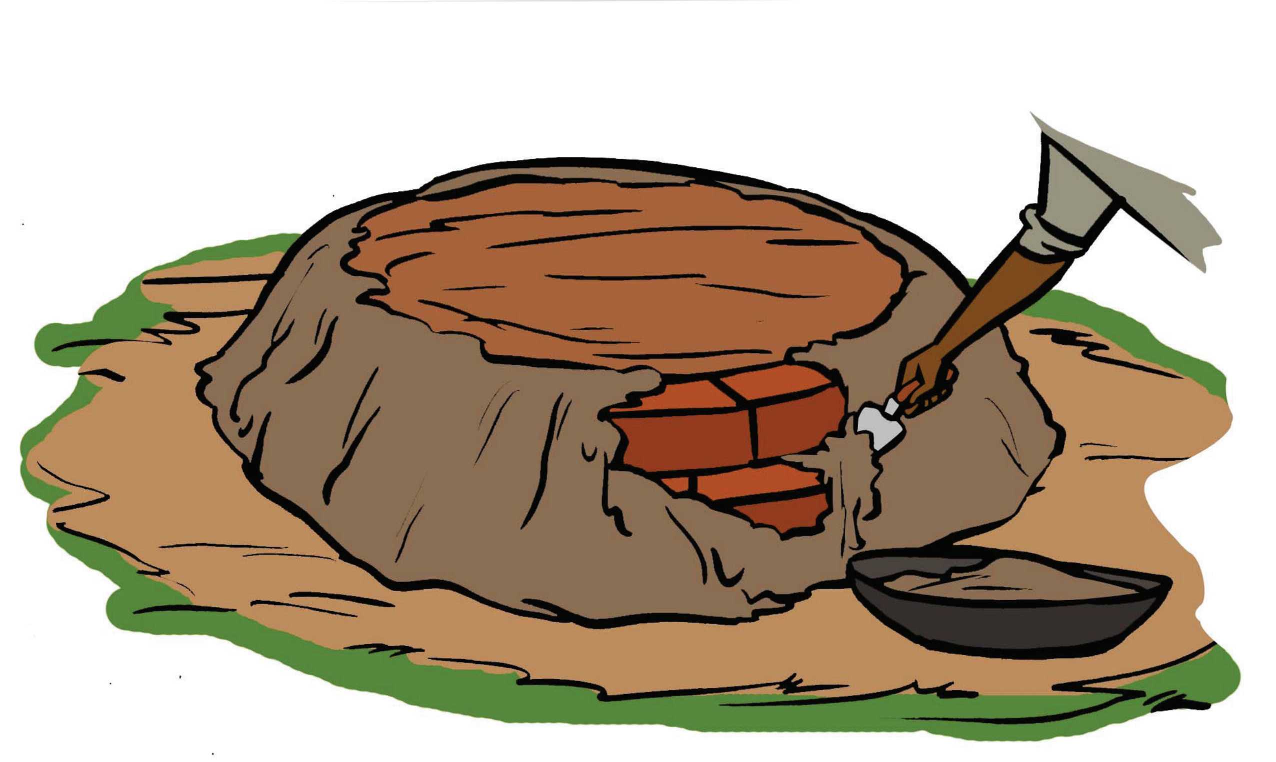


Figure 46: Plaster the wall of the platform

To ensure durability, cement plaster is recommended. Leave the plaster for cure for at least a day (Figure 47). Apply the second coat to make smooth finishing

Figure 47: Curing of the plaster

Step 2: Installing the bag:

Plant four supporting poles, one in each corner (Figure 48). Install two cross bars joining the poles

Using ropes tie the rainwater bag on the cross bars. Ensure the cross bars and ropes are strong enough to resist the weight of the tank when it is full of water.

Figure 48: Installing of the bag

Step 3: Install the gutters and tap

Ensure you install the gutters and tap correctly (Figure 49)

Figure 49: Install the gutters and tap

Step 4: Protecting the bag:

To protect the bag from external damage, construct a ring fence around it (Figure 50)

The materials may be locally available such as reeds,brick wall or chain link depending affordability

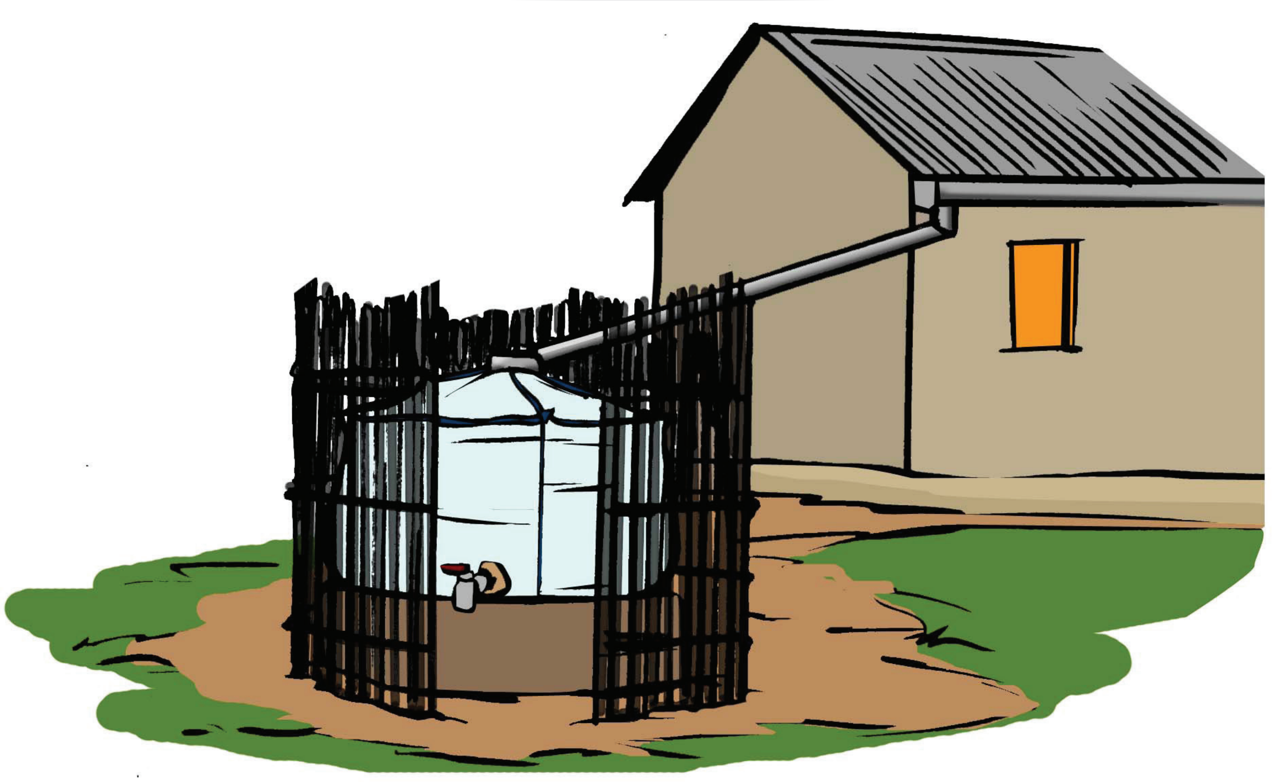


Figure 50: Install a ring fence around the bag

3.9.3 Advantages and Disadvantages of bob rainwater bag

Advantages

- Very easy to transport – weighs 3.6kg only
- Low Cost - costs USD 50 or (UGX 160,000) for 1000 litre bag
- Easy to install – locally available materials (cement, bricks, mud and plastic gutters and fittings) can be used to install the tank
- Adaptable to wide variety of conditions
- Maintains water quality over time

Disadvantages

- They have limited storage capacity and are not suitable to meet larger demands.
- They can be easily vandalised and repairs may be difficult.
- They can be easily stolen and material reused for other purposes.

3.9.4 Operation and Maintenance of bob rainwater bag

- Proper maintenance of the rainwater bag requires that the household takes extra caution to protect the bag from external damage. Do not allow children or animals near the rainwater bag because they may damage it.
- During dry season when the rainwater is not in use, remove and take it where it can be safely be kept.
- Install wire mesh screen on the inlet to trap the debris
- Clean the bag regularly to ensure clean water.

For more information

EnterpriseWorks a Division of Relief International - Headquarters 1100 H Street, Suite 930 NW Washington, DC 20005 USA Tel: +1 202 639 8660 Fax: +202 639 8664

Relief International http://drwh.enterpriseworks.orgEmail: dc@ri.org

Or

Water and sanitation department: Joint efforts to save the environment (JESE) P.O.Box 728, Fort Portal Uganda - http://www.jese.org Email: mailto:jese@jese.org Tel:+256483-25253

Annex 1: Tank size selection for households

Size of household	Average Rainfall	Storage size (Litres)			Comments
		Roof size			
		5m x 8m	7m x 12m	9m x 15m	
5 people	500mm	5,000	9,000	10,000	10,000L is needed for year round supply
7 people	500mm	5,000	9,000	14,000	14,000L is needed for year round supply
9 people	500mm	5,000	9,000	15,000	18,000L is needed for year round supply
11 people	500mm	5,000	9,000	15,000	22,000L is needed for year round supply
5 people	800mm	7,000	10,000	10,000	10,000L is needed for year round supply
7 people	800mm	7,000	14,000	14,000	14,000L is needed for year round supply
9 people	800mm	7,000	15,000	16,000	18,000L is needed for year round supply
11 people	800mm	7,000	15,000	22,000	22,000L is needed for year round supply
5 people	1,000mm	9,000	10,000	10,000	10,000L is needed for year round supply
7 people	1,000mm	9,000	14,000	14,000	14,000L is needed for year round supply
9 people	1,000mm	9,000	18,000	18,000	18,000L is needed for year round supply
11 people	1,000mm	9,000	18,000	22,000	22,000L is needed for year round supply
5 people	1,200mm	10,000	10,000	10,000	10,000L is needed for year round supply
7 people	1,200mm	10,500	14,000	14,000	14,000L is needed for year round supply
9 people	1,200mm	10,500	18,000	18,000	18,000L is needed for year round supply
11 people	1,200mm	10,500	22,000	22,000	22,000L is needed for year round supply

Note:

The key factor in determining the capacity of tank is the need to have the amount of water required to meet the dry season demand in storage at the end of the rainy season. For a given number of beneficiaries, this factor is affected by the amount of rainfall and the size of the catchment area.

In computing access the ministry recognises tanks of 6,000ltrs capacity and above as a way of improving access figures but also encouraging the preference on that capacity among promoters like NGOs.

Table above provides a guide for selecting tank size to provide year round domestic water supply of water for households in different parts of the country with a given quantity of rainfall. Following the example above, it is assumed that the average domestic water demand is 20litres/person/day.

1. The small roof area (5mx8m) can only meet the full demand for the household of 5 in areas with average annual rainfall of 1,200mm.

2. Where amount of water stored is less than the minimum required for year round supply, households should reduce water consumption rate during the dry seasons to ensure that water is available for the most critical needs like drinking and cooking.

3. For larger roofs in areas of high rainfall, additional storage can be provided to meet other needs like vegetable gardening or even for sale.

Annex 2: Population served by techniques

No.	District	Population	Population served by technology					
			PS	SW	DBH	RHT	PT	Total
TSU 1								
1	ADJUMANI	420,000	8,000	18,600	143,700	198	5,700	176,198
2	ARUA	806,000	200,200	41,100	303,000	918	12,000	557,218
3	KOBOKO	264,200	50,200	18,000	62,700	51	4,800	135,751
4	MARACHA	202,800	81,800	21,900	73,800	390	1,500	179,390
5	MOYO	470,700	6,400	8,700	123,300	375	21,300	160,075
6	NEBBI	362,800	36,000	32,400	188,100	399	4,350	261,249
7	YUMBE	624,600	7,200	33,600	173,700	288	4,350	219,138
8	ZOMBO	227,300	184,800	12,000	32,100	240	20,400	249,540
Total		**3,378,400**	**574,600**	**186,300**	**1,100,400**	**2,859**	**74,400**	**1,938,559**
TSU 2								
1	AGAGO	327,700	3,600	36,900	188,700	543	9,450	239,193
2	ALEBTONG	234,800	70,400	63,900	82,500	228	6,000	223,028
3	AMOLATAR	134,200	800	4,200	94,500	330	1,350	101,180
4	AMURU	179,100	25,200	17,100	105,600	135	8,100	156,135
5	APAC	371,700	3,200	51,000	206,700	1,158	3,150	265,208
6	DOKOLO	195,800	34,600	58,500	75,900	108	2,700	171,808
7	GULU	417,900	37,400	45,900	203,100	507	1,650	288,557
8	KITGUM	267,700	200	4,500	250,500	1,611	1,350	258,161
9	KOLE	246,900	44,800	66,000	68,700	672	3,150	183,322
10	LAMWO	187,000	0	3,900	205,500	147	1,050	210,597
11	LIRA	408,200	91,000	117,300	99,000	264	4,350	311,914
12	NWOYA	56,900	12,600	9,900	76,200	84	3,150	101,934
13	OTUKE	91,400	7,800	20,400	67,800	117	1,950	98,067
14	OYAM	404,100	39,800	86,100	117,000	408	3,300	246,608
15	PADER	246,000	2,000	10,800	192,000	246	3,150	208,196
Total		**3,769,400**	**373,400**	**596,400**	**2,033,700**	**6,558**	**53,850**	**3,063,908**
TSU 3								
1	ABIM	57,800	1,000	5,700	71,100	153	0	77,953
2	AMUDAT	126,300	200	3,000	47,700	0	0	50,900
3	AMURIA	468,600	6,400	36,300	197,400	15	900	241,015
4	BUKEDEA	202,700	40,400	45,600	51,300	60	1,950	139,310
5	KAABONG	445,100	0	6,600	108,000	6	300	114,906
6	KABERAMAIDO	206,700	6,400	21,300	117,300	96	1,200	146,296
7	KATAKWI	190,600	200	18,900	149,100	66	2,250	170,516
8	KOTIDO	262,000	0	600	114,900	216	2,250	117,966

No.	District	Population	Population served by technology					
			PS	SW	DBH	RHT	PT	Total
9	KUMI	270,600	32,200	48,000	78,900	210	300	159,610
10	MOROTO	150,700	200	900	73,500	66	0	74,666
11	NAKAPIRIPIRIT	185,900	1,400	9,900	77,100	27	3,300	91,727
12	NAPAK	224,600	1,000	300	107,700	180	0	109,180
13	NGORA	171,700	800	40,800	55,200	78	2,700	99,578
14	SERERE	323,300	6,200	63,900	152,400	96	0	222,596
15	SOROTI	354,000	18,600	43,800	154,200	279	5,100	221,979
Total		**3,640,600**	**115,000**	**345,600**	**1,555,800**	**1,548**	**20,250**	**2,038,198**
TSU 4								
1	BUDAKA	188,600	29,400	5,400	116,700	117	1,350	152,967
2	BUDUDA	194,200	93,600	900	3,900	99	44,850	143,349
3	BUGIRI	458,900	38,400	49,200	111,600	609	5,400	205,209
4	BUKWO	79,400	20,600	1,500	600	30	40,200	62,930
5	BULAMBULI	130,300	60,400	19,200	25,500	21	35,100	140,221
6	BUSIA	310,400	49,400	24,600	122,400	189	5,850	202,439
7	BUTALEJA	234,900	800	10,800	138,000	21	150	149,771
8	BUYENDE	278,000	0	2,400	127,500	165	1,050	131,115
9	IGANGA	529,900	19,400	79,200	185,700	234	150	284,684
10	JINJA	527,000	70,600	101,100	100,800	219	900	273,619
11	KALIRO	231,200	200	6,900	120,600	39	150	127,889
12	KAMULI	534,900	3,400	122,700	192,300	345	5,400	324,145
13	KAPCHORWA	123,500	56,000	0	2,100	78	31,800	89,978
14	KIBUKU	194,200	8,400	11,400	102,900	81	1,500	124,281
15	KWEEN	111,800	25,200	300	12,900	48	12,900	51,348
16	LUUKA	278,600	25,200	53,700	102,300	51	0	181,251
17	MANAFWA	392,400	133,400	4,800	71,700	231	18,900	229,031
18	MAYUGE	493,100	51,800	65,400	98,700	39	600	216,539
19	MBALE	467,900	94,200	12,600	74,400	96	59,100	240,396
20	NAMAYINGO	253,000	5,600	34,200	45,600	420	1,350	87,170
21	NAMUTUMBA	230,800	12,400	29,400	103,800	96	150	145,846
22	PALLISA	388,500	43,600	18,000	136,500	81	450	198,631
23	SIRONKO	264,900	76,400	4,800	20,100	72	74,100	175,472
24	TORORO	511,300	46,000	7,800	220,200	318	450	274,768
Total		**7,407,700**	**964,400**	**666,300**	**2,236,800**	**3,699**	**341,850**	**4,213,049**
TSU 5								
1	BUIKWE	452,100	152,600	51,900	50,700	237	6,600	262,037
2	BULIISA	84,700	6,400	30,300	32,400	75	12,450	81,625
3	BUTAMBALA	102,300	51,200	72,000	17,700	189	7,200	148,289

No.	District	Population	Population served by technology					
			PS	SW	DBH	RHT	PT	Total
4	BUVUMA	58,200	5,400	10,800	11,400	33	3,600	31,233
5	GOMBA	156,900	17,000	76,800	38,100	408	6,000	138,308
6	HOIMA	583,900	126,400	155,100	117,900	702	7,800	407,902
7	KAYUNGA	372,800	13,800	76,500	147,900	231	6,600	245,031
8	KIBOGA	178,700	19,000	46,800	36,000	603	17,550	119,953
9	KIRYANDON-GO	349,700	3,800	76,200	93,900	57	0	173,957
10	KYANKWANZI	197,700	4,200	46,200	52,200	540	4,800	107,940
11	LUWERO	462,400	3,000	135,300	161,100	678	8,550	308,628
12	MASINDI	388,000	77,400	140,400	74,400	339	2,850	295,389
13	MPIGI	221,600	53,600	145,800	25,800	429	3,750	229,379
14	MUKONO	579,900	129,400	92,400	116,100	891	17,850	356,641
15	NAKASEKE	203,600	1,800	93,600	99,000	753	10,350	205,503
16	NAKASON-GOLA	163,000	200	12,300	110,400	828	69,300	193,028
17	WAKISO	1,505,300	195,400	378,000	89,700	2,817	129,000	794,917
Total		**6,060,800**	**860,600**	**1,640,400**	**1,274,700**	**9,810**	**314,250**	**4,099,760**
TSU 6								
1	BUNDIBUGYO	286,900	43,400	0	2,700	228	107,100	153,428
2	KABAROLE	428,400	104,400	208,500	20,100	897	62,400	396,297
3	KAMWENGE	346,900	98,200	171,300	17,700	936	79,650	367,786
4	KASESE	796,500	141,000	18,600	21,600	498	306,900	488,598
5	KIBAALE	749,300	145,200	206,400	109,500	1,494	1,650	464,244
6	KYEGEGWA	171,100	14,400	58,500	31,500	333	3,150	107,883
7	KYENJOJO	415,200	99,400	168,000	46,500	597	17,100	331,597
8	MITYANA	321,400	19,600	131,400	83,100	2,295	29,550	265,945
9	MUBENDE	654,600	15,200	121,800	53,700	531	10,650	201,881
10	NTOROKO	92,200	12,600	29,700	15,300	174	16,200	73,974
Total		**4,262,500**	**693,400**	**1,114,200**	**401,700**	**7,983**	**634,350**	**2,851,633**
TSU 7								
1	BUKOMAN-SIMBI	157,100	28,400	73,200	24,900	786	15,750	143,036
2	KALANGALA	74,500	5,000	20,100	600	522	9,600	35,822
3	KALUNGU	180,600	29,200	125,400	31,200	459	21,450	207,709
4	LWENGO	273,200	22,000	140,400	69,000	2,166	4,650	238,216
5	LYANTONDE	83,300	0	7,800	29,100	1,479	4,500	42,879
6	MASAKA	255,600	27,600	114,900	16,800	207	0	159,507
7	RAKAI	501,700	13,600	107,700	90,000	5,409	6,900	223,609
8	SEMBABULE	228,300	0	46,500	46,200	1,896	1,500	96,096
Total		**1,754,300**	**125,800**	**636,000**	**307,800**	**12,924**	**64,350**	**1,146,874**

No.	District	Population	Population served by technology					
			PS	SW	DBH	RHT	PT	Total
TSU 8								
1	BUHWEJU	105,500	46,600	5,700	600	156	16,950	70,006
2	BUSHENYI	260,400	157,600	35,400	6,600	327	25,650	225,577
3	IBANDA	268,200	35,400	45,300	6,300	204	54,000	141,204
4	ISINGIRO	439,400	9,200	29,700	30,300	15,927	29,400	114,527
5	KABALE	510,300	226,000	1,800	28,500	2,547	251,400	510,247
6	KANUNGU	261,400	202,000	13,800	21,900	612	77,400	315,712
7	KIRUHURA	321,400	200	46,800	67,200	4,929	22,500	141,629
8	KISORO	261,300	83,800	0	1,800	1,530	31,800	118,930
9	MBARARA	470,300	86,000	25,800	43,800	10,935	111,450	277,985
10	MITOOMA	244,700	149,200	26,700	4,800	375	28,050	209,125
11	NTUNGAMO	508,100	159,600	119,400	63,600	615	55,350	398,565
12	RUBIRIZI	129,500	33,200	17,400	1,800	849	26,550	79,799
13	RUKUNGIRI	334,400	248,600	25,500	19,200	1,491	70,350	365,141
14	SHEEMA	229,200	75,400	46,800	11,100	537	79,350	213,187
Total		**4,344,100**	**1,512,800**	**440,100**	**307,500**	**41,034**	**880,200**	**3,181,634**
GRAND TOTAL								**22,533,615**

Source: Ministry of Water and Environment, MIS

Key

Population served by technology: Total population served per Technology without capping

PS: Protected Springs, SW: Shallow Wells, DBH: Deep Boreholes, RHT: Rainwater Harvest Tanks, PT: Public Taps

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