CONSTRUCTION OF A WATER STORAGE TANK FOR MICRONESIA

A reprint of a publication authored by

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UNIVERSITY OF GUAM

Water Information Bulletin N0. 4
Reprinted February 2003

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MARCH 1983

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A Technical Report

By

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ACKNOWLEDGEMENT

The author is most grateful to Mr. Nchsa Siren, Executive Director, Environmental Protection Board, Trust Territory, Saipan; Mr. Carl Dannis, Environmental Health Co-coordinator, Federated States of Micronesia, Pohnpei; and Mr. Eris Haine, Environmental Health Staff, State of Chuuk, for their technical consultation in the practical methods of construction of this tank.

The Peace Corps/Micronesia Staff in Saipan was most helpful in allowing the construction of this tank at their in-service training held in Saipan, August 1982. It was at this training that the concept of a technical report was conceived.

Last, the author would like to acknowledge his good wife, Nola, and children for their encouragement and support in completing this task.

NOTE: FUNDING FOR THE PRINTING OF THIS REPORT WAS PROVIDED BY THE TRUST TERRITORY ENVIRONMENTAL PROTECTION BOARD.

WERI NOTE:
This publication has been reprinted by WERI for distribution. The original photos were unavailable so in some cases these photos might be difficult to see clearly. We felt that the value of this publication far out weighted the cosmetic problems with a few of the illustrations. We thank Mr. Hogge and recognize his important contributions to the rural water supplies of the Western Pacific through this publication. We would like to also recognize the efforts of Ms. Laura Rumong who retyped the manuscript of the report and did the lay out work for this reprinting.

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INTRODUCTION

The purpose of this report is to describe the construction of a strong, durable, and inexpensive water storage tank. The tank is cylindrical in shape and consists of perforated galvanized metal sheets covered inside and out with a cement, sand, and water mixture called grout.

The objective is to provide a practical "how-to" guide. It is hoped that sufficient details are included in order that anyone with limited construction abilities can plan, design, and construct a tank of this type.

It is recognized that many materials and methods are available for water storage tanks: to name a few; reinforced concrete, ferrocement, steel, galvanized iron, wood stave, fiberglass, etc. However, many of the above materials and methods have the disadvantages of high cost, corrosion, or short life in the tropical setting of Micronesia. The specialized skills required for their construction, such as the form work, the welding, and fiberglass resin, may also create obstacles.

The water storage tank described in this report is constructed of materials that are available on most islands in the Pacific. Although this tank can be used to store water for any type of water system, the main purpose is for rainwater catchment. It can be constructed in many sizes depending on the need and financial capability of its recipient.

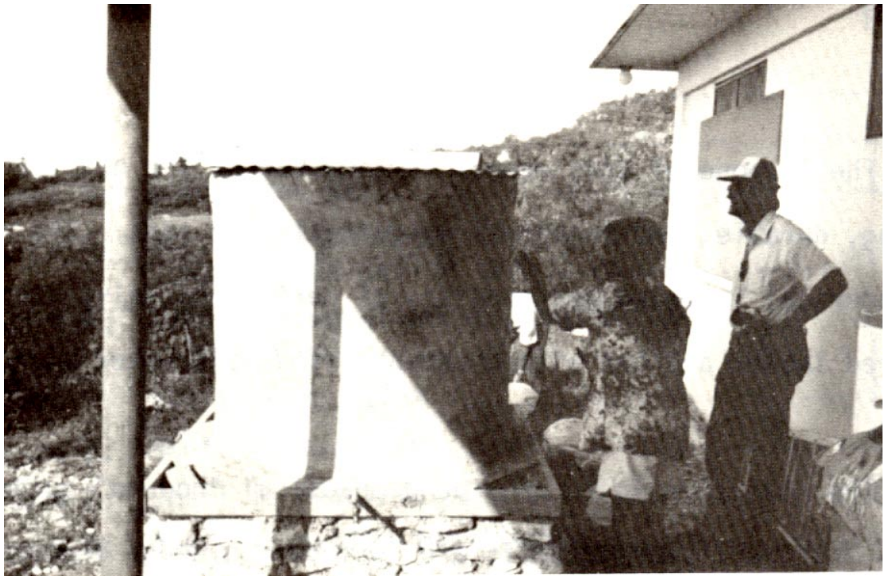


Figure 1: Water Storage Tank

In many Micronesian Islands, rainwater is by far the best source of potable water; and may also be the most sanitary source if an adequate catchment system including a water storage tank is constructed.

It is beyond the scope of this report to describe the roof catchment system except for these basic features:

1. The roof should have a smooth surface, such as metal or concrete.
2. If painted, be certain that the paint is not lead-base, which is Toxic.
3. The gutters should take advantage of the entire roof surface in order to maximize the catchment.
4. The gutters and downspouts should be easy to clean.
5. The water should be screened before it enters the tank.
6. Although the tank may be covered and sealed from rodents and insects, the water <u>must</u> still be disinfected using bleach, iodine, or boiling.

7. After a long dry spell, allow the first rainfall to be wasted in order to prevent the accumulation of dust, leaves, bird droppings, etc., from entering the tank.

8. Appendix A contains sources of information on roof catchment systems.

The size of the tank will depend on the size of the family, the uses of the water, and the length of the dry season. One must consider whether the water is needed for all water needs, or for just drinking and cooking. Many Micronesians prefer the taste of rainwater to other sources. If water is available from wells, springs, or surface water, it is possible that the catchment system can be used for consumed water and the other sources for bathing and washing, but that first priority should be given to the water consumed.

BACKGROUND

The storage tank described in this report is certainly not an original design. It is reported that the Japanese built small tanks, similar to this design, prior to World War II. In Micronesia, some of these old tanks are still in use today!

In recent years this method of construction has been revived and over 300 tanks of this type have been built in Pohnpei, Chuuk, and Kosrae. Chuuk has about 250 of these tanks. Mr. Carl Dannis, Pohnpei and Mr. Eris Haine, Chuuk, have been responsible for the construction of most of these tanks.

The largest tank has about 10,000-gallon capacity with a 6-foot height and 17 foot diameter. The most common size in Chuuk is 3,000 gallons, whereas the tanks in Pohnpei and Kosrae are generally about 500 gallons. The reason for the great difference in size is that Pohnpei and Kosrae have a great abundance of fresh water available and Chuuk does not.

Funding for these tanks has been approached in a variety of methods. For example, the Kosrae Legislature agreed to fund one-half of the cost of the tank, if the individual family would provide the other half. The family provides the labor with technical assistance by Environmental Health Service. In Pohnpei, several of the larger tanks have been government funded and the smaller tanks by individual families. In Chuuk, the individual families pay for all of the materials and provide labor with technical assistance by the Environmental Health staff. In Chuuk, the entire water catchment system including gutters, downspout, and 3,000-gallon tank cost about $400.00.

PLANNING

Prior to construction of any project, the following steps should be considered:

A. Design

1. The first step in design is to decide the overall project size, shape, and type of construction.

2. Generally the site is already known, but if not, the site should be chosen.

3. Plans or drawings of the project are necessary. These drawings show all necessary dimensions and appurtenances. This can be accomplished by sketches of formal plans by a draftsman depending on the size and complexity of the project.

4. A comprehensive materials list should then be prepared. This list should have all items necessary for construction.

5. Next, unit costs are obtained by local vendors for each item on the materials list. A cost estimate can then be prepared by multiplying the unit costs by the quantities on the materials list and totaling each item.

6. An estimate must also be made of the time required for the project.

7. An adequate labor force must be organized to complete the tasks.

8. The life of the project should also be considered since this may have an influence on the quality of construction.

9. Last, one must be concerned with maintenance of the project. Some changes in design may be necessary to allow for adequate and simple maintenance. The ultimate success of the project will be determined by how well it is maintained.

B. Pre-Construction

1. Materials must be ordered and delivered prior to construction.

2. The site may require some preparation, i.e., leveling, elevating.

3. A time schedule for construction should be established.

4. The labor force should be organized and briefed on the project.

5. A method of payment of the labor force must be decided. Even if the project is by volunteer labor, one must consider food and drink for the workers.

6. Adequate tools and equipment must be obtained.

7. The recipient of the project should be briefed on the type of construction, time required for construction, and the maintenance required.

C. Construction

1. The work schedule should be organized to be certain that the proper skills are available for each phase.

2. The “critical path” must be considered. In other words, item “A” must be complete prior to beginning item “B”.

3. Management of the project is essential. The labor force must know who is in charge and makes decisions.

4. Someone must be responsible for quality control. This is generally the most experienced, but does not have to be the supervisor.

5. The weather must be considered in outdoor projects.

6. The supervisor should consider the possible “unknowns”. What could we be short of, and what will we do when this occurs.

7. Proper finishing of the project is also very important. This includes the final touch-up before concrete sets and covering the concrete to protect it from the sun, or rain.

8. The cleanup after the project is also important. This includes returning tools that have been borrowed, disposing of debris, and leaving the site orderly.

9. Last, the project should be reevaluated to determine the good and bad points in order to improve the next construction.

DESIGN

This section of the report gives specific design considerations for the water storage tank.

A. Select capacity of the tank in gallons:

In order to illustrate the process in determining the tank size, the following simple example is given:

1. A family of (10) people desires a catchment system for drinking and cooking water only.

2. They have an adequate roof in terms of material and size for a catchment system.

3. The island in which they live has distinct wet and dry seasons and a drought may last six (6) months. It has also been determined that the average rainfall justifies a rainwater catchment system.

Since the family plans to only use the water for drinking and cooking, we can estimate 1½ gallons of water per person per day. Therefore, the daily water needs of this family are:

1 ½ gallons X 10 people = 15 gallons per day

If we assume that the tank is full as the drought begins, then the storage must last for six (6) months or 180 days:

180 days X 15 gallons per day = 2700 gallons

A tank can then be selected which will yield this quantity of water. For example, a tank with a height of 6 feet and diameter of 9 feet will contain 2854 gallons of water. The volume is found by this formula:

$$V = \pi r^2 H \text{ X } 7.48 \text{ gallons/cubic feet}$$

Where V = volume in gallons
$\Pi = 3.14$
r = radius or one-half the diameter in feet
H = height of the tank in feet; and for each cubic foot of volume, there is 7.48 gallons

Using the tank dimensions from the previous example:

$V = \pi r^2 H \text{ x } 7.48$
$= 3.14\ (4.5)\ 2\ (6) \text{ X } 7.48$
$= 2854$ gallons

The capacities of tanks with various diameters are given in Table I. The heights of 4, 5, and 6 feet are given since these are the most common heights of these tanks. Since the base of the tank is generally 2 feet, a maximum height of 6 feet is necessary because the roof height is generally 8 feet. However, a taller tank is possible if the roof height is greater than 8 feet.

Table I

Capacity of Cylindrical Tanks in Gallons

Height in Feet

Diameter In Feet	4	5	6
4	376	470	564
5	588	735	882
6	844	1,055	1,266
7	1,152	1,440	1,728
8	1,504	1,880	2,256
9	1,904	2,380	2,856
10	2,348	2,935	3,522
11	2,844	3,555	4,266
12	3,384	4,230	5,076
13	3,972	4,965	5,958
14	4,604	5,755	6,909
15	5,288	6,610	7,932
16	6,012	7,515	9,018
17	6,788	8,485	10,182
18	7,608	9,510	11,412

The previous example is a simple method to determine the size of the tank. It is recognized, however, that the size may depend on the funds available for the project. Needless to say, the larger the tank is the longer the water stored will last between rainfalls. If the family is unable to provide a tank large enough for their needs, a water conservation program should be established with all family members. It may be that such a program will allow for adequate supply throughout the dry season.

B. Choose the dimensions of the tank-using Table I. The considerations are:

(a) Dimensions of sheet metal shell

(b) Height of the roof

(c) Area available near the house

C. Examine the basic materials list given in Table II, to be certain that the materials are available in the area.

D. Make a materials list with the quantities needed for the size tank desired. (Note: Methods of material estimation are given later in this report.)

E. Using the above materials list and the unit costs for each item make a cost estimate of the project.

F. Be sure that adequate funds are available. (Note: always add about 20% to the cost since additional items are often necessary.)

G. Order the materials.

H. Organize the labor force for the construction. Remember that many hands make light work. Also, several tasks must be completed in one day. Generally, you can figure four or five days to complete the construction.

I. Remember that gutters and downspout are essential items and must be included in the cost of the project.

J. The tools for the project must also be obtained. A basic list is given in Table III.

Table II

Basic Materials List

1. Flat galvanized sheet, 4 ft. X 8 ft., 26 or 28 gage
2. Cement
3. Sand
4. Rock
5. Rebar, #3
6. Pipe, galvanized iron (G.I.), ¾” diameter X24”long
7. Faucet, ¾”
8. Coupling, G.I. ¾” (or reducer, ¾” X ½” for a ½”
9. Tee, G.I. ¾”
10. Lumber, 2” X 4” (for form work)
11. Nails
12. Tie Wire
13. Pipe, PVC, 2” diameter X 12 long (for clean-out or drain)
14. Corrugated galvanized sheets (optional for roof)
15. Lumber, 2” X 2” (also for roof)

Table III

Basic Tools List

1. Carpenter’s Hammer
2. Tape Measure
3. Level, Carpenter’s
4. Work Gloves
5. Hack Saw
6. Cement Trowels
7. Large pliers
8. Wire Cutters
9. Wheelbarrow
10. Shovels
11. Hoe
12. Buckets
13. Saw, Carpenter’s

CONSTRUCTION

A. Tank Base

The main purpose of the tank base is to raise it up off the group in order that the faucet can be located at the bottom of the tank and allow water containers under it. By having a raised tank base the full volume of the tank can be used. The base is generally two feet high, although this can vary. In addition, since the faucet is raised of the ground, it is more sanitary.

The tank base can be constructed of a variety of materials. Figures 2 and 3 illustrate two different types. The construction consist of a square outer wall of mortared block, mortared stone, or concrete with the center area filled with loose rock and/or sand in order to raise the base up to the two foot height. The tank base must be at least 8 inches wider that the diameter of the tank.

Figure 2: Stone Tank Base

Figure 3: Block Tank Base

The outside wall should be built in a sturdy manner since it must support the total weight of the tank and water. To illustrate the weight of just the water, Table IV gives the weight in pounds of various quantities of water.

Table IV

Gallons of Water	Weight in Pounds
300	2,500
500	4,170
1,000	8,340
2,000	16,700
3,000	25,000
5,000	41,700
10,000	83,400

After the tank base is constructed, be certain that the loose material in the center is thoroughly compacted. Surface water should be diverted away from the base to prevent erosion and unsanitary conditions. Once this work is complete, the next step is the tank shell.

B. Tank Shell

Flat galvanized steel sheets generally come in two sizes: 3½ ft. X 8 ft. and 4 ft. X 8 ft. The thickness is measured by gage. The two widths that have been successfully used are 26 gage and 28 gage, the later being thinner (as the number increases the thickness decreases).

An important formula in laying out the shell is the circumference of a circle:

$C = \pi D$

D= diameter of a circle, in feet

Let's now return to our previous example of a 2854-gallon tank. If we chose a 6-foot height, then we will need a 9-foot diameter tank. What is our circumference?

$C = \pi D$

$= 3.14\ (9.0\ \text{ft.})$

$= 28.3\ \text{ft.}$

This means that we will need a continuous length of metal sheets almost 30 feet long. Also, we will need two lengths in order to get the six-foot height. Since the sheets come in eight-foot lengths, we will need a total of eight pieces as shown in Figure 4.

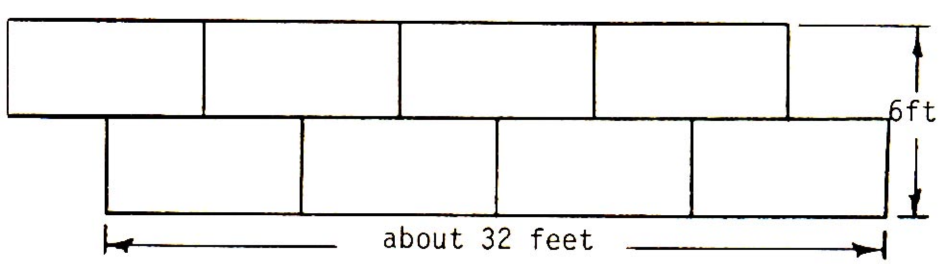


Figure 4: Layout of the Metal Sheet For a 2854 gallon tank

The first step is to join the lengths by folding the end over and interlocking two pieces. Measure one inch from the end and place the sheet on a piece of lumber while you bend it with a hammer or piece of lumber. The interlocked pieces appear from the end shown in Figure 5.

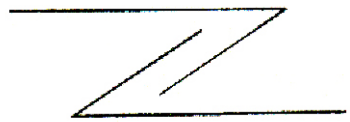


Figure 5: Interlocking of Sheet lengths (end view)

Once the lengths are interlocked, they can be hammered flat. Then punch holes with nails along this seam and use tie wire to prevent them from coming apart. This process is continued until the four lengths (in our example) are connected. The same process is used to connect the remaining four lengths. At this point, there should be two approximately 32-foot lengths of metal sheets.

The next step is to punch holes over the entire surface of both lengths. A practical tool, to punch holes, is a short length of #3 or #4 rebar which has been sharpened with a file. This will produce a 3/8-inch or ½ inch hole, which is ideal for the construction. See Figure 6 for a concept of this procedure.

Figure 6: Shell Preparation

Once the holes have been punched, the lengths can be tied together. In the previous example we chose a 6-foot height. Assuming that the sheets are 3½-feet wide, then the two lengths must be overlapped six inches to yield the six-foot height. The sheets are connected about every 12 inches with tie wire.

The next step is to carefully bend the shell into a cylindrical shape. It is best to do this with the shell standing upright, (See Figure 7). The circumference of the tank is then established by overlapping the ends and connecting them with tie wire. It is recommended that only 4 to 6 inches of overlap be used. Too much overlap will block the puncture holes and will not allow grout to pass through the shell. Excess tin can is cut off. The circular shape is checked by measuring the diameter at several points.

Figure 7: Shell Preparation

The shell should be reinforced using #2 or #3 rebar or heavy wire. The reinforcing gives the tank strength and resists the pressure exerted by the water. Small tanks (less than 500 gallons) require only two lengths or rebar. One is positioned about 6 inches from the bottom and the other about 6 inches from the top. The rebar must be bent into a circular shape with the approximate diameter of the shell. There should be a minimum of one-foot overlap. The rebar is then connected to the shell using tie wire. Larger tanks required additional reinforcing. See Appendix B for a discussion of reinforcement. It should be closely spaced at the bottom of the tank with increased space between rebar or wire at the top. Tanks above 5,000 gallons also require vertical rebar spaced every 4 feet along the circumference.

It is recommended that the rough side of the shell be faced outward. This will allow the first layer of grout to be placed on the outside of the tank. An overflow pipe should be placed on the tank. A plastic pipe with a 1½ inch or 2 inch diameter can be used. The first step is to cut an opening at the top of the shell large enough for the pipe.

Once the shell has the approximate diameter and the reinforcing is attached, it is ready to be placed into the slab. (See Figure 8) The shell is lifted over the soft concrete, centered on the slab, and pushed into the concrete. It should be pushed into the concrete a minimum of ¾ inch. (See Figure 9) A discussion of the tank slab follows:

Figure 8: Shell is ready for Installation

Figure 9: Shell Installed into Slab

C. Tank Slab

Although the tank base is square, it is not necessary to construct the slab square. A more economical methods is to construct it with eight sides or octagonal. This pattern will save concrete and avoid large corners that easily crack or break off. The formwork is not difficult. First, construct a square form with inside dimensions at least 6 inches greater than the tank diameter. Make certain that your form will fit on the tank base. Next, insert a short length of lumber at each corner. Figure 10 illustrates a tank slab for a 4-foot diameter tank. It is not essential that all sides are of equal length, but it improves the appearance of the slab.

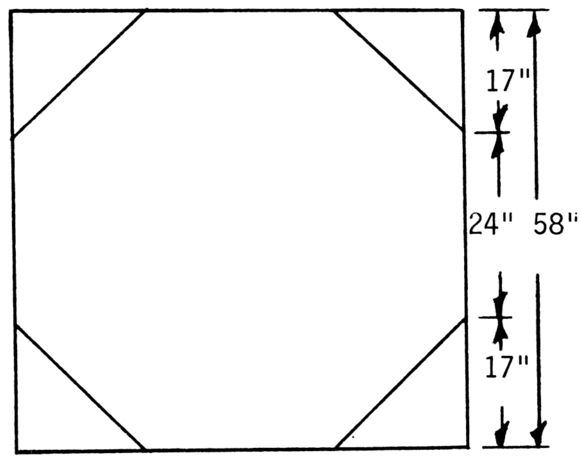


Figure 10: Concrete Forms for Octagonal Slab

The form lumber can be 2” X 4” or 2” X 3”. For small tanks, a 2½ inch-thick slab is adequate. Since 2” by 3” lumber is actually 1½” X 2½”, this size lumber can be used. For larger tanks (above 3,000 gallon) it is recommended that the slab be at least 3½ inches thick; therefore, the 2” X 4” lumber should be used.

The concrete should be reinforced with No. 3, rebar or wire mesh. For the slab shown in Figure 10, the rebar could be cut at 4-foot lengths. Since rebar generally comes in 20-foot lengths, this will yield 5 pieces. Two lengths can be laid in one direction and two, perpendicular with the remaining one diagonal, as shown in Figure 11.

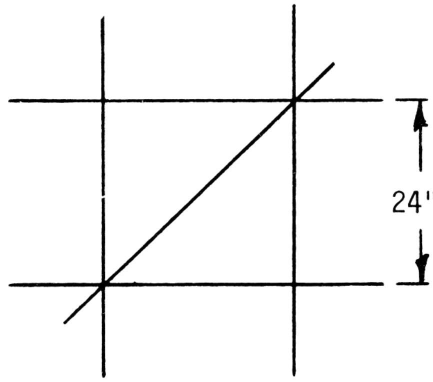


Figure 11: Rebar for a Four-foot Diameter Tank Slab

To prepare the base for the slab first place the form work on the base. Make sure that it fits well and there are no holes for the concrete to escape. It may be advisable to anchor it on the base to prevent movement when the concrete is added. Next the rebar or wire mesh is placed on the base. Place small rocks under the reinforcement such that it is positioned about in the center (up and down) of the slab. Finally, a drainpipe (2" PVC) and an outlet pipe (3/4" galvanized iron) are placed on the base.

The drainpipe must be at least one foot long and one end is cut at an angle in order to be flush with the top of the tank slab. (See Figure 12) The other end is held against the formwork and is later plugged when the form is removed.

The outlet pipe consists of a two-foot length of 3/4-inch tee and is place in the wet concrete with the tee plugged with paper to prevent the entrance of concrete. (See Figure 13) The other end has the faucet. (As an aside, left over concrete should be placed on the ground beneath the faucet as a splash pad). A gate valve can be installed before the faucet, which will prevent that tank from draining if the faucet is broken.

Figure 12: Slab Preparation

Figure 13: Preparing the Piping

Once all of the above work is complete, mixing of the concrete can begin. The slab must be watertight; therefore, it is recommended that a mixture of 3:2:1 is used. This means that we add 3 parts rock to 2 parts sand to1 part cement. The rock should be no larger than ¾ inch in diameter and contain smaller rock down to about ¼ inch size. The rock should be strong; one should not be able to crush it easily. It should also be free of fine silt, clay, or dirt. The sand should be fine with no particles larger than ¼ inch. Beach sand can be used, however, a ¼ inch screen should be used to shift and remove large particles. The cement may be purchased in 80 or 94 pound sacks. The water used for mixing should be free of dirt or other particles. It is recommended that fresh water be used. If only salt water is available, care must be taken to add as little water as possible to the mix.

Begin mixing only the dry ingredients—rock, sand, and cement. Use an accurate container such as a pan or bucket, and be sure to maintain the 3:2:1 mixture. Concrete can be mixed in a wheelbarrow for small amounts or on a sheet of plywood with sideboards for larger amounts. Useful tools include square shovels and hoes. Once the dry materials are thoroughly mixed, begin adding water slowly. Remember that you can always add more water, but if you add too much the concrete will be weak and may not be watertight. Continue mixing as the water is added until there are no dry materials. The mix should be thoroughly wet but not soupy (or watery). The mix can then be placed in the formwork and a new batch begun.

While some workers are mixing concrete, one person can vibrate the concrete to make sure that it flows against the form, reinforcing, and fixtures. (See Figure 14)

Figure 14: Concrete Slab

The slab can be smoothed off level using a piece of lumber resting across the forms and moving it in a seesaw fashion. Once the entire area is filled with concrete, float the top with a board. The idea is to push the rock down slightly and to bring a smooth watery cement mixture to the top. Later as the water disappears, a smooth finish can be made using a towel.

While the concrete is still soft, the tank shell is pushed down into the slab, at least 3/4 of an inch. This is done to create a water stop. If the shell were set on hard concrete, water would escape at this seam. (See Figure 15)

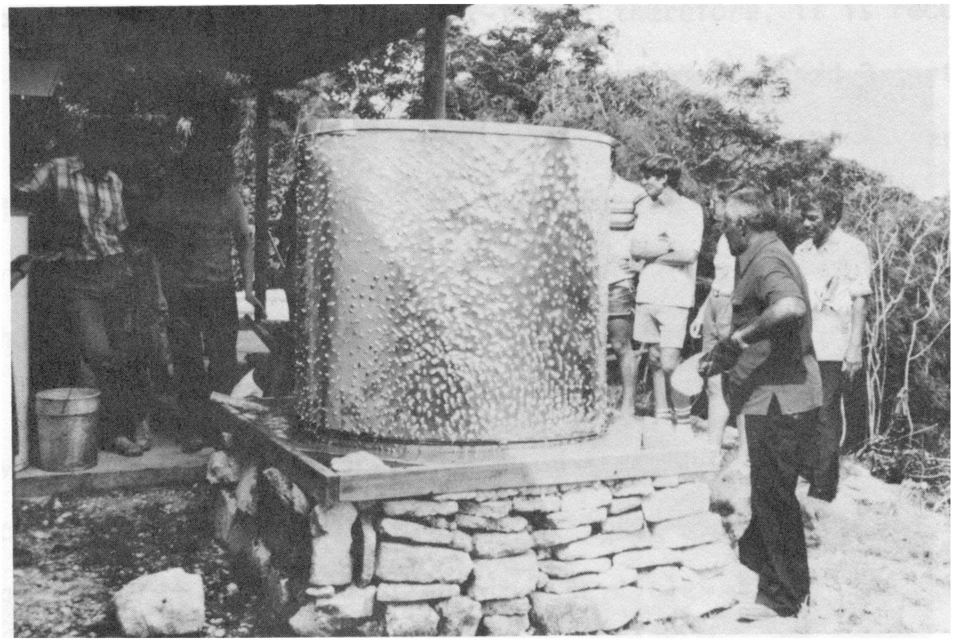


Figure 15: Shell Set into Slab

D. Grouting

All of the work described above on the tank base, shell, and slab can be done the same day. The grouting cannot be done in one day. It is recommended that the grouting begin the second day, which will extend the construction period to at least four days.

Grout is a sand, cement, and water mixture. It is basically concrete without rock. The sand must be fine, with no particles larger than ¼ inch. The recommended mixture for watertight grout is 2:1 or two parts sand to one part cement. The dry ingredients should be mixed first. Again, as with concrete, water should be added slowly to avoid adding too much. Adequate water has been added when the grout is smooth after running a trowel over it. It will have a broken appearance with too little water and soupy appearance with too much.

Once the grout has been mixed, it can be immediately applied to the outside of the tank shell. A handy method to apply the grout is to use small boards (about 5 inch by 6 inch) on which the grout is held. Then using a small trowel, the grout is pushed onto the rough side of the tank shell. (See Figure 16) The board is held below the trowel to catch grout that falls.

Figure 16: Grouting

Here are a few tips about grouting the tank:

1. Sprinkle a small amount of water on the shell prior to grouting.

2. Try to keep each layer thin. (About ½ inch)

3. Begin applying the grout at the bottom and work up. A larger amount can be applied at the bottom as a base and later be thinned down as it hardens.

4. Push hard with the first layer of grout so that it will flow through the holes in the shell and provide a rough surface for the inside layer, which will be applied the next day.

5. If the grout is too watery, it will have tendency to slide down the shell. Carefully add the same proportions of sand and cement to dry out the mix.

6. If the grout is too dry, it will have a tendency to crumble and fall away from the shell. A small amount of water can be added to remedy this problem.

7. Leave the first layer of grout inside and outside a rough texture. This will make the final layers easier to apply.

8. Several people can apply grout if trowels are available. (See Figure 17)

9. If several workers are available, some can be mixing grout and supplying it to the workers continuously.

10. Be sure to fill all holes with grout.

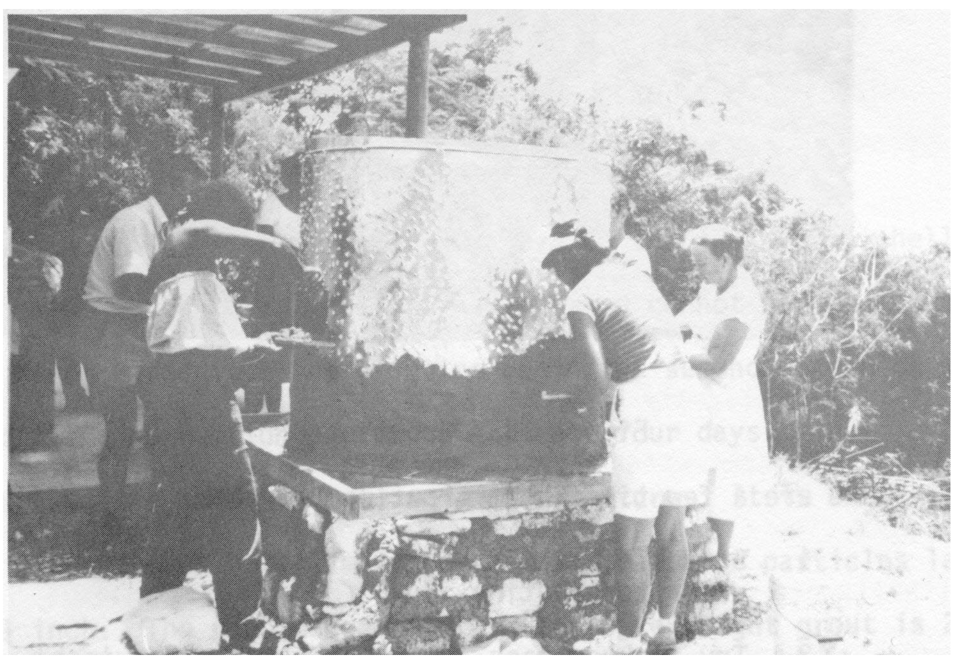


Figure 17: Grouting

If the shape of the shell disfigures by bending, it can be corrected by tying a straight piece of lumber on the outside. The shell is pulled until the desired shape is obtained. Once the first layer of grout is dry, the lumber support can be removed. Another method is to attach a wire to the shell and the other end to a stake driven into the ground.

When the outside of the tank shell is completely covered with grout, the work is complete for that day. It may be necessary to cover the grouting with a plastic sheet to protect it from the sun, rain, and other elements.

The next day, the same process is repeated inside the tank shell. Care should be taken in climbing into and out of the tank shell. Care should be taken in climbing into and out of the tank that the first day of grouting is not damaged. A ladder can be used. Before grouting the inside, remove the grout that has dropped through holes onto the slab. It can easily be chipped away from the slab.

On the third day of grouting, a second layer is applied on the inside and outside of the tank shell. (See Figure 18) Since this is the final layer, a smooth surface should be left. A paintbrush can be used to give a nice finish.

Figure 18: Grouting

Grout should cover the top of the tank shell. The final shape of the top of the shell will depend on the type of roof that is chosen. The following section presents two possible alternatives. The overflow pipe should be placed in the opening of the top of the shell. It can be grouted in place with the final layer of grout. Later a screen can be placed on the outer opening to prevent the entrance of insects and rodents.

E. Tank Roof

One possible roof material is a corrugated galvanized sheet. The corrugated metal is laid out and cut so that it overlaps the tank shell by at least two inches. The outside is cut round to match the tank shell. Seams can be made by overlapping the corrugations. A frame made of 2" X 2" lumber is used on the inside of the roof. A simple square pattern for the lumber is adequate for small tanks. The metal is then nailed to the lumber.

A screened hatch is required for the water to enter. An easy method is to construct a 6” X 6” frame made of 2” X 2” lumber with the screen mounted on it. The lumber is cut in order that it will fit flush on the corrugated metal. The hatch is not permanently attached to the roof. It must be removed periodically for cleaning. It can be held onto the roofing with wire attached to the hatch and roof by nails. (See Figure 19)

Figure 19: Tank Roof

In order to prevent the entrance of rodents, birds, insects, etc. into the tank, the roof must be sealed off as much as possible. As the corrugated metal is laid on the tank shell, gaps are left in the corrugations. These should be filled with grout. In fact, this can be accomplished on the last day of grouting if the roof has been prepared ahead of this time. Later when the grout has hardened, the roof can be sagely removed without disturbing the grout. Thus a corrugated grout surface is left on the top of the tank shell. Therefore, the roof can be removed for inspection and cleaning and replaced allowing a relatively sealed tank.

The roof can be tied down if there is a problem with wind blowing it off. This can be accomplished with wire attached to the edge of the roof and at a nail or loop in the slap or tank base.

Larger tanks require more structural lumber, possibly 2" X 4" or 2" X 6" lengths. With diameters greater than 12 feet, it may be wise to install a center post in the slab to support the roof. The post could be 6-inch plastic pipe, if available since it will not corrode or deteriorate.

A second type of roof, which has been used successfully in Chuuk is a grout-type. The roof is constructed in a manner similar to the shell grouting. It is important that vertical rebar taller than the tank height be placed on the inside of the shell. After the shell grouting is complete, the rebar is bent toward the center of the tank in a dome-pattern and tied together. Flat roofing tin is placed over the rebar and attached to it. A manhole hatch (about 20" X 20") is cut in the metal at an appropriate location. This hatch will serve as an entrance into the tank for inspection and cleaning as well as the water entrance. During construction, the hatch is also essential for installing and removing formwork. Lumber must be installed inside to brace the rebar and tin on the roof as the grout is applied. The weight of the grout and the workers must be supported by these temporary forms. Two layers of grout are placed on the roof over the tin. Care should be taken to seal the roof and shell wall. Once the grout has set for several days, the forms are removed and the tank is ready for use.

MATERIALS ESTIMATION

Materials list for 350, 500, 3,000 and 10,000-gallon tanks are given in Tables V, VI, VII, and VIII respectively. These tables give a fairly comprehensive list of materials. Using these tables and the following discussion as a guide, the appropriate list of materials for a given size tank can be developed.

TABLE V

Materials List for a 350-Gallon Tank
Unit Costs are From Saipan

Item	No. Of Units	Unit Cost	Total Cost
1. Lumber 2" x 4" x 15'	2 lgth.	$ 4.90	$ 9.80
2. Nails, 8D	2 lbs.	.90	1.80
3. Rebar 20' length	1 pc.	3.70	3.70
4. Portland Cement	5 Bags	6.50	32.50
5. *Sand	1 Cu. Yd.	----	----
6. *Gravel, ½" minus	½ Cu. Yd.	----	----
7. Tin, #26 gauge, 4' x 8'	2 Sheets	13.95	27.90
8. Rebar #3m 20' length	2 pc.	2.10	4.20
9. Baling Wire	1Rl. (5 lb.)	1.00 p/lb.	5.00
10. Galvanized iron pipe. 3/4" x 24"	1 pc.	5.65	5.65
11. Faucet, 3/4"	1 pc.	3.50	3.50
12. Reducer ¾" x ½"	1 pc.	1.35	1.35
13. Tee, 3/4"	1 pc.	1.30	1.30
			Subtotal-->$96.70

ROOF

Item	No. Of Units	Unit Cost	Total Cost
1. Corrugated tin, 27" x 8'	1 Sht.	9.80	9.80
2. Lumber, 2" x 2" x 16'	1 lgth	3.05	3.05
			Subtotal ->$12.85

GUTTER

1. Tin, Flat 4' x 8'	1 Sht.	13.95	13.95
2. Lumber, 2" x 2" x 16'	1 Lgth.	3.05	3.05

Subtotal ->$17.00

Total→$126.55

*No cost is given since sand and rock are readily available in Micronesia.

NOTE: The above materials are intended for a 4-foot high, 4-foot diameter tank with a corrugated tin roof.

TABLE VI

Materials Lists for a 500-Gallon Tank
Unit Cost is Representative for Pohnpei, Chuuk and Kosrae

Item	No.	Unit	Unit Cost	Total Cost
1. Flat roofing tin, 3½ ft. x 8 ft.	4	Ea.	11.00	44.00
2. Cement, Portland	6	Sacks	8.00	48.00
3. *Sand	1	Cu. Yd.	----	----
4. *Rock	1/3	Cu. Yd.	----	----
5. Rebar, #3, 18 or 20 foot	2	Ea.	2.40	4.80
6. Pipe, Galv. iron, ¾" diam. x 24"	1	Ea.	2.00	2.00
7. Faucet, ¾"	1	Ea.	5.00	5.00
8. Coupling, ¾"	1	Ea.	.50	.50
9. Tee, ¾"	1	Ea.	.90	.90
10. Gate Valve, ¾" (Optional)	1	Ea.	5.00	5.00
11. Lumber, 2" x 3" – 12 foot	4	Ea.	4.00	16.00
12. Nails, 3½"	1	Lb.	1.25	1.25
13. Tie Wire, (#9)	3	Lb.	1.25	3.75
14. Pipe, PVC 2" x 24"	1	Ea.	6.00	6.00
15. Corrugated roofing tin, 27' x 9'	1	Ea.	12.00	12.00

Total -- $327.20

*No cost is given since sand and rock are readily available in Micronesia.

NOTE: The above materials are intended for a 6-foot high, 4-foot diameter tank with a corrugated tin roof.

TABLE VII

Materials List for a 3,000-Gallon Tank
Unit Cost is Representative for Pohnpei, Chuuk and Kosrae

	Item	No.	Unit	Unit Cost	Total Cost
1.	Flat roofing tin, 3½ ft. x 8 ft.	9	Ea.	11.00	99.00
2.	Cement, Portland	18	Sacks	8.00	144.00
3.	*Sand	4	Cu. Yd.	----	----
4.	*Rock	1½	Cu. Yd.	----	----
5.	Rebar, #3, 18 or 20 foot	12	Ea.	2.40	28.80
6.	Pipe, Galv, iron, ¾” dia. x 24”	1	Pc.	2.00	2.00
7.	Faucet, ¾”	1	Ea.	5.00	5.00
8.	Coupling, ¾”	1	Ea.	.50	.50
9.	Tee, ¾”	1	Ea.	.90	.90
10.	Gate Valve, ¾” (Optional)	1	Ea.	5.00	5.00
11.	Lumber, 2” x 3” – 12 foot	4	Ea.	4.00	16.00
12.	Nails, 3½”	1	Lb.	1.25	1.25
13.	Tie Wire, (#9)	15	Lb.	1.25	18.75
14.	Pipe, PVC 2” x 24”	1	Ea.	6.00	6.00
					Total -- $327.20

*No cost is given since sand and rock are readily available in Micronesia.

NOTE: The above materials are intended for a 6-foot high, 9½-foot diameter tank with a grout roof.

TABLE VIII

Materials List for a 10,000-Gallon Tank
Unit Costs are representative for Pohnpei, Chuuk and Kosrae

1. Flat roofing tin, 3½ x 6'	20	Ea.	11.00	220.00
2. Cement, Portland	60	Ea.	8.00	480.00
3. *Sand	5.5	Cu. Yd.	---	---
4. *Rock	6	Cu. Yd.	---	---
5. Rebar - #3, 20 foot	78	Ea.	2.40	187.20
6. Pipe, galv. Iron 3/4¼ x 24"	5	Ea.	2.00	10.00
7. Faucet ¾"	5	Ea.	5.00	25.00
8. Coupling ¾"	5	Ea.	.50	2.50
9. Tee, ¾"	5	Ea.	.90	4.50
10. Gate Valve, ¾" (Optional)	5	Ea.	5.00	25.00
11. Lumber, 2" x 4" – 18 ft. long	12	Ea.	8.00	96.00
12. Lumber, 2" x 6" – 20 ft. long	4	Ea.	16.00	64.00
13. Nails, 16D common	6	Lb.	1.25	7.50
14. Wire (#19)	2750	Ft.	.05	137.50
15. Tie Wire	20	Lb.	1.25	25.00
16. Pipe, PVC 3" x 48"	1	Ea.	20.00	20.00
17. Roofing Nails	10	Lb.	1.25	12.50
18. Corr. Roofing tin, 2' x 10	18	Ea.	12.50	216.00
				Total -- $1,532.70

* No cost is given since sand and rock are readily available in Micronesia.

NOTE: The above materials are intended for a 6-foot high, 17½-foot diameter tank with a corrugated tin roof.

1. Flat galvanized metal: As discussed previously, the amount of this material will depend on the circumference, and the height of the tank. The dimensions of the sheet metal available locally should be known before designing the tank.

2. Cement: The quantity required for the tank is broken into two parts: The slab and the shell.

a. The cement for the slab: First, the volume of the concrete must be known. Using the example given previously of a slab 58” x 58” with the corners deleted, the volume can be found using a slab thickness of about 3 inches.

$$V = L \times W \times T$$

Where: V = Volume
L = Length
W = Width
T = Thickness

First, convert all dimensions to feet:

$$L = 58 \text{ inches}/12 \text{ inches} = 4.83 \text{ feet}$$

$$W = 4.83 \text{ feet}$$

$$T = 3 \text{ inches}/12 \text{ inches} = 0.25 \text{ feet}$$

Then, if the slab is square, the volume is:

$$\begin{aligned} V &= L \times W \times T \\ &= 4.83 \times 4.83 \times 0.25 \\ &= 5.83 \text{ Cubic Feet.} \end{aligned}$$

But since the corners are not included, this volume must be subtracted.

Each corner, since it is a triangle, has a volume of:

$$V = \tfrac{1}{2} L \times W \times T$$

The length and width are 17 inches or:

$$17 \text{ inches}/12 \text{ inches} = 1.42 \text{ ft.}$$

Then, the volume of each corner is:

$$\begin{aligned} V &= \tfrac{1}{2}\ (1.42)\ (1.42)\ (0.25) \\ &= 0.25 \text{ cubic feet} \end{aligned}$$

Therefore, the volume of all four corners is:

$$4V = 4\ (0.25) = 1.0 \text{ cubic feet}$$

If this volume is subtracted from the volume of the square slab, the result is the actual volume of the slab:

$$5.83 - 1.0 = 4.83 \text{ cubic feet}$$

This volume of concrete required about two sacks of cement. <u>Therefore, it can be estimated that one sack of cement will produce about 2.5 cubic feet of concrete, with 3:2:1 mix.</u>

b. The cement for the shell: The quantity of cement for the shell will depend on the amount of grout applied on each layer. If about ½ inch is applied each time, the complete thickness of the tank should be about 2 inches.

The surface area of the tank can be found by multiplying the circumference by the height. For example, a 4-foot diameter tank with a 4-foot height has the following surface area:

	$C = D\Pi$	Where C = Circumference
	$= 3.14\ (14)$	$\Pi = 3.14$
	$= 12.56$	D = Diameter
Surface Area	$= C \times H$	H = Height
	$= 12.56\ (4)$	
	$= 50.2$ Square Feet	

This amount of surface area required about three sacks of cement. Therefore, it can be estimated that one sack of cement will produce enough grout for about 17 square feet of shell surface area, (inside and out) with a 2:1 mix. Additional cement will be needed if the roof is to be made of grout.

3. Sand: A simple method to estimate the amount of sand needed is to assume that for every sack of cement (one cubic foot) about three times as much sand as needed (three cubic feet). This will allow for waste. It has also been found that a 50-pound rice sack will hold about one cubic foot of sand. Therefore, if for example 5 sacks of cement are needed for the tank, then 15 cubic feet or 15 rice sacks of sand are also needed.

4. Rock: Since rock is only required for the slab, the quantity should be based on the amount of cement needed for the slab only. A simple method is to estimate four cubic feet of rock for every sack of cement.

5. Other Materials: The balance of the materials can be estimated by having a drawing of the tank prior to ordering the materials. For example, the drawing should show the amount of corrugated sheets required for the roof and the lumber structure to support it. Each fixture (drain, outlet, and overflow) should be thought-out in advance, especially if materials are not available locally.

SUMMARY

The Micronesian Islands of the Pacific are generally blessed with an abundance of fresh water in the form of rainfall. It is true that some of the islands have much less rainfall than others. The irony is that most of this precious water provided by nature is not captured before it returns to the ocean and completes another endless water cycle.

The challenge is to find simple and inexpensive methods for catchment and storage of this essential liquid. At the same time, the system should be durable and provide many years of service. This report proposes a water storage tank that meets these criteria.

The tank is determined by the water needs of the family and the funds available for the project. It should be located close to the house in a location that will allow proper roof drainage though the gutters and downspout. Since the tank base is generally about two feet tall, the tank will not exceed six feet in height considering the normal roof height of eight feet.

The shell is cylindrical shape and is made of thin galvanized sheets with perforations. The shell is placed into a wet concrete slab in order to provide a water seal. Two layers of grout are placed on the inside and outside of the shell. Finally, a corrugated sheet metal roof or a grout-type roof completes the construction.

Prior to using the new tank, it should be disinfected. The objective is to kill any disease-causing microorganisms before storing the

rainwater. This can be done with a bleach and water mixture (use a teaspoon of bleach per gallon of water). One possibility is to place the mixture in a spray bottle and spray the inside shell, roof, and slab. Allow the mixture to collect at the bottom of the tank and pass through the outlet pipe and faucet in order to disinfect them also. It is a good idea to wash down the roof and gutter system with water.

It should be remembered that all of the above precautions would not insure a clean and safe drinking water. The water must also be disinfected by boiling, iodine, or bleach to be certain it is safe. If bleach is chosen, use 20 drops per gallon or ½ teaspoon per 5 gallons. Place the water in the shade and allow it to stand for 30 minutes.

The new tank is ready for use after disinfections, which can be done the day after the last grouting.

The tank should be cleaned out periodically as well as the roof, gutters and down spout. By keeping the system as free as possible from dirt, leaves, bird droppings, etc., the water should require very little disinfections.

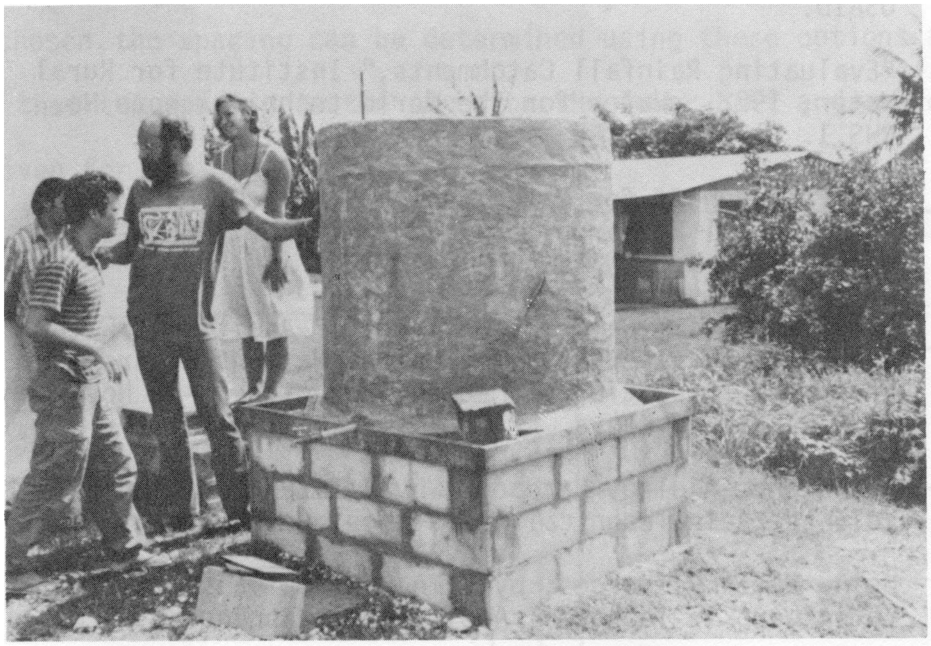


Figure 20: Water Storage Tank

APPENDIX A

Information on Roof Catchment System

1. "Rainwater Harvesting for Domestic Water Supplies in Developing Countries," by Kent Keller, September 1982.

   Water and Sanitation for Health (WASH) Working Paper No. 20, prepared for the Office of Health, Bureau of Science and Technology, Agency for International Development, Washington, D.C. 20523

2. "Roof Catchments: The Appropriate Safe Drinking Water Technology for Developing countries," by B. Z. Diamant, 1982. Proceedings of the International Conference on Rain Water Cistern Systems, June 1982, University of Hawaii at Manoa, Pages 276-283.

3. Planning for an Individual Water System, by G.E. Henderson, E.E. Jones and G.W. Smith, 1973, American Association for Vocational Instructional Materials, Athens, Georgia.

4. "Constructing, Operating, and Maintaining Roof Catchments, " Institute for Rural Water, 1982. Water for the World technical notes No. RWS.1.C.4, USAID.

5. "Designing Roof Catchments," Institute for Rural Water, 1982. Water for the world technical notes No. RWS.1.D.4, USAID.

6. "Evaluating Rainfall Catchments," Institute for Rural Water, 1982. Water for the World technical notes No. RWS.1. P.5, USDAID.

7. "Rooftop Runoff for Water Supply," by W.O Ree, 1976. Agricultural Research Service/USDA Report ARS-S-133, Washington, D.C.

8. "Rain and Storm Water Harvesting for Additional Water Supply in Rural Areas," by United Nations Environment Programme, Expert Group Meeting 30 October – 2 November 1979, Nairobi, Kenya.

9. Village Technology Handbook, by VITA Publications, 1973. Volunteers in Technical Assistance, Washington, D.C.

10. Using Water Resources, by VITA Publications, 1977. Volunteers in Technical Assistance, Washington, D.C.

11. Water Supply and Sanitation in Developing Countries, by E.J. Schiller and R.L. Droste. Published by Ann Arbor Science, 10 Tower Office Park, Woburn, MA 01801.

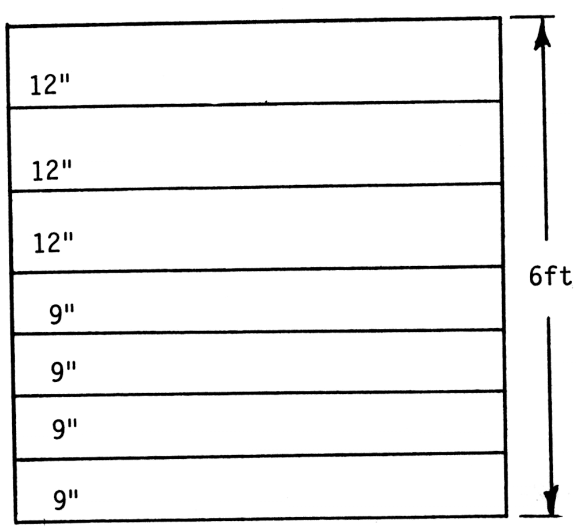
APPENDIX B

Tank Shell Reinforcement

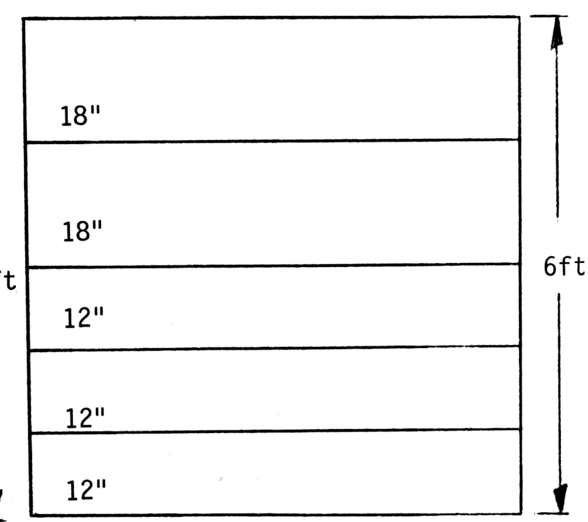
The size and placement of the tank shell reinforcement depends on the volume of the tank itself. The shell gives the tank quite a bit of strength to resist the pressure of the water. However, as the volume increases, additional strength is required by placing rebar or heavy wire on the shell. The reinforcement is connected to the shell using tie wire. Only rebar is discussed here. If heavy wire is chosen, consultation with an experienced individual is recommended.

Tanks with less than 500-gallon capacity do not require reinforcement. It is advisable to use a hoop of rebar at the top and bottom of the shell for ease in applying the grout and maintaining the shell shape.

Two possible options (A and B) are shown for rebar placement of tanks over 500-gallon size. Since larger tanks are about six-foot height, the options shown are for this height only. If other heights are chosen, the spacing can be determined using these options as a guide. Note that the spacing is the same for the lower half and a greater spacing is given for the upper half.



Option A



Option B

The recommended reinforcement is given in the following table:

Tank Volume (Gallons)	Option	Rebar Size
Less than 500	none	none
500 to 1,000	A	#2
1,000 to 3,000	B	#3
Greater than 3,000	A	#3

Tanks with volumes greater than 5,00 gallons also require vertical rebar. It is suggested that #3 rebar spaced every 4 feet along the circumference be used.