Water for the World

Designing a Household Cistern
Technical Note No. RWS. 5.D.1

Household cisterns are an important means of storing rainwater for family use. In areas where rainwater is the primary source of drinking water, adequate storage is necessary to ensure that people have access to a sufficient quantity of good quality water year-round. One major problem is that rainfall often is not reliable throughout the year or from year to year. People cannot count on a certain supply. Therefore, cistern design is very important to provide water for times when rainfall is seasonably or abnormally scarce.

Useful Definition

CATCHMENT - A surface from which rainfall run-off is collected; common catchments are roofs and especially prepared ground areas.

This technical note describes the design of several types of household cisterns and the conditions under which each should be used. Follow all design steps carefully. The design process should result in the following items which should be given to the person in charge of construction:

1. A list similar to Table 1 or 2 of all materials and tools needed to build the type of cistern or storage reservoir chosen.

2. A plan of the cistern similar to Figure 1 showing the dimensions and important design features.

The choice of the type of cistern to build depends on two very important factors:

1. <u>The purpose of the cistern</u>. Rainwater may be the only source of water. If so, a cistern must be designed to hold a sufficient volume of water to meet people's needs throughout the entire year. Cisterns may be used only during the dry season to replace a source that disappears during times of little or no rain. Such cisterns need only sufficient capacity to store water during the rainy season to be used during the dry season.

2. <u>The materials available for construction, the skills of the people, and the amount each family is able to spend</u>. Whenever possible, locally available materials should be used to keep costs low.

Table 1. Sample Materials List for a Reinforced Concrete Cistern

Item	Description	Quantity	Estimated Cost
Labor	Local workers	____	____
Supplies	Portland cement	____	____
	Clean sand and gravel	____	____
	Clean water for mixing cement	____	____
	Reinforcing rods	____	____
	Screened mesh	____	____
	Boards and plywood for frames	____	____
	Nails	____	____
	Old motor oil or other oil for lubricating forms	____	____
	Galvanized pipe for overflow	____	____
	Tap for outlet	____	____
	Guttering	____	____
Tools	Shovels and picks	____	____
	Measuring tape	____	____
	Hammers	____	____
	Saws	____	____
	Carpenter's square	____	____
	Pliers	____	____
	Wire cutters	____	____
	Mixing bin (mortar box)	____	____
	Buckets	____	____
	Trowel	____	____
	Adjustable wrench	____	____
	Screw drivers	____	____
	Paint brush	____	____
	Level	____	____

Total Estimated Cost = ____

Table 2. Sample Materials List for a Ferrocement Cistern

Item	Description	Quantity	Estimated Cost
Labor	Local workers	___	___
Supplies	Portland cement	___	___
	Plain wire, 2.5mm	___	___
	Chicken wire	___	___
	Water pipe	___	___
	Water tap	___	___
	Overflow pipe	___	___
	Galvanized iron sheet and angle iron	___	___
	Sand	___	___
	Gravel	___	___
	Bolts	___	___
	Water	___	___
Tools	Shovels and picks	___	___
	Wire cutters	___	___
	Wrenches (adjustable and open)	___	___
	Screw drivers	___	___
	Paint brushes	___	___
	Trowels	___	___
	Mixing bin (mortar box)	___	___
	Wheelbarrow	___	___
	Buckets	___	___
	Hacksaw and blades	___	___
	Hammers	___	___

Total Estimated Cost = ___

Storage Tank Capacity

The capacity of the cistern depends on the maximum amount of water that must be stored to meet individual family needs. To find the ideal capacity, determine:

- average annual and monthly quantities of rainfall;
- amount of water available from the catchment area;
- number of people who must use the water;
- average daily water use per family.

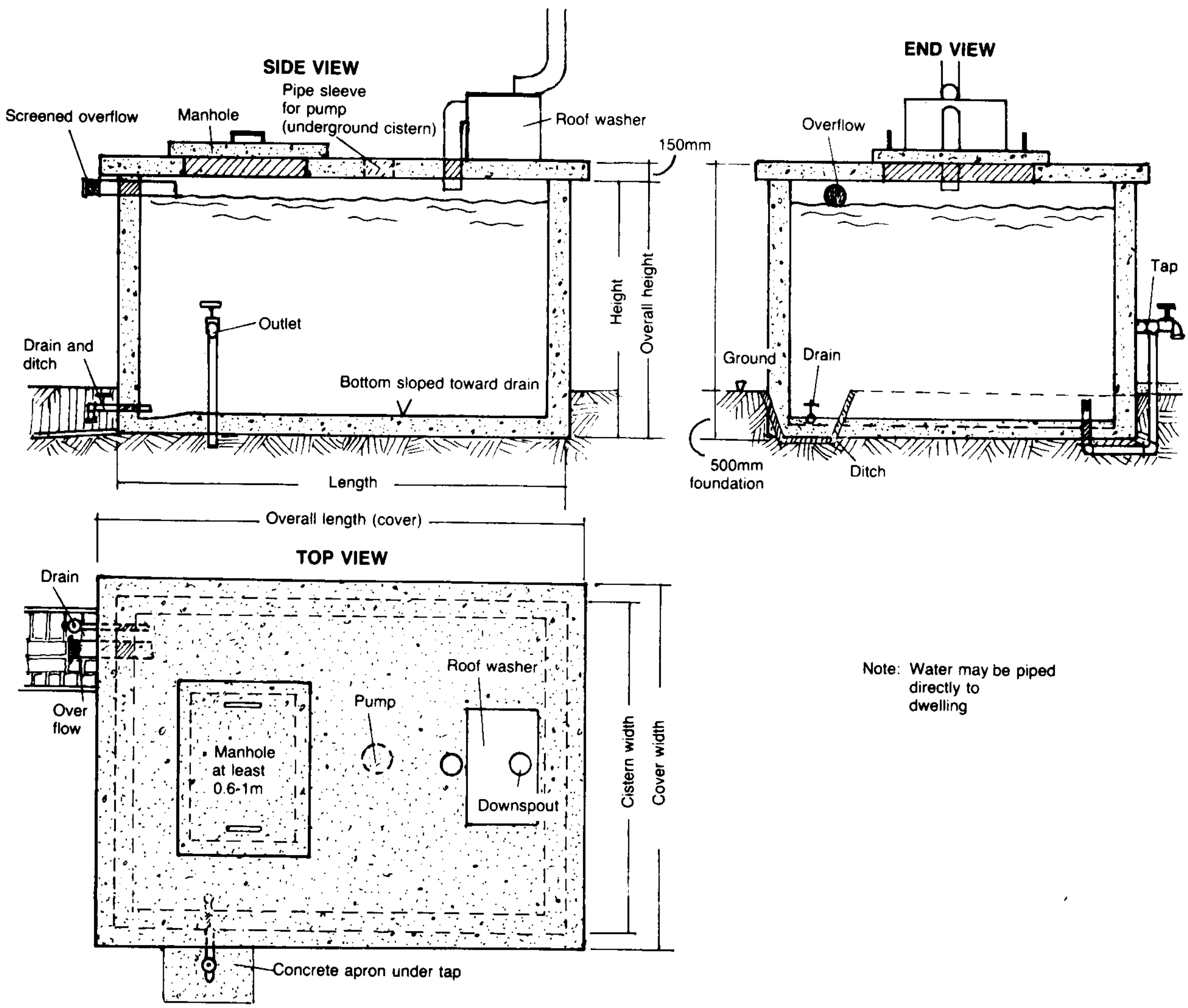

Figure 1. Plan for Household Cistern

Regional data on average monthly rainfall may be available from a government agency, airport or weather station. Try to obtain at least estimates of monthly rainfall rates.

The catchment area is the complete surface area of the roof: the length of the roof times the width of the roof base. Figure 2 shows the dimensions of a catchment area $48m^2$. The amount of water in millimeters each month from a catchment area is found by multiplying the average monthly rainfall by the catchment area and then by 0.8 to take into account losses: catchment area x rainfall x 0.8 = available monthly rainfall. A complete discussion of the technique used to determine the volume of available rainfall may be found in "Determining the Need for Water Storage," RWS.5.P.1.

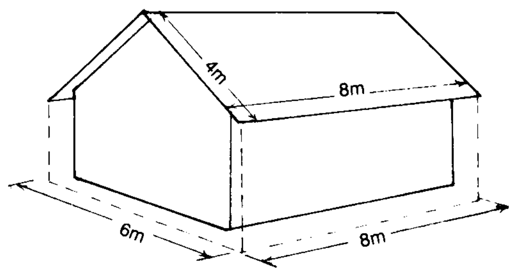

Figure 2. Roof Catchment Area

Determine the maximum storage capacity using Figure 3. The average monthly rainfall figures are in the table at the top of the page. These rainfall figures are only an example. The rainfall is great during several months but in June and July no rain falls at all. Design of storage jars and cisterns should take these variations into account.

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Rainfall (millimeters)	226	188	173	46	2.5	0	0	5	5	41	130	216	1,032.5
Available Water (in liters)	8,678	7,219	6,643	1,766	96	0	0	192	192	1,574	4,992	8,294	39,646

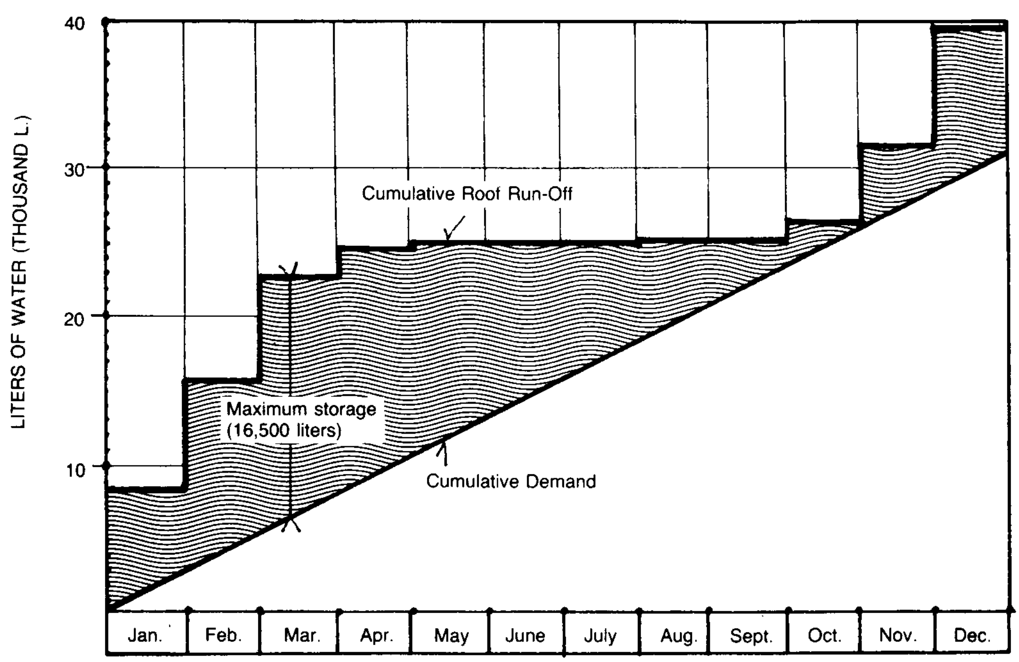

Figure 3. Determining Maximum Storage Capacity

The second set of figures on Figure 3 shows the potential monthly available supply of water. These figures are obtained by multiplying the average rainfall by the catchment area x 0.8. For example, in March rainfall is 173mm. Therefore, the amount of water potentially available is:

$$173\text{mm} \times 48\text{m}^2 \times 0.8 = 6643 \text{ liters.}$$

The graph in Figure 3 has two curves. The top curve is called the cumulative run-off and is the sum of each month's potential supply. The diagonal line represents the cumulative demand. The demand is assumed to be constant and the line should touch the supply curve at only one point as shown. In this example, demand is approximately 2580 liters/month or 86 liters/day.

Maximum storage capacity needed is determined by finding the greatest distance between the two curves. In the example, the greatest distance represents 16500 liters or a storage capacity of 16.5m^3.

Remember that this is only a rough estimate to use in planning and design. During the rainy season when water is plentiful, people will use greater quantities of water. During the dry season, people tend to conserve water, using their best sources only for drinking and some cooking. It is unlikely that a tank of this volume would be constructed by an individual household. In most cases, the cost would be too great. Instead, smaller volume tanks would be used. Rather than 86 liters per family per day, consumption might fall to 50 or even 40 liters per day. This would lower the storage volume needed to 4000-5000 liters. A tank just under 10m^3 would then be practical. A general rule to follow is that if cisterns are to be used for supplementary water supply, a minimum storage of 500 liters should be provided. Where such water is the principal supply, a much greater capacity is needed. Whenever resources permit, install the largest possible cistern to meet estimated needs. Design of a cistern with maximum capacity may be impossible but an attempt should be made to come as close as possible. Users should be educated in wise water use practices so that they can count on a year-long supply.

Cistern Design

Concrete, ferrocement, mortar or clay storage jars or underground cisterns are all useful and practical for storing rainwater. Reinforced concrete cisterns are usually rectangular in shape and are located adjacent to the house. They can either be built at ground level as shown in Figure 4 or underground as in Figure 5. Reinforced concrete is preferred because it is watertight.

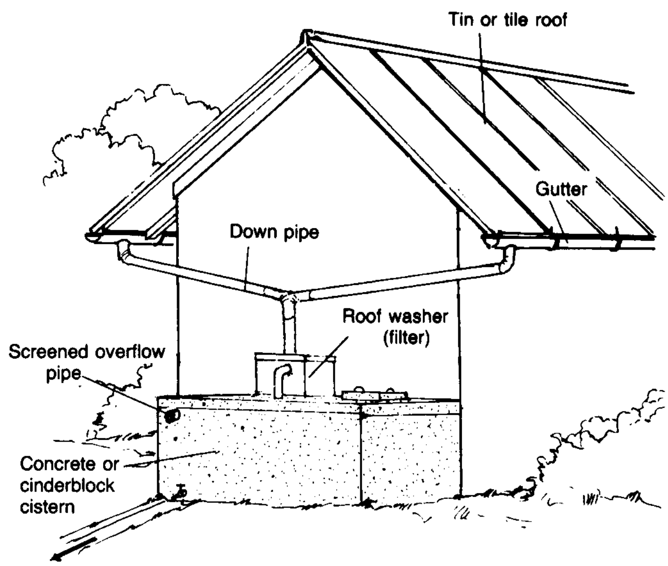

Figure 4. Rainfall Catchment with Cistern

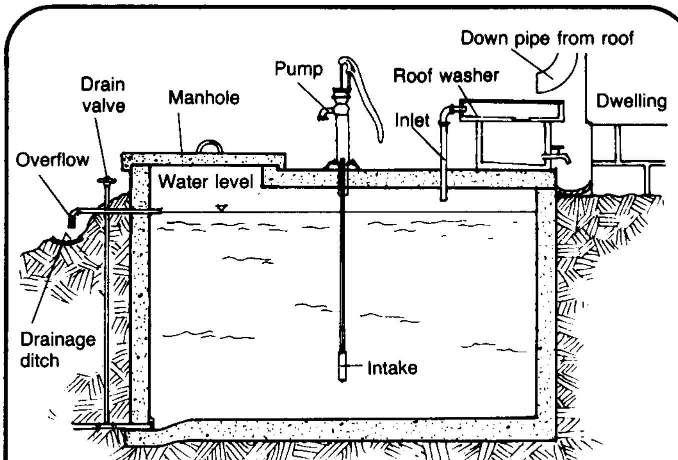

Figure 5. Underground Storage for Roof Catchment

In designing a cistern, follow these steps:

1. Choose the best site for the cistern and determine whether to build it underground. Underground cisterns offer the advantages of improved structural strength in construction and cooler water temperatures. The major disadvantages is that water must be taken from the cistern with a pump. Always make sure that the cistern is on higher ground than excreta disposal systems and is separated from them by at least 15m.

2. Determine the capacity of the tank needed. For example, if 10000 liters should be stored, design an above ground tank 2.8m x 2.3m x 1.6m or an underground tank narrower but taller; perhaps 2m x 2m x 2.5m. All walls should be reinforced and have a minimum thickness of 200mm.

3. Design above ground cisterns so that there is at least a small foundation in the ground. Make this foundation at least 300mm deep. Underground tanks should extend about 200-300mm above the ground's surface to provide for the installation of an overflow and to prevent any difficulties in maintenance.

4. Use a thick concrete mix to ensure that the walls are watertight. Use a mixture of one part cement to two parts sand and three parts gravel (1:2:3). To make the correct paste, use 23 liters of water for each bag of cement. Worksheet A shows how to determine the correct quantity of materials needed.

5. Each cistern should have an impermeable, reinforced concrete cover with a manhole that allows access for maintenance. Manhole openings should be covered tightly to prevent entrance of light, dust or other substances that could contaminate the water.

6. Install a screened overflow pipe at the top of the cistern as shown in Figure 4. Slightly above the bottom of the tank, place an outlet pipe or tap. The tap should be high enough so that a container used for collecting the water can be placed underneath it. For an underground tank, the outlet will probably be a hand pump installed on the top cover. The pump's intake pipe should extend to near the bottom of the cistern.

7. On top of the cistern, install a device for diverting the run-off from the roof. The first run-off is likely to be contaminated. Several designs of run-off diversion devices are shown in "Designing Roof Catchments," RWS.1.D.4.

8. Pile dirt around the base of above ground cisterns to provide support for the walls and drainage away from the tank. Adequate drainage should be provided at the overflow pipe so that standing water does not accumulate at the cistern. Standing water is a breeding place for mosquitoes.

9. Brick and masonry cisterns can be constructed and are recommended when the materials are available locally at low prices. Brick or stone cisterns are built in the same way as reinforced concrete tanks but special care should be taken to ensure their strength and impermeability. Masonry walls should be at least 300mm thick and should be lined on the inside with two 130mm coats of mortar in a mixture of 1:3 (one part cement to three parts sand).

10. All walls should be very carefully built with strong cement mortar joints. A general rule to follow is that brick or masonry tanks should only be made by an experienced builder since construction must be especially good to make them watertight. Tanks more than 2m across should be circular rather than rectangular.

Ferrocement Tanks and Storage Jars

Cylindrical ferrocement water tanks are built by hand. Cement mortar (one part cement to three parts sand) is trowelled onto a mesh of wire reinforcement. A $10cm^3$ capacity ferrocement tank similar to the one shown in Figure 6 can be made by one experienced builder and several unskilled laborers.

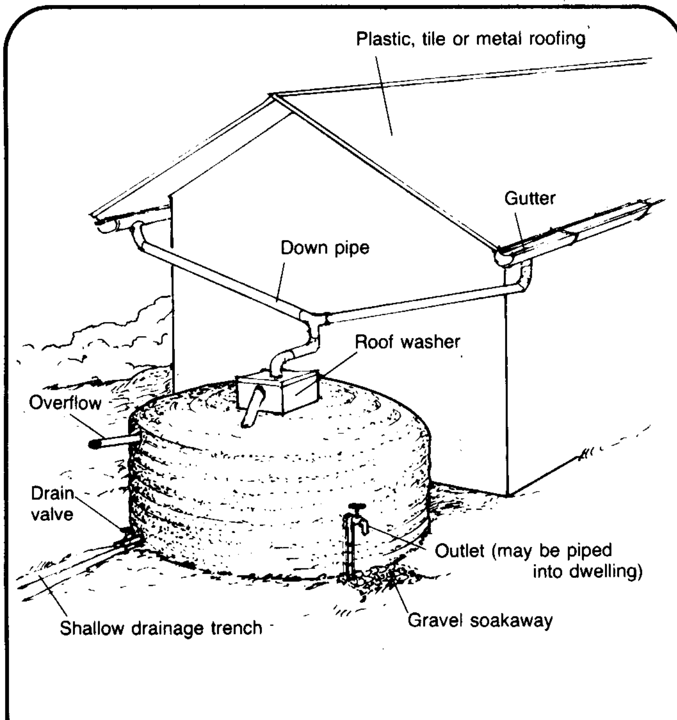

Figure 6. Roof Catchment with Ferrocement Cistern

The cistern shown in Figure 7 has a diameter of 2.8m and a height of 1.6m for a total capacity of $10m^3$:

$$\text{Volume} = .785 \times d^2 \times h$$

$$\text{Volume} = .785 \times 2.8m^2 \times 1.6m$$

$$\text{Volume} = .785 \times 7.84m^2 \times 1.6m$$

$$\text{Volume} = 10m^3$$

The walls should be 40mm thick to support the weight of the water. For best results in building the ferrocement cistern, use sheets of standard galvanized roofing iron approximately 0.6m thick with 75mm corrugations. The forms are put together as shown in Figure 7. The tank sits on a foundation slab made of concrete.

The cistern needs a roof to protect the water from contamination and evaporation. Two basic roof designs are available. A curved roof, 30-50mm thick, made of ferrocement can be constructed. The roof is cast in the same method as the walls and actually is no more than a continuation of the walls. The roof should be either thickened or painted white to protect it from heat.

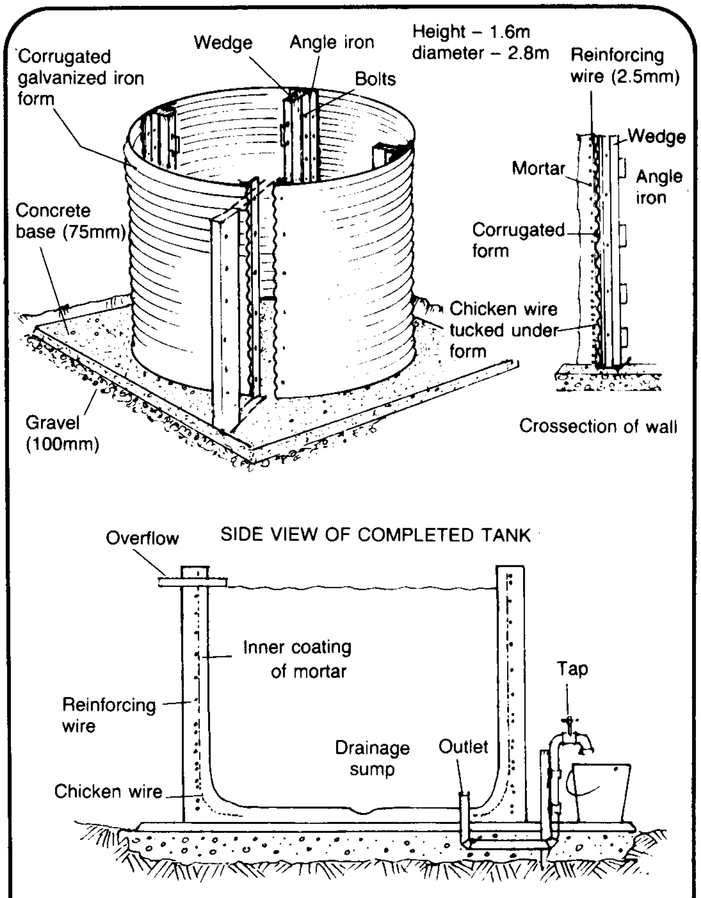

Figure 7. Ferrocement Cistern Construction

The roof can also be built from light weight sheet metal attached to a typical roof structure. This method is less practical than the curved roof design and it is best used only when the diameter of the tank is greater than 5m.

Figure 7 shows the installation of the outlet and tap system and the overflow. A drainage sump is included to capture sediment that settles out from the stored water.

Storage Jars

Rainwater can be stored in jars. Typical pottery jars can be used to collect small volumes of water. Larger volumes can be collected using jars made with wire mesh reinforcing and mortar. Jars with a capacity of $4m^3$ can be made in several days using simply mortar, mesh and gunny cloth as shown in Figure 8. Because of the curved design, stress is not a big factor and reinforcing is not necessary.

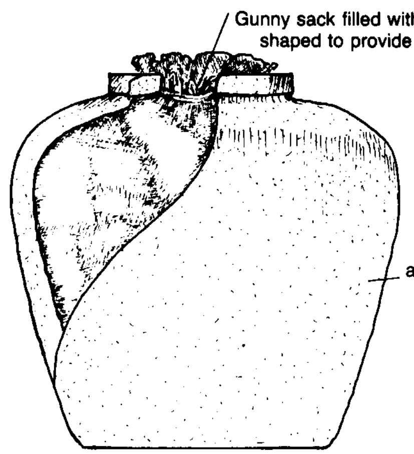

Figure 8. Storage Jar of Unreinforced Concrete

Sew together pieces of gunny cloth to the design desired and fill the cloth with sand and sawdust. The mortar is simply troweled onto the sack. Several $4m^3$ capacity jars can be built to provide large storage. For example, three of the jars will provide a 12000 liter capacity. A typical jar may have a bottom diameter of approximately 1m and a height of between 1.3-1.7m. Special care must be taken to form the gunny cloth to the correct shape and volume. As with other cisterns, install a cover to prevent contamination and a tap for easy access to the stored water.

Summary

This technical note describes several practical and efficient methods for storing water and rainwater for domestic use. Choice of the most appropriate design is very important when deciding to install a system. When choosing a design:

- identify which materials are most readily available and whether sufficient funds are available to buy them,
- choose a design that can be constructed with available technical skill,
- identify demand needs and the storage capacity which will meet them; design to meet these needs or for the largest affordable capacity.

Well-designed and constructed cisterns and storage jars will provide water for many years and should be considered where other suitable sources of water are not available. Information on construction of storage reservoirs discussed in this paper is in "Constructing a Household Cistern," RWS.5.C.1.

Worksheet A. Calculating Quantities Needed for Concrete (Calculations for a cistern 2.8m × 2.3m × 1.6m)

Total volume of cistern = length (l) x width (w) x height (h). Thickness of walls = 200mm.

1. Volume of cover = 3.0 m x 2.5 m x .2 m = 1.5 m^3
2. Volume of bottom = 2.8 x 2.3 x .2 m = 1.29 m^3
3. Volume of two sides = 2.8 m x 1.6 m x .2 m x 2 = 1.79 m^3
4. Volume of two ends = 2.3 m x 1.6 m x .2 m x 2 = 1.47 m^3
5. Total volume = Sum of steps 1, 2, 3, 4 = 6.05 m^3
6. Unmixed volume of materials = Total volume x 1.5 = 6.05 m^3 x 1.5 = 9.1 m^3
7. Volume of each material (cement, sand, gravel 1:2:3)

   Cement: 0.167 x volume from line 6 9.1 m^3 = 1.52 m^3

   Sand: 0.33 x volume from line 6 9.1 m^3 = 3.0 m^3

   Gravel: 0.5 x volume from line 6 9.1 m^3 = 4.55 m^3
8. Number of 50kg of cement = $\frac{\text{volume of cement}}{\text{volume per bag}}$

   Volume of cement = 1.52 m^3 ÷ .033 m^3/bag = 46 bags
9. Volume of water = 23 liters/bag x 46 bags = 1058 liters
10. Number of reinforcing bars = $\frac{\text{length}}{.15} + \frac{\text{width}}{.15}$

    Number of rods in cover = $\frac{3.0}{.15} + \frac{2.5}{.15}$ = 20 + 17 = 37

    Number of rods in two ends x 2 = $\frac{2.3}{.15} + \frac{1.6}{.15}$ x 15 + 11 x 2 = 26 x 2 = 52

    Number of rods in two sides = $\frac{2.8}{.15} + \frac{1.6}{.15}$ x 2 = 19 + 11 x 2 = 30 x 2 = 60

Note: To determine the length of each bar, subtract 0.05 from the total length (0.025m from each side). For example, the bars in the cover should be 2.8m - 0.5 = 2.25m and 2.3m - 0.5m = 2.25m.