AN
INTRODUCTORY
GUIDE
TO
WATER HARVESTING
IN
AMBOS NOGALES

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1.0 INTRODUCTION

Many ancient civilizations effectively applied water harvesting methods to divert, collect, and store rainwater for drinking and irrigation purposes. The technique of harvesting water is believed to have been developed in Ancient Iraq, 4,000 to 6,000 years ago (1). Runoff farming, channeling across sloped areas to collect rainwater (see Figure 1), was commonly put to use by many arid land civilizations. Negev Desert farmers practiced diverting water from cleared hillsides to irrigate crops over 4,000 years ago (2). There are indications that 500 years ago American Indians in the southwest also applied water harvesting techniques to irrigate crops (3).

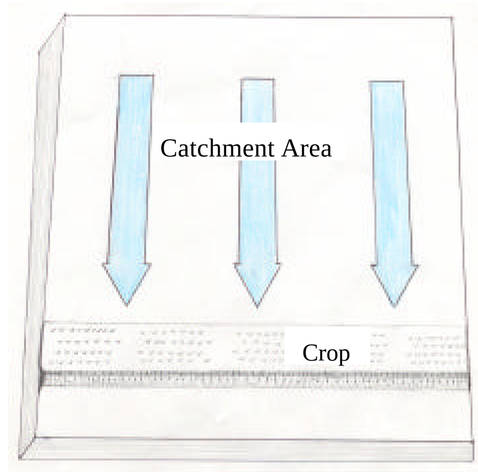


Figure 1
Diagram of Runoff Farming

Researchers have found that, prior to European settlement in Mexico, runoff farming in semi-arid regions was practiced by the indigenous people (4). Maize was grown on accumulated sediments deposited by runoff water. During this time period, fertile agriculture extended much further into semi-desert areas than is known today. The extent of pre-conquest agriculture is not attributed to better climate conditions, but rather to the employment of rainwater collection and conservation techniques (5). In the Yucatán peninsula of Mexico, preceding the Spanish conquest, underground cisterns were constructed for the purpose of collecting rainwater (see Figure 2a). A constructed catchment area directed the runoff rainwater to a plaster, cement-lined cistern built within the underlying limestone (6, see Figure 2b).

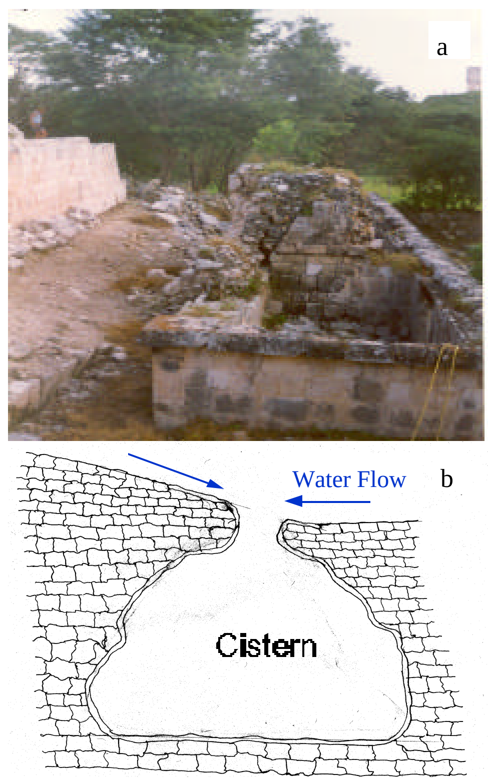


Figure 2
a) Remains of an Underground Mayan Cistern in the Yucatán of Mexico

b) Cross-sectional Area Diagram of an Underground Mayan Cistern

In recent times, especially in larger cities of Mexico, traditional methods of collecting rainwater are not readily seen (see Figure 3). Perhaps as people moved from rural areas into the cities, these methods were not utilized because municipalities supplied water to the residents. As the municipalities grew, they were capable of delivering more water to residents that lived further and further away from the city center. With readily available water, people forgot or abandoned old traditions of harvesting water. However, recently there has been a renewed interest in water harvesting across North America. Growing concern over water supply demands has forced us to take a new look at traditional ways of capturing and conserving water.

Figure 3
Rainwater Collection Tank,
Rural Area in the Yucatán

In the past, harvested rainwater has been a source of drinking water. However, due to increased water-soluble atmospheric pollutants, harvested rainwater should be properly treated before drinking. Filtration systems can be added to water storage systems to improve water quality; however, those techniques are beyond the scope of this booklet. This guide has been developed to give a brief history about harvesting water and explain some basic principles about water harvesting. It will help you develop some simple water harvesting designs, both active and passive, for diverting, collecting, and storing water for supplemental irrigation.

1.1 <u>What is Water Harvesting?</u>

Water harvesting is the process of diverting, collecting, and storing rainwater from surface runoff and effectively using the water for beneficial purposes. Water harvesting systems can be either passive or active. Passive systems are simple modifications to the existing landscape that utilize gravity to redirect rainwater. They require only minimal attention and direct water to the area of immediate use. Active systems redirect rainwater and also incorporate the collection and temporary storage of water. These systems require additional maintenance and active involvement both after a rainfall has occurred and during water applications. Either system, or a combination of the two systems, can be very simple to install if certain principles are followed and designs are carefully planned.

1.2 Water Harvesting Principles

Managing water flow on landscapes can seem overwhelming at first, but if you follow a few simple guidelines, the process is relatively simple. According to the Sonora Permaculture Teacher's Guild, there are seven principles of water harvesting (7).

1.2.1 Manage Water At The Top Of The Watershed

To capture water efficiently, examine the topography of your site to see how water flows across all surfaces in the area. Identifying catchment areas and managing water at the highest point of the watershed will help prevent erosion and reduce the need for managing large volumes of water at the lowest point of the property.

Figure 4
Catchment Area

1.2.2 Create Multiple Microbasins

Microbasins are small, concave depressions in the soil where rainwater is captured and allowed to drain, collect, and infiltrate the soil. They include shallow basins, bermed basins, swales, french drains, or gabions[1] (refer to section 2.4, Redirect, Slow And Infiltrate Water, page 8, to learn more about these specific type of microbasins).

Figure 5
Microbasin

1.2.3 Collect, Slow, And Infiltrate Water

The least expensive place to store rainwater is in the soil. Allowing the water to flow slowly across as much surface area as possible increases the amount of infiltration and reduces soil erosion. Rooftop runoff can be collected and diverted through the use of gutters and downspouts. Rainwater collected from the rooftop can also be diverted to a cistern (water collection tank) and stored for later use.

Figure 6
Steel Culvert Cistern

[1]Gabions are used divert large volumes of water. The construction of gabions are not discussed in this guide.

1.2.4 Prepare For Overflow

All water harvesting systems need to be designed to allow for water overflow. Heavy rains can cause systems to fill quickly. Spillways should be constructed within bermed areas to allow for intense rainfall. Overflow devices should be installed on storage tanks and maintained on a regular basis.

Figure 7
Spillway

1.2.5 Mulch To Reduce Evaporation

Soils have different water holding capacities; however, evaporation can reduce the amount of water that can be collected and stored in any soil. Thick layers of mulch placed on top of the soil will reduce evaporation. Mulches can be organic or inorganic.

1.2.6 Put Harvested Water To Beneficial Use

Well-mulched soils increase the availability of water to plants during and after rains. Tank stored water can be used when other water resources are not available.

1.2.7 Observe And Adjust Your Systems As Needed

Whether you install a passive or active system, you should observe how well the system functions. Basins may need to be expanded to allow for plant growth and more tanks may be added to capture additional water flow.

2.0 DESIGNING & CONSTRUCTING A WATER HARVESTING SYSTEM

The most critical aspect of water harvesting is planning. Efficient water harvesting systems are constructed only after observing topography and addressing certain planning factors.

2.1 Sketch A Plan of Your Existing Site

Sketch the current layout of your site (see Appendix A for an example site layout). Examine the way your property slopes and record it on the layout. Identify and note any catchment areas (roofs, parking lots, sidewalks, and soil). Draw in directional lines of how water currently flows over your property. Any signs of erosion, should also be noted on your design plan. Knowing the topography of the site will help you take advantage of natural surface runoff and minimize the amount of work needed to create collection systems.

2.2 Estimate the Potential Water Supply From Catchments Areas

The potential supply of water that can be captured by rain harvesting techniques is estimated by:

$$\underset{\text{(gallons)}}{\textbf{Potential Supply}} = \underset{\text{(ft)}}{\textbf{Rainfall}} \times \underset{\text{(gal/ft}^3\text{)}}{\textbf{7.48}} \times \underset{\text{(ft}^2\text{)}}{\textbf{Catchment Area}} \times \textbf{Runoff Coefficient}$$

$$= \underset{\text{(m)}}{\textbf{Rainfall}} \times \underset{\text{(gal/m}^3\text{)}}{\textbf{264.2}} \times \underset{\text{(m}^2\text{)}}{\textbf{Catchment Area}} \times \textbf{Runoff Coefficient}$$

2.2.1 Rainfall

The most important factor in harvesting water is the amount of rainfall that is received during the year, which can be extremely variable in the Nogales area. Therefore, average monthly rainfall values are used to approximate the amount of rain that may occur over a monthly period. Table 2 lists the average monthly rainfall in Nogales, Arizona.

Table 1: Average Monthly Rainfall in Nogales[2]

Month	Centimeters	Inches	Feet
	(rounded off)		
January	2.36	0.93	0.077
February	2.25	0.88	0.074
March	1.66	0.65	0.054
April	0.69	0.27	0.023
May	0.31	0.12	0.010
June	1.15	0.45	0.038
July	11.04	4.35	0.36
August	10.95	4.31	0.36
September	3.98	1.57	0.13
October	2.09	0.82	0.069
November	1.59	0.63	0.052
December	3.43	1.35	0.113
Total	**42.49**	**16.73**	**1.36**

2.2.2 Conversion Factor

To convert the amount of rain collected from feet cubed to gallons, a conversion factor of 7.48 gal/ft^3 is used. To convert the amount from cubed centimeters to gallons use 264.2 gal/m^3.

2.2.3 Catchment Area

A catchment area is any surface that allows water to run off, such as roofs, parking lots, sidewalks, and soil. The amount of water that can be captured depends on the size of the catchment area and the material of the surface. The catchment area of a roof can be calculated by multiplying the length of the building by its width.

Figure 8
Rooftop Catchment Area
Length x Width

[2] The author could not find consistent climatological data for Nogales, Mexico. Therefore, the author used forty-one years (1931 to 1972) of climatological data from Nogales, Arizona to calculate average rainfall data. Data was gathered from *Arizona Climate* (Reference Number 8).

2.2.4 Runoff Coefficient

Figure 9
Rainwater Runoff

Different amounts of water can be harvested from specific surfaces. Some surfaces are more permeable to water than others. Immediate runoff occurs from surfaces that are impervious. The amount of water running off a particular surface can also vary due to the temperature and water saturation of the material. Runoff from soil and lawns does not occur until the rainfall runoff rate exceeds the soil infiltration rate. Table 2 lists the high and low runoff coefficients, which describes the percentage of water that may run off of each specific surface. Low runoff coefficients describe the percentage of rainwater runoff that may occur after dry conditions. High runoff coefficients are used when surfaces are at saturation.

Table 2: Runoff Coefficients
Source: Harvesting Rainwater for Landscape Use (9)

	High	Low
Roof		
Metal, gravel, asphalt, shingle, fiber glass, mineral paper	0.95	0.90
Paving		
Concrete, asphalt	1.00	0.90
Gravel	0.70	0.25
Soil		
Flat, bare	0.75	0.20
Flat, with vegetation	0.60	0.10
Lawns		
Flat, sandy soil	0.10	0.05
Flat, heavy soil	0.17	0.13

2.2.5 Example Calculations

Assuming a house has a square footage of 1,500 (139.4 m^2), with it's roof covered in shingles, the potential supply of rainwater that could be captured by rain harvesting techniques for a typical year in Nogales is:

$$1.36 \text{ ft} \times 7.48 \text{ (gal/ft}^3) \times 1{,}500 \text{ ft}^2 \times .90 = 13{,}733 \text{ gallons.}$$

Potential rainwater supply that could be captured in Nogales during a typical July month is:

$$0.1104 \text{ m} \times 264.2 \text{ (gal/m}^3) \times 139.4 \text{ m}^2 \times .90 = 3{,}659 \text{ gallons.}$$

2.3 <u>Plant Location and Watering Requirements</u>

Select plants based on rainwater capture/storage potentials and on the amount of water they require throughout the year. Young plants require more water than older established plants. Therefore, additional information needs to be ascertained about the different types of vegetation that will be planted in the area, keeping in mind any new construction designs. In order to create efficient water harvesting systems, total landscape water requirements for each area must be determined. This must include the type of plants, age of the plants, and number of plants that will encompass the area.

Examine your sketch and designate planting areas where natural water flow tends to occur. Plants that require the most water should be placed in microbasins or next to catchment areas (i.e., near buildings, parking lots, and sidewalks). Select plants based on the amount of water that they receive naturally, and sow plants with a similar watering requirement together. Plant drought tolerant species in areas located the furthest away from the water harvesting system. Using native plants will also help conserve water. For information about native plants, consult *The Guide to Native Vegetation of Nogales*.

2.4 <u>Redirect, Slow, and Infiltrate Water</u>

If erosion is apparent, this should be dealt with first. Redirect water by building spillways, berms, swales, or french drains. Any drains or outlets in passive and active water harvesting systems should be placed at least six feet away from any buildings or structures to prevent water damage to the foundation. Utilize the natural topography of your site by placing microbasins in areas where runoff already occurs.

NOTE: Always know the location of utility lines before digging into the ground.

2.4.1 Constructing Spillways

Spillways (see figure 10) direct water away from over-saturated areas to high water usage areas. To construct a spillway, remove soil from the area with insufficient drainage. Compact the soil and place river rock in the excavated area to prevent erosion. Check the stability of the structure after rainfall. Make adjustments as needed.

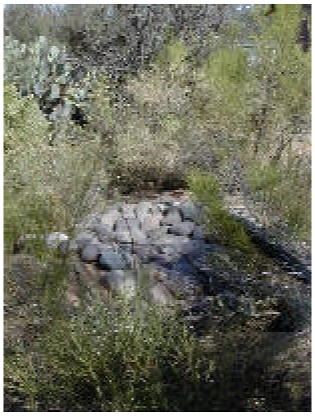


Figure 10
Spillway

2.4.2 Constructing Shallow Basins

Shallow basins (see figure 11) are simple to construct. They are made by shoveling out a few inches of earth, thereby creating a depressed area where water can collect, drain, and slowly infiltrate. Distribute organic mulch over the basin to increase water retention. Enclosing part of the area with river rock at the lower end of the watershed will not only help slow and retain water, but will add aesthetic beauty.

Figure 11
Shallow Basin

2.4.3 Constructing Berms

Berms are made by first creating a slightly sloped basin. The soil removed from the depression is placed down slope at the edge of the basin, usually in a crescent shape. The elevated area, the berm, is compacted to prevent erosion. If water flow is fairly moderate, add a rock spillway to the berm and direct the water to another microbasin. Mulching the basin helps to slow water and provides additional water for plants. After heavy rainfall, check the area for any overflow problems.

Figure 12
Berm

2.4.4 Constructing Swales

Figure 13
Constructing a Swale

Swales (see figure 13) are gently sloped trenches used to control water over large catchment areas. They can be constructed next to elevated sidewalks, courtyards, and roads. Gently slope the soil downward from the catchment area and place a berm on the opposite side to provide a small gentle valley to allow infiltration of water. Be sure to make the slope gradual so that no safety hazards are created. Installing a fence around the area provides additional protection. Again, after rainfall check the area for any overflow problems and incorporate spillways if erosion occurs.

2.4.5 Constructing French Drains

Figure 14
French Drain

French (see figure 14) drains are rock-filled trenches that shortly detain fairly moderate amounts of water. Remember to place the drains at least six feet away from any buildings or structures to prevent water damage to the foundation (8). Water collected from rooftops through downspouts can be redirected and released in french drains via pipes and perforated pipes (see section 2.6, Collecting and Storing Rainwater). To utilize the water place plants near the area of the french drain. Surface debris must be removed to prevent clogging the system and perforated pipes need to be checked for sediment buildup.

2.5 Mulch

Evaporation rates can be as high as 0.25 inches per day (5). To reduce evaporation, fill basins with 3 to 6 inches of mulch (9). Organic mulches are used in areas where water velocity is fairly low. Organic mulches include straw, wood chips, bark, plant material, and composted material. Inorganic mulches, such as rock and gravel, work best on steep slopes where water travels quickly. Organic mulches break down over time. Apply new applications of mulch as needed. Check inorganic mulches occasionally to ensure that water has not undercut the area.

2.6 Collecting and Storing Rainwater

Figure 15
Downspout

Gutters and downspouts (see figure 15) can be added to building rooftops for the purpose of collecting and redirecting rainwater. In a passive system, piping delivers the water away from buildings (remember at least six feet away). Potentially, a large volume of water can be collected from a rooftop, therefore perforated pipes need to be added to slow the water delivered by a passive system. Diverting the water to a french drain will allow slower infiltration into the soil.

An active water harvesting system includes collecting and holding the water in a tank/ cistern for use at a later time. Downspouts directly connect to a cistern or series of cisterns. Water storage tanks range from small 55-gallon drums to underground storage tanks. Only simple above-ground storage tanks are described in this manual.

2.6.1. Rooftop Runoff

Figure 16
Gutter Water Outlet

Measure the edge of your rooftop to find the amount of guttering material you will need. For every 600 square feet of rooftop, you will need one water outlet (see figure 16). Gutter lengths of more than 20 feet will require a downspout at each end of the roof. Gutters should be at least 4 to 5 inches in width (5). Cover gutters with screening material to prevent leaf litter from backing up the system.

2.6.2 Water Storage Tank

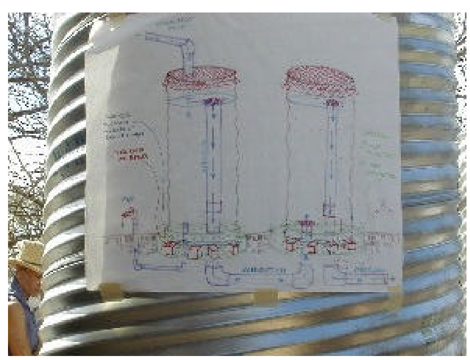


Figure 17
Design Plans for a Cistern

Above ground water storage tanks (see figure 16) should be positioned at least six feet away from buildings and be located on firm, level ground not vulnerable to settling or slope failure (9). For safety reasons, overflow devices must be installed. Install an outlet pipe of greater capacity than the inlet pipe or downspout. One end of the outlet pipe extends into the tank approximately two inches from the top (7). The other end of the pipe exits the tank and should be directed to a french drain or other suitable drainage area. If an additional tank is added, the exiting overflow pipe from the existing tank can be connected to the new tank.

The tank requires a lid to avoid any possibility of children or animals falling into the tank. Covering the tank will also reduce evaporation and prevent mosquitoes from laying eggs within the system. The lid needs to contain two openings, one for the downspout and the other for an airflow pipe (equalizes pressure differences inside and outside the tank). Also, the lid should be removable to allow access for cleaning mineral deposits and algae growth.

There are two methods of retrieving water from the cistern. A bucket can be used to retrieve and transfer the stored water into a watering can. Or, if a garden hose is to be attached to the system, then installation of a hose bib is necessary (see figure 18). However, water pressure in the hose will be very low. Gravity can be utilized to increase water pressure by placing the storage tank on a metal stand, slightly above the ground.

Figure 18
Hose Bib Attached to Cistern Piping

Water retrieved from the system ***is not for human consumption***. Put a sign on your system stating that the water is not safe to drink.

Storage tanks come in all shapes and sizes. Most above ground tanks are cylindrical. The volume of water that a cistern can hold depends on its diameter and height. To calculate the holding capacity of a cistern in gallons, the following equation is used:

$$\mathbf{(p) \; x \; (r)^2 \; x \; (h) \; x \; (7.48 \; gal/ft^3)}$$

$$\mathbf{(p) \; x \; (r)^2 \; x \; (h) \; x \; (264.2 \; gal/m^3)}$$

where r is the radius (half the diameter) of the cistern in feet (or meters), h is the height in feet (or meters), 7.48 is the conversion factor for converting square feet to gallons, and 264.2 is the conversion factor for converting square meters to gallons. If the diameter of the cistern is 1 1/2 feet and the height is 4 1/4 feet then its holding capacity is:

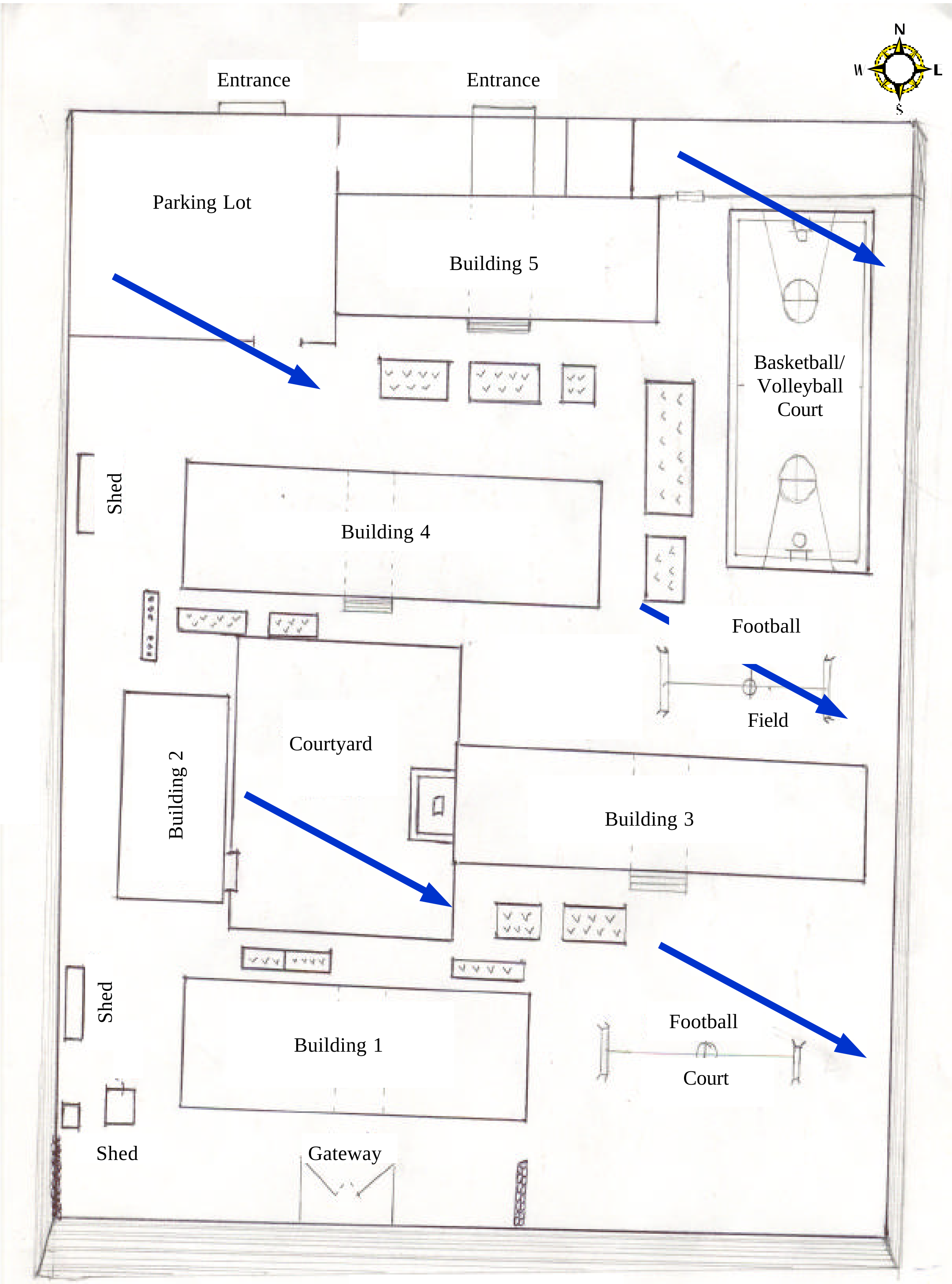
$(\pi) \text{ x } (1.5/2)^2 \text{ x } (4.25) \text{ x } (7.48\text{gal/ft}^2) = 56$ gallons.

Most barrels and drums are available in 50 to 60 gallon sizes. It is possible to purchase steel culverts (see figure 19) in a variety of sizes, but they require a water-sealed, concrete base and installation is more labor intensive.

2.7 <u>Observe and Adjust Your Systems</u>

Always check your water harvesting systems after rainfall. Periodically, check microbasins for any signs of overflow problems or erosion. Ensure that berms are compacted and add spillways if needed. Basin water should not stand for more than 12 hours. Allowing water to stand for longer periods of time will create breeding environments for mosquitoes. Ideally, water should stand for two hours after rainfall (8). This permits plants to easily uptake water without depriving them of oxygen. Expand basins in areas where plant growth is inhibited by confinement.

Keeping a log of your water usage will help you determine adjustments that you will want to make to your water harvesting systems. This will also help you realize your financial gains from installing water harvesting systems. If cisterns are installed, note the levels of the system at different times of the year as well as when you need to apply municipal water to your garden. Expand the system as needed.



Not Drawn to Scale

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