# Harvesting Rainwater for Landscape Use

**Patricia H. Waterfall**
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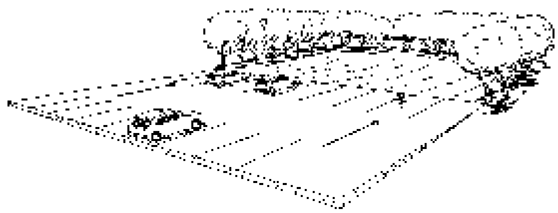
## Introduction

In the arid Southwest, rainfall is scarce and evapotranspiration ( $ET_o$ ) [1] rates are high. In Tucson the average historical $ET_o$ rate is approximately 77 inches and average rainfall is 11 inches, in Phoenix average historical $ET_o$ is approximately 80 inches and average rain is 10 inches. For Tucson, this is a 7:1 ratio between water that is evapotranspired and what is available from rainfall, for Phoenix the ratio is 8:1. Only natives and some desert-adapted plants (plants from other desert areas that can flourish in our soils and our climate) can live on 10 or 11 inches of annual rainfall. Other desert-adapted plants may require some supplemental irrigation. Plants from non-arid climates require a great deal of supplemental irrigation.

***Series of planted water harvesting basins on a slope.***

Harvesting rainwater can reduce the use of drinking water for landscape irrigation. Coupled with the use of native and desert-adapted plants, rainwater harvesting is an effective water conservation tool because it provides "free" water that is not from the municipal supply. There are many benefits to harvesting rainwater. Water harvesting not only reduces dependence on ground water and the amount of money spent on water, but also reduces off-site flooding and erosion by holding rainwater on the site. If large amounts of water are held in highly pervious areas (areas where water penetrates easily), some of the water may percolate to the water table. Rainwater is a clean, salt-free source of water for plants. In addition, rainwater harvesting can reduce salt accumulation in the soil which can be harmful to root growth. When collected, rainwater percolates into the soil, forcing salts down and away from the root zone area. This allows for greater root growth and water uptake, which increases the drought tolerance of plants. Limitations of water harvesting are few and are easily met by good planning and design.

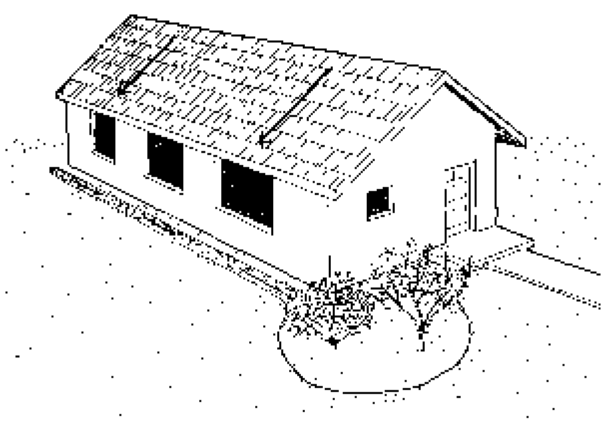
Water harvesting is the capture, diversion, and storage of rainwater for plant irrigation and other uses. It is appropriate for large scale landscapes such as parks, schools, commercial sites, parking lots, and apartment complexes, as well as small scale residential landscapes. System design ranges from simple to complex. But whether your landscape is large or small, the principles outlined in this manual apply. There are many water harvesting opportunities on developed sites, even very small yards can benefit from water harvesting. And, water harvesting can easily be planned into a new landscape during the design phase.



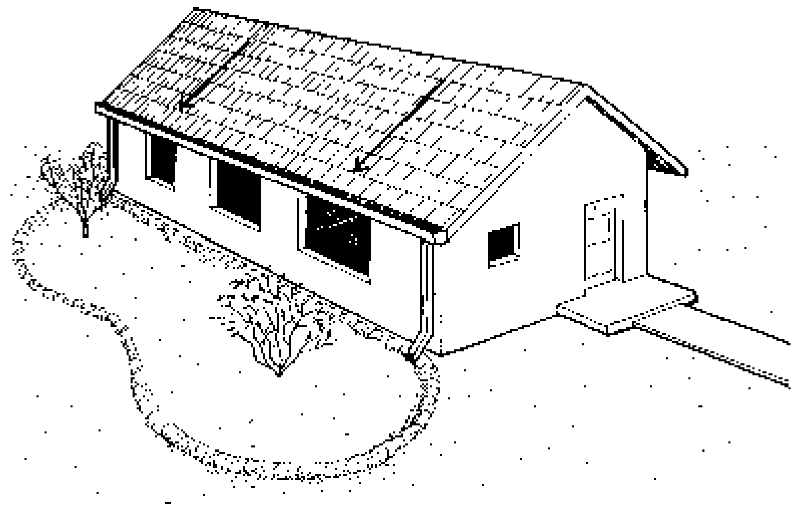
***Parking lot draining into concave lawn area.***

## Water Harvesting System Components

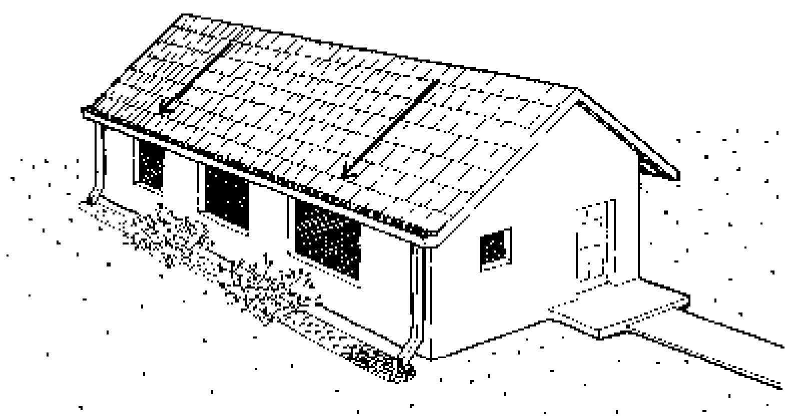
A rainfall water harvesting system has three components: the supply (rainfall), the demand (landscape water requirement), and the system that moves the water to the plants. Storage is an additional element which is optional.



***Simple system - Roof catchment, channel, and planted landscape holding area.***



***Simple system — Roof catchment, gutters, downspouts, and bermed landscape holding area.***



***Simple system — Roof catchment, gutters, downspouts, and french drain.***

**Rainfall.** Rainwater runoff refers to rainwater which flows off a surface. If the surface is impervious (water cannot penetrate it), then runoff occurs immediately. If the surface is pervious (water can penetrate it), then runoff will not occur until the surface is saturated. Runoff can be harvested (captured) and used immediately to water plants or can be stored for later use. Several factors affect runoff, the most important being the *amount* of rainfall. Rainfall *duration* refers to the length of time the rain falls, the longer the duration, the more water available to harvest. The *intensity* of the rainfall affects how soon the water will begin to run off and also how fast it runs off. The harder it rains and the longer it lasts the more water there is for harvesting. The *timing* of the rainfall is also important. If only one rainfall occurs, water percolates into the dry soil until it becomes saturated. If a second rainfall occurs soon after the first, more water may runoff because the soil is already wet.

**Plant Water Requirement.** The type of plants selected, their age and size, and how closely together they are planted all affect how much water is required to maintain a healthy landscape.

Because rainfall is scarce in arid regions, it is best to select plants with low water requirements and control planting densities to reduce overall water need. Native plants are well-adapted to seasonal, short-lived water supplies, and most desert-adapted plants can tolerate drought, making them good choices for landscape planting.

**Water Collection and Distribution System.** Water harvesting systems range from simple to complex. In a simple system the rainwater is used immediately. Most homeowners can design simple water harvesting systems to meet the needs of their existing site. Designing water harvesting systems into new construction allows the homeowner to be more elaborate and thorough in developing a system. In the case of very simple systems, the pay back period may be almost immediate.

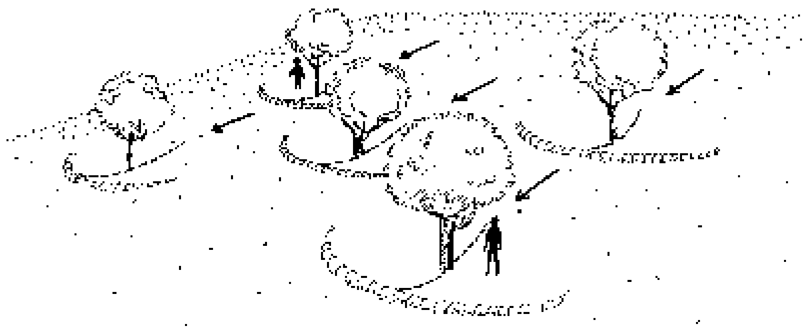
A simple system usually consists of a *catchment area*, and a means of *distribution*, which operates by gravity. The water is deposited in a *landscape holding area*, a concave area or planted area with "edges" to retain water, where it can be used immediately by the plants. Water collects on roofs, paved areas or the soil surface. A good example of a simple system is water dripping from the edge of the roof to a planted area or diversion channel directly below. Gravity moves the water to where it can be used. In some cases, small containers are used to hold water for later use.

A *catchment area* is any area from which water can be harvested. The best catchments have hard, smooth surfaces, such as concrete or metal roofing material. The amount of water harvested depends on the size, surface texture, and slope of the catchment area.

The *distribution system* connects the catchment area to the landscape holding area. Distribution systems direct water flow, and can be very simple or very sophisticated. For example, gutters and downspouts direct roof water to a holding area, and gently sloped sidewalks distribute water to a planted area. Hillsides provide a perfect situation for moving water from a catchment area to a holding area. Channels, ditches, and swales all can be utilized to move water. Elaborate open channel distribution systems may require gates and diverters to direct the water from one area to another. Standard or perforated pipes, and drip irrigation systems can be designed to distribute water. Curb cutouts can channel street or parking lot water to planted areas. If gravity flow is not possible, a small pump may be required to move the water.

*Landscape holding areas* store water in the soil for direct use by the plants. Concave depressions planted with grass or plants serve as landscape holding areas, containing the water, increasing water penetration, and reducing flooding. Depressed areas can be dug out, and the extra soil used to berm (a bank of soil used to retain water) the depression. With the addition of berms, moats, or soil terracing, flat areas also can hold water. One holding area or a series of holding areas can be designed to fill and then flow into adjacent holding areas via spillways (outlets for surplus water).

Soil erosion can be a problem with water moving quickly over the soil surface. Basins and spillways help reduce this. Crescent-shaped berms constructed around the base of the plant on the down-hill side are useful on slopes for slowing and holding water. Gabions (a stationary grouping of large rocks encased in wire mesh) are widely used to contain water and reduce erosion. French drains (holes or trenches filled with gravel) can also hold water for plant use. And lastly, pervious paving materials, such as gravel, crushed stone, open paving blocks, and pervious paving blocks, allow water to infiltrate into the soil to irrigate plants with large, extensive root systems, such as trees.

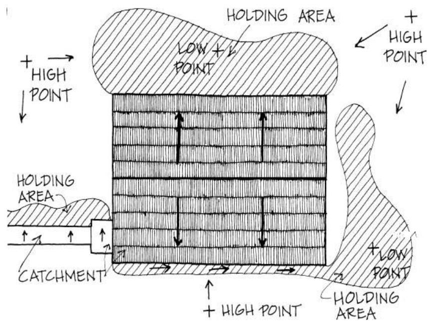


***Crescent-shaped landscaped holding areas on a slope.***

## Simple Water Harvesting System Design And Contruction

By observing your landscape during a rain, you can locate the existing drainage patterns on your site. Identify low points and high points. Utilize these drainage patterns and gravity flow to move water from catchment areas to planted areas. If you are harvesting rainwater from the roof, extend downspouts to reach planted areas or provide a path, drainage, or hose to move the water where it is needed. Take advantage of existing sloped paving to catch water and redistribute it to planted areas.The placement and slope of new paving can be designed to increase runoff. If sidewalks, terraces, or driveways are not yet constructed, slope them two percent (1/4 inch per foot) toward planting areas and utilize the runoff for irrigation. Bare dirt can also serve as a catchment area by grading the surface to increase and direct runoff.

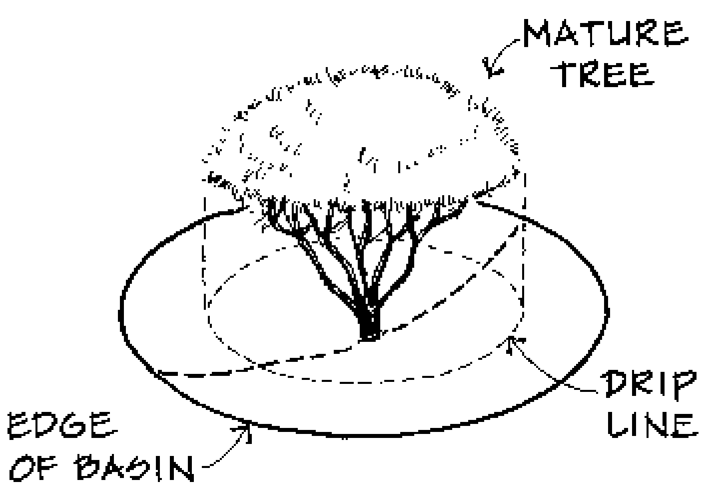
Next locate and size your landscape holding areas. Locate landscape depressions that can hold water or create new depressions where you want to locate new plants. Rather than digging a basin around existing plants, construct berms or moats on the existing surface to avoid damaging roots. Do not mound soil at the base of trees or other plants. Holding areas around existing plants should extend beyond the "drip line" to accommodate and encourage extensive root systems. The more developed a plant's root system, the more drought tolerant the plant becomes because the roots have a larger area to find water. For new plantings, locate the plants at the upper edge of concave holding areas to encourage extensive rooting and avoid extended inundation (flooding). With either existing or new landscapes you may want to connect several holding areas with spillways or channels to distribute the water throughout the site.




*Site plan showing drainage patterns and landscape holding areas (aerial view).*

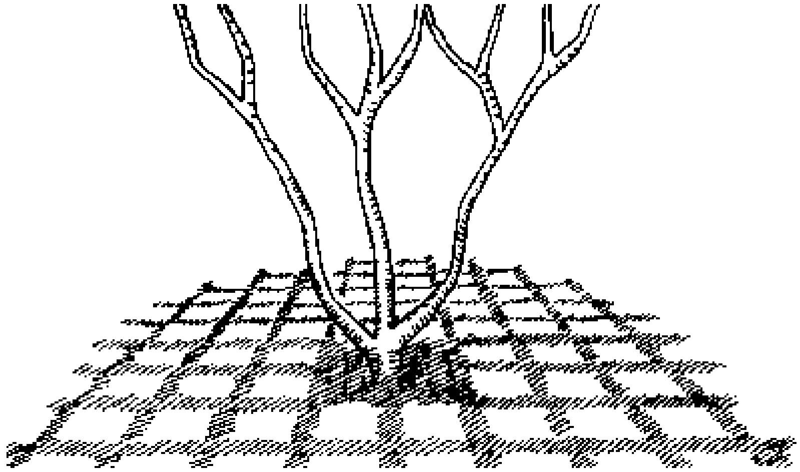
**Selecting Plant Material.** Proper plant selection is a major factor in the success of a water harvesting project. Native and desert-adapted plants can be grown successfully using harvested rainwater for irrigation. Some plants cannot survive in the actual detention area if the soil is saturated for a long period of time. Careful plant selection for these low lying areas is important. Select plants that can withstand prolonged drought and prolonged inundation--native plants or plants adapted to the Sonoran Desert. If plants are going to be planted in the bottom of large, deep basins, low water use, native riparian trees may be the most appropriate choice (hackberry, desert willow, acacia, mesquite).

To take advantage of water free-falling from roof downspouts (canales) plant large rigid plants where the water falls or hang a large chain from the downspout to the ground to disperse and slow the water. Provide a basin to hold the water for the plants and also to slow it down. It may be necessary to use rocks or other hard material to break the fall and prevent erosion. If this is a sloped site, large, connected, descending holding areas can be constructed for additional plants.




***Tree dripline and basin edge.***

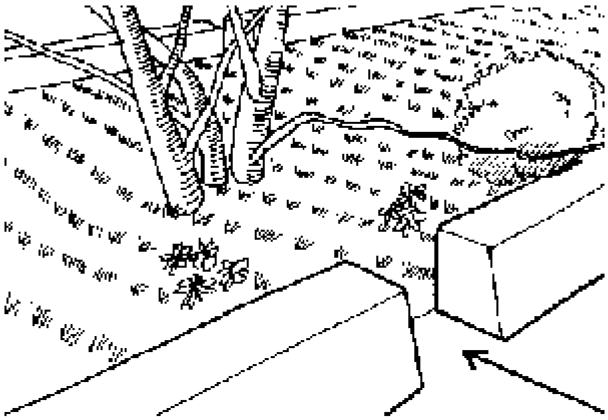
Seeding is another alternative for planting holding basins. Select seed mixes containing native or desert-adapted wildflowers, grasses, and herbaceous plants. Select annual plants for instant color and perennial plants for extended growth. Perennial grasses are particularly valuable for holding the soil and preventing erosion and soil loss.



***Pervious paving block with grass.***

**Construction Hints.** If you are going to dig, particularly if you are going to be using a bobcat, small tractor, or rototiller, call Arizona Blue Stake (1_800_782_5348) to locate where utility lines come into your property. This will eliminate leaks and breaks. Even if you are constructing a simple system with a rake and shovel, be aware of utility line locations. Soils in the landscape holding areas should not be compacted because this inhibits the water moving through the soil. If the soil is compacted, loosen it by tilling. If the soil is too sandy and will not hold water for any length of time, you may wish to add composted organic matter to the soil to increase moisture holding potential (This is not necessary with native or desert-adapted plants). After planting apply a 1 1/2 _ 2 inch layer of mulch to reduce evaporation.

**System Maintenance.** Developing a water harvesting system is actually an on-going process that can be improved and expanded over time. Water harvesting systems are always in a state of "construction". It is necessary to reality test your system during rain events. Determine whether the water is moving where you want it, or whether you are losing water. Also determine if the holding areas are doing a good job of containing the water. Make changes as your system requires. As time goes on you may discover additional areas where water can be harvested and where water can be channeled. Water harvesting systems should be inspected before each rainy season and ideally after every rain event to keep the system operating at optimum performance.



***Parking lot curb cutout directing water into planted area.***

Table 1 - Maintenance Checklist

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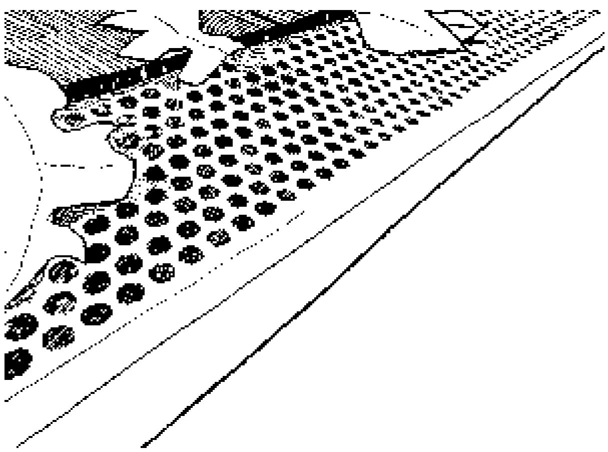
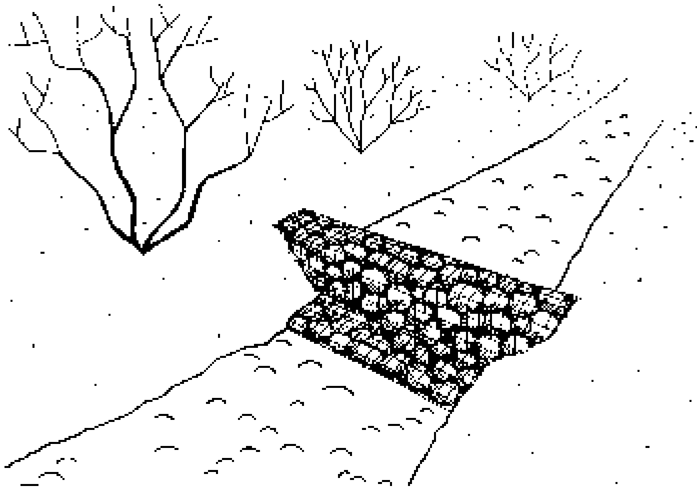
- Keep holding areas free of debris.
- Control and prevent erosion, block erosion trails.
- Clean, repair channels.
- Clean, repair dikes, berms, moats
- Keep gutters and downspouts free of debris
- Flush debris from the bottom of storage containers, if possible.
- Clean and maintain filters, including drip filters.
- Expand the area of concentration as plants grow.



***Gutter leaf filter***

**Monitor Water Use.** Now that you have your system operating, it is a good idea to monitor your landscape water use. If you have constructed water harvesting basins in an existing landscape, use last year's water bills to compare your pre-water harvesting use to your post-water harvesting use. If you have added new plants to a water harvesting area, the water savings begins when they are planted. Every time they can be irrigated with harvested rainwater there is a water savings!



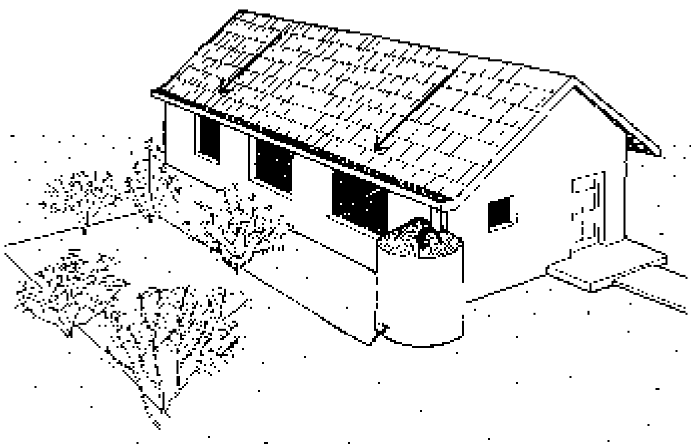
***Gabion in a stream bed.***

## Complex Water Harvesting Systems

Water harvesting cannot provide a completely dependable source of irrigation water because it is dependent on the weather, and weather is not dependable. To get the maximum benefit from rainwater harvesting, some storage can be built into the water harvesting system to provide water between rainfall events. In Southern and Central Arizona there are two rainy periods (summer and winter) with long dry periods between the two. Heavy rain events can produce more water than is needed by a landscape during that rainfall. Once the root zone of the plants have been thoroughly wetted, the rainwater begins to move below the root zone. At this point plants are well irrigated. As the soil becomes saturated, water begins to run off or stand on the surface. The saturation point and the onset of runoff is dependent on the texture and condition of the soil. (Sandy soils accept more water than clayey soils.)

Many people ask whether they can harvest enough water in an average year to provide sufficient irrigation for an entire landscape. The answer is, it depends. If you are interested in designing a totally self-sufficient water harvesting system, then the amount of water harvested and the water needed for landscape irrigation should be in balance. Storage capacity plays a big role in this equation by making rainwater available in the dry seasons when the plants need it.

Rainfall harvesting systems that utilize storage result in larger water savings and higher construction costs. These more complex systems are more appropriate for larger facilities and may require professional assistance to design and construct. With such a system the cost of storage, particularly the disposal of soil and rock from underground storage construction, is a major consideration. The investment pay back period may be several years. Is the cost of storage greater than the cost of water? In many cases, yes. In this case the personal commitment to a "water conservation ethic" may come into play. A more realistic goal, and one that is followed by most people is to harvest less than the total landscape requirement. Another option is to reduce your demand by reducing planting areas or planting densities. This involves less storage and is therefore less expensive.



***Complex water harvesting system with roof catchment, gutter, downspout, storage, & drip irrigation distribution system.***

**Elements of a Complex Water Harvesting System**

Components of complex systems that utilize storage include *catchment areas,* usually a roof, *conveyance systems, storage,* and *distribution system*s, to control where the water goes. The amount of water or *"yield"* that the catchment area will provide depends on the size of the catchment area and its surface texture. Concrete, asphalt, or brick paving and smooth-surfaced roofing materials provide high yields. Bare soil surfaces provide harvests of medium yield, with compacted clayey soils yielding the most. Planted areas, such as grass or groundcover areas, offer the lowest yields because the plants hold the water longer allowing it to infiltrate into the soil. This is not necessarily a problem, depending whether you want to use collected water directly or store it for later use.

Conveyance systems direct the water from the catchment area to the storage container. With a roof catchment system the gutter and downspouts are the means of conveyance. Gutters and downspouts are either concealed inside the walls of buildings or attached to the exterior of buildings. They can be added to the outside of a building at anytime. Proper sizing of gutters is important to collect as much rainfall as possible.

Table 2 --Annual Supply Form Roof Catchement

| Inches/Rainfall | Gallons/Square Foot |
|---|---|
| 0 | 0 |
| 1 | .6 |
| 2 | 1.3 |
| 3 | 1.9 |
| 4 | 2.5 |
| 5 | 3.1 |
| 6 | 3.7 |
| 7 | 4.4 |
| 8 | 5.0 |
| 9 | 5.6 |
| 10 | 6.2 |
| 11 | 6.8 |
| 12 | 7.5 |
| 13 | 8.1 |
| 14 | 8.7 |
| 15 | 9.3 |

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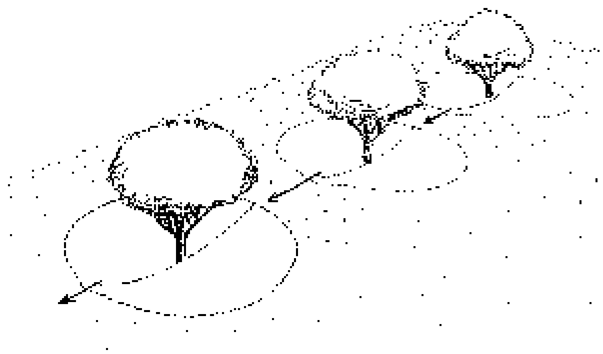

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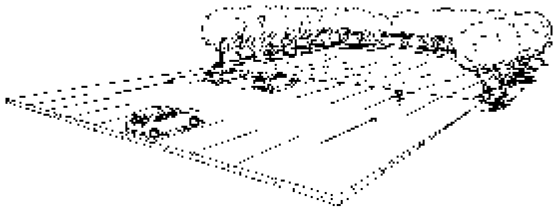

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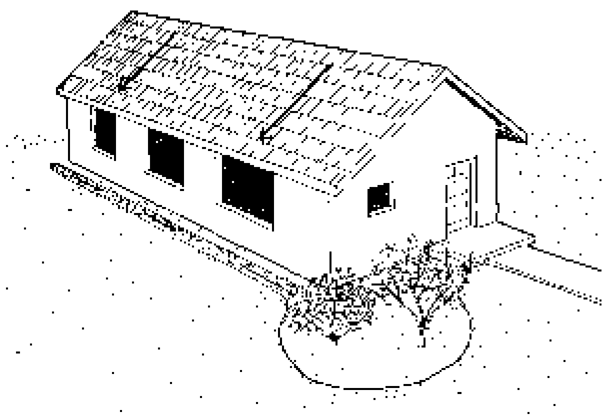

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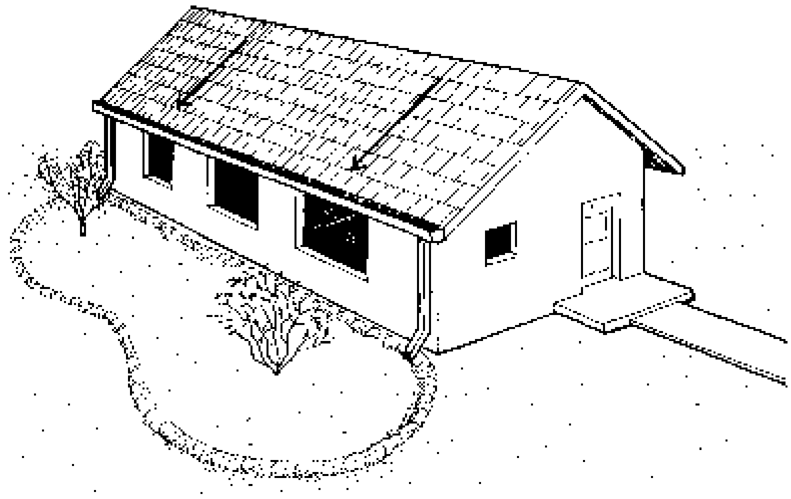

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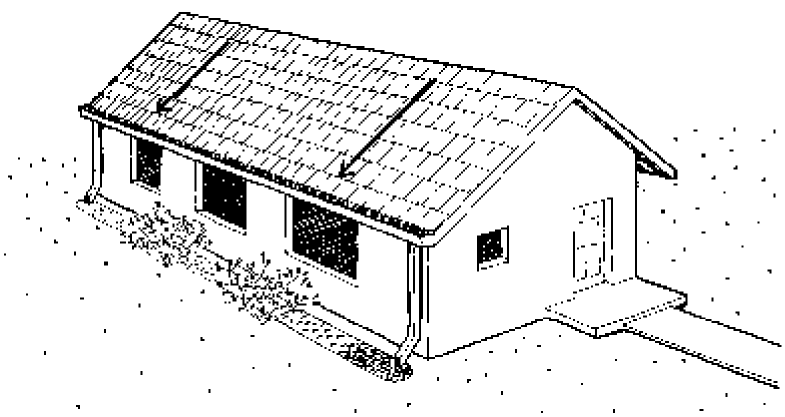

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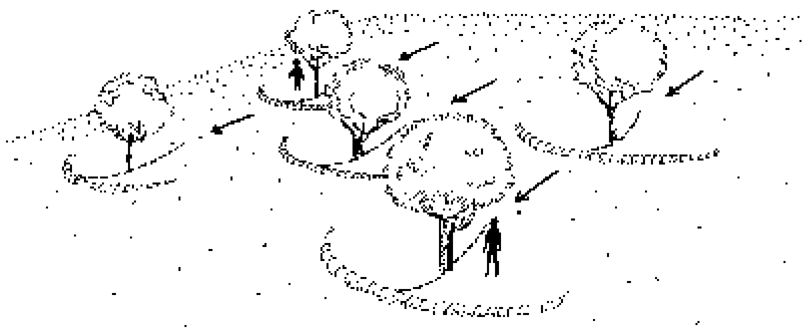

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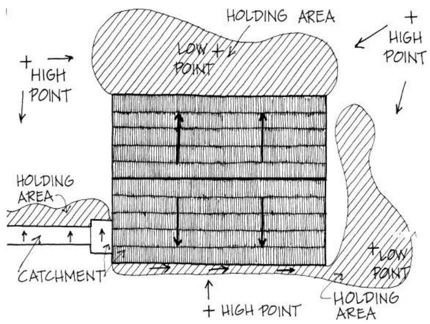
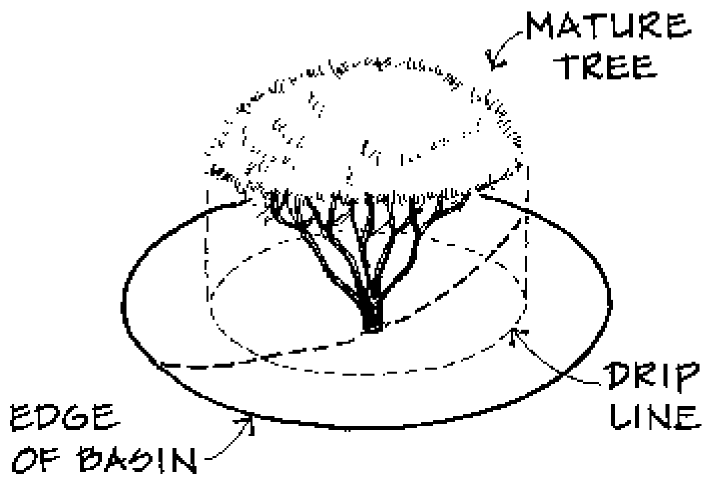



*Site plan showing drainage patterns and landscape holding areas (aerial view).*

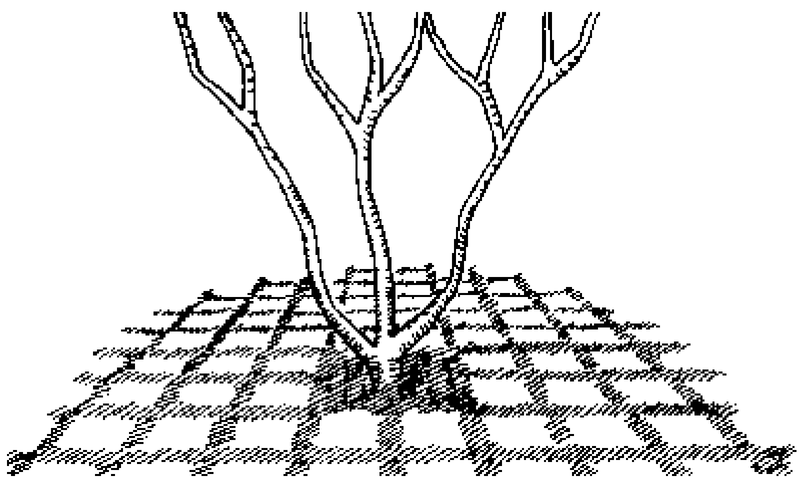
**Selecting Plant Material.** Proper plant selection is a major factor in the success of a water harvesting project. Native and desert-adapted plants can be grown successfully using harvested rainwater for irrigation. Some plants cannot survive in the actual detention area if the soil is saturated for a long period of time. Careful plant selection for these low lying areas is important. Select plants that can withstand prolonged drought and prolonged inundation--native plants or plants adapted to the Sonoran Desert. If plants are going to be planted in the bottom of large, deep basins, low water use, native riparian trees may be the most appropriate choice (hackberry, desert willow, acacia, mesquite).

To take advantage of water free-falling from roof downspouts (canales) plant large rigid plants where the water falls or hang a large chain from the downspout to the ground to disperse and slow the water. Provide a basin to hold the water for the plants and also to slow it down. It may be necessary to use rocks or other hard material to break the fall and prevent erosion. If this is a sloped site, large, connected, descending holding areas can be constructed for additional plants.




***Tree dripline and basin edge.***

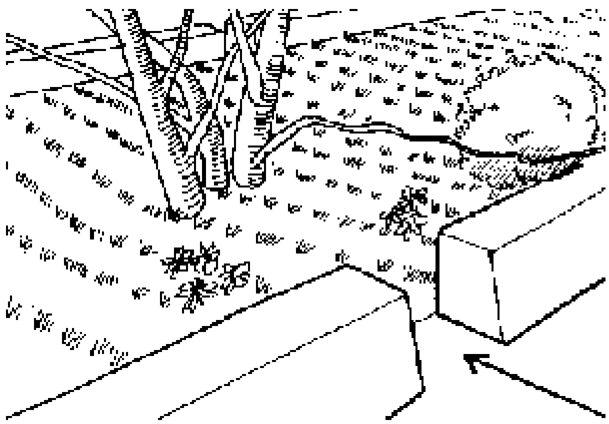
Seeding is another alternative for planting holding basins. Select seed mixes containing native or desert-adapted wildflowers, grasses, and herbaceous plants. Select annual plants for instant color and perennial plants for extended growth. Perennial grasses are particularly valuable for holding the soil and preventing erosion and soil loss.



***Pervious paving block with grass.***

**Construction Hints.** If you are going to dig, particularly if you are going to be using a bobcat, small tractor, or rototiller, call Arizona Blue Stake (1_800_782_5348) to locate where utility lines come into your property. This will eliminate leaks and breaks. Even if you are constructing a simple system with a rake and shovel, be aware of utility line locations. Soils in the landscape holding areas should not be compacted because this inhibits the water moving through the soil. If the soil is compacted, loosen it by tilling. If the soil is too sandy and will not hold water for any length of time, you may wish to add composted organic matter to the soil to increase moisture holding potential (This is not necessary with native or desert-adapted plants). After planting apply a 1 1/2 _ 2 inch layer of mulch to reduce evaporation.

**System Maintenance.** Developing a water harvesting system is actually an on-going process that can be improved and expanded over time. Water harvesting systems are always in a state of "construction". It is necessary to reality test your system during rain events. Determine whether the water is moving where you want it, or whether you are losing water. Also determine if the holding areas are doing a good job of containing the water. Make changes as your system requires. As time goes on you may discover additional areas where water can be harvested and where water can be channeled. Water harvesting systems should be inspected before each rainy season and ideally after every rain event to keep the system operating at optimum performance.



***Parking lot curb cutout directing water into planted area.***

Table 1 - Maintenance Checklist

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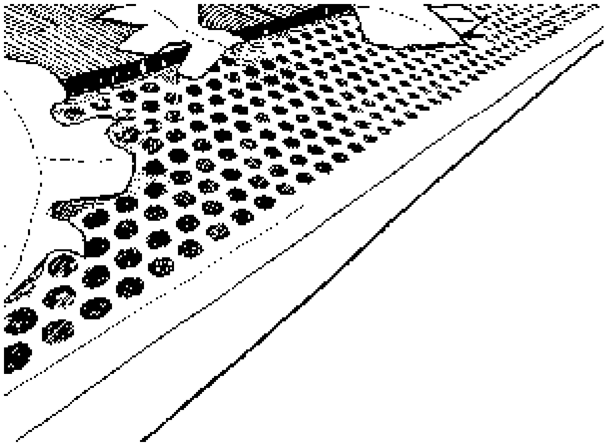
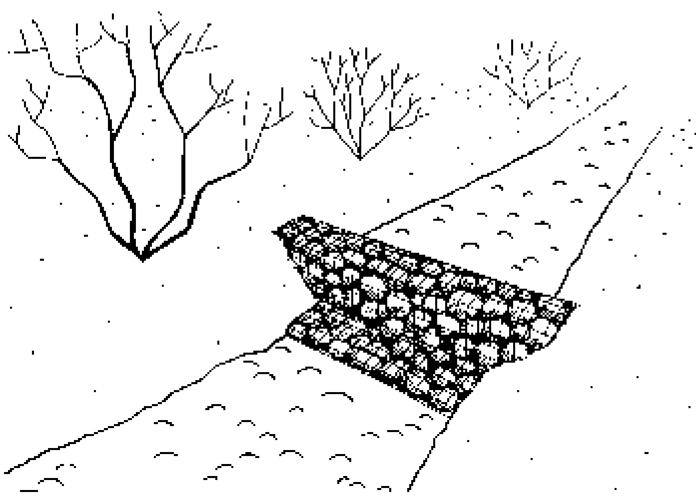
- Keep holding areas free of debris.
- Control and prevent erosion, block erosion trails.
- Clean, repair channels.
- Clean, repair dikes, berms, moats
- Keep gutters and downspouts free of debris
- Flush debris from the bottom of storage containers, if possible.
- Clean and maintain filters, including drip filters.
- Expand the area of concentration as plants grow.



***Gutter leaf filter***

**Monitor Water Use.** Now that you have your system operating, it is a good idea to monitor your landscape water use. If you have constructed water harvesting basins in an existing landscape, use last year's water bills to compare your pre-water harvesting use to your post-water harvesting use. If you have added new plants to a water harvesting area, the water savings begins when they are planted. Every time they can be irrigated with harvested rainwater there is a water savings!



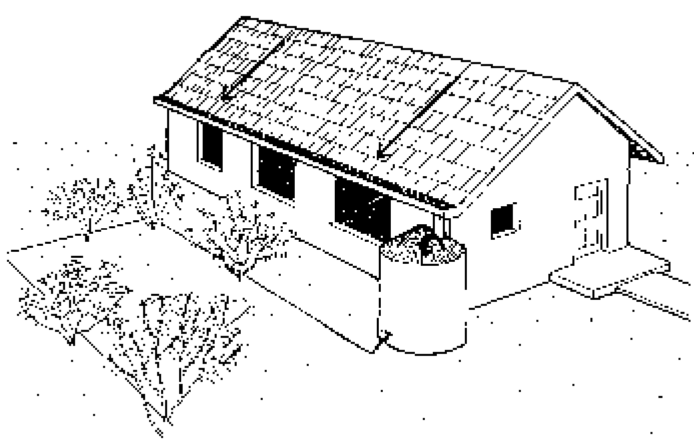
***Gabion in a stream bed.***

## Complex Water Harvesting Systems

Water harvesting cannot provide a completely dependable source of irrigation water because it is dependent on the weather, and weather is not dependable. To get the maximum benefit from rainwater harvesting, some storage can be built into the water harvesting system to provide water between rainfall events. In Southern and Central Arizona there are two rainy periods (summer and winter) with long dry periods between the two. Heavy rain events can produce more water than is needed by a landscape during that rainfall. Once the root zone of the plants have been thoroughly wetted, the rainwater begins to move below the root zone. At this point plants are well irrigated. As the soil becomes saturated, water begins to run off or stand on the surface. The saturation point and the onset of runoff is dependent on the texture and condition of the soil. (Sandy soils accept more water than clayey soils.)

Many people ask whether they can harvest enough water in an average year to provide sufficient irrigation for an entire landscape. The answer is, it depends. If you are interested in designing a totally self-sufficient water harvesting system, then the amount of water harvested and the water needed for landscape irrigation should be in balance. Storage capacity plays a big role in this equation by making rainwater available in the dry seasons when the plants need it.

Rainfall harvesting systems that utilize storage result in larger water savings and higher construction costs. These more complex systems are more appropriate for larger facilities and may require professional assistance to design and construct. With such a system the cost of storage, particularly the disposal of soil and rock from underground storage construction, is a major consideration. The investment pay back period may be several years. Is the cost of storage greater than the cost of water? In many cases, yes. In this case the personal commitment to a "water conservation ethic" may come into play. A more realistic goal, and one that is followed by most people is to harvest less than the total landscape requirement. Another option is to reduce your demand by reducing planting areas or planting densities. This involves less storage and is therefore less expensive.



***Complex water harvesting system with roof catchment, gutter, downspout, storage, & drip irrigation distribution system.***

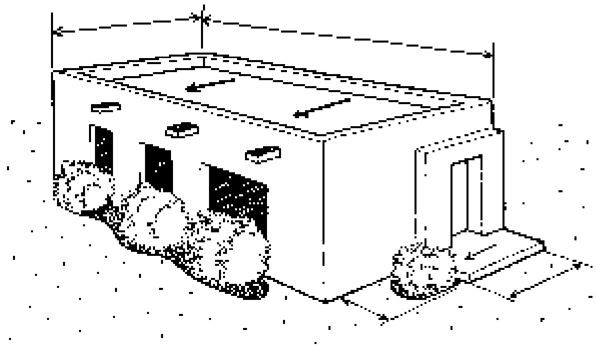
**Elements of a Complex Water Harvesting System**

Components of complex systems that utilize storage include *catchment areas*, usually a roof, *conveyance systems, storage,* and *distribution system*s, to control where the water goes. The amount of water or *"yield"* that the catchment area will provide depends on the size of the catchment area and its surface texture. Concrete, asphalt, or brick paving and smooth-surfaced roofing materials provide high yields. Bare soil surfaces provide harvests of medium yield, with compacted clayey soils yielding the most. Planted areas, such as grass or groundcover areas, offer the lowest yields because the plants hold the water longer allowing it to infiltrate into the soil. This is not necessarily a problem, depending whether you want to use collected water directly or store it for later use.

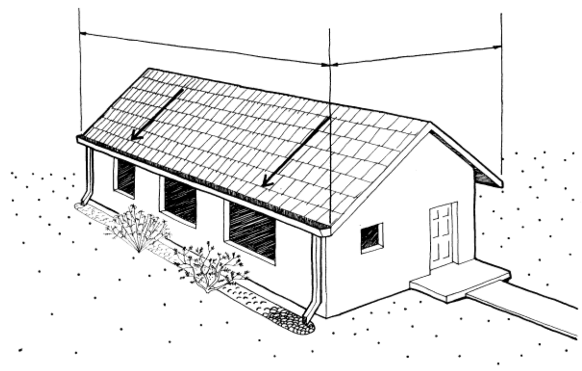
Conveyance systems direct the water from the catchment area to the storage container. With a roof catchment system the gutter and downspouts are the means of conveyance. Gutters and downspouts are either concealed inside the walls of buildings or attached to the exterior of buildings. They can be added to the outside of a building at anytime. Proper sizing of gutters is important to collect as much rainfall as possible.

Table 2 --Annual Supply Form Roof Catchement

| Inches/Rainfall | Gallons/Square Foot |
|---|---|
| 0 | 0 |
| 1 | .6 |
| 2 | 1.3 |
| 3 | 1.9 |
| 4 | 2.5 |
| 5 | 3.1 |
| 6 | 3.7 |
| 7 | 4.4 |
| 8 | 5.0 |
| 9 | 5.6 |
| 10 | 6.2 |
| 11 | 6.8 |
| 12 | 7.5 |
| 13 | 8.1 |
| 14 | 8.7 |
| 15 | 9.3 |



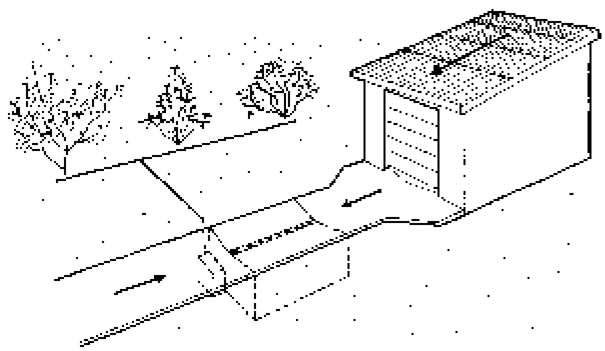
***Area of flat roof - Length X width***



***Area of slopped roof - Length X width***

Before the water is stored it should be filtered to remove particles and debris. The degree of filtration is dependent on the size of the distribution tubing (drip systems would require more and finer filtering than water distributed through a hose). Filters can be in-line or a leaf screen can be placed over the gutter at the top of the downspout. Many people divert the first part of the rainfall to eliminate debris from the harvested water. The initial rain "washes" debris off the roof, the later rainfall, which is free of debris and dust, is then collected. Always cover the storage container to prevent mosquito and algae growth and also to prevent debris from getting into the storage container.

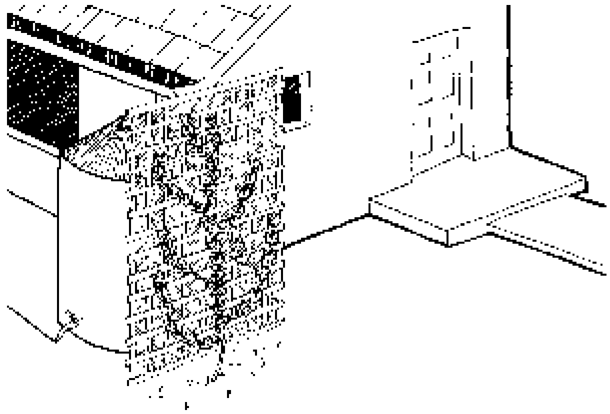
Storage allows full utilization of excess rainfall, by making water available later when it is needed. Locate storage near downspouts or at the end of the downspout. Storage can be underground or above-ground. Storage containers can be made of polyethylene, fiberglass, wood, or metal. Underground containers are a more expensive choice because of the cost of soil excavation and removal. Pumping the water out of the container adds an additional cost. Swimming pools, stock tanks, septic tanks, ferrocement culverts, concrete block, poured in place concrete, or building rock can be used for underground storage. Look in the Yellow Pages under "Tanks," "Feed Dealers," "Septic Tanks," and "Swimming Pools" to locate storage containers. Estimates for the cost of storage ranges from $100 to $3500, depending on the system, degree of filtration, and the distance between the storage and the place of use.[2] Examples of above ground containers include large garbage cans, 55-gallon plastic or steel drums, barrels, tanks, cisterns, stock tanks, fiberglass fishponds, storage tanks, and above ground swimming pools. Above ground storage buildings or large holding tanks made of concrete block, stone, plastic bags filled with sand, or rammed earth also can also be used.



***Roof catchment with sloping driveway, french drain, and underground storage.***

If storage is unsightly, it can be designed into the landscape by placing it in an unobtrusive place or hiding it with a structure, screen, and/or plants. In all cases, storage should be located close to the area of use and placed at an elevated level to take advantage of gravity flow. Ideally, on a sloped lot the storage area is located at the high end of the property to facilitate gravity flow. Some times it is more useful to locate several smaller cisterns near where water is required because they are easier to handle and camouflage. If the landscaped area is extensive, several tanks can be connected to increase storage capacity. In the case that all storage tanks become full and rainfall continues, alternative storage for the extra water must be found. A concave lawn area would be ideal as a holding area where the rain water could slowly percolate into the soil.

The distribution system directs the water from the storage containers to landscaped areas. The distribution device can be a hose, constructed channels, pipes, perforated pipes, or a manual drip system. Gates and diverters can be used to control flow rate and flow direction. A manual valve or motorized ball valve located near the bottom of the storage container can assist gravity fed irrigation. If gravity flow is not possible, an in-line electric pump hooked to a hose can be used. The distribution of water through an automatic drip irrigation system requires extra effort to work effectively. A small submersible pump will be required to provide enough pressure to activate the remote control valve (minimum 20 psi). The pump should have the capability of turning off when there is no water in the tank to avoid burning the pump out.



***Vine used to screen storage tank.***

**Complex Water Harvesting System Design & Construction**

If you are designing a complex water harvesting system, draw your system on paper before you begin to construct it to save time and effort. You may not want to do any calculations, but if you do, a more functional and efficient system will result. However, doing the calculations does not eliminate the need to field test the system. The steps involved in designing a complex water harvesting system include site analysis, calculation, design, and construction. If the project is complicated, divide the site into sub-drainage areas and repeat the following steps for each sub-area.

**Site Analysis.** If you are starting with a new landscape or working with an existing one, draw your site and all the site elements to scale. Plot the existing drainage flow patterns by observing your property during a rain. Show the direction of the water flow with arrows. Also, indicate high and low areas on your plan. Look for catchment areas to harvest water; for example, paved areas, roof surfaces, and bare earth. Next, find planted areas or potential planting areas that require irrigation. Also, locate above or below ground storage near planted areas. Decide how you are going to move water from the catchment area to the holding area or storage container. Rely on gravity to move water whenever you can. Also decide how you are going to move the water through the site from one landscaped area to another landscaped area. Again, if the site is too large or the system too complicated divide the area into sub-drainage systems.

**Calculations.** Calculate the monthly supply (rainfall harvest potential) and the monthly demand (plant water requirement) for a year. Next, calculate your monthly storage requirement if you are designing a more complex system.

**1 CUBIC FOOT (CF) = 7.48 GALLONS**

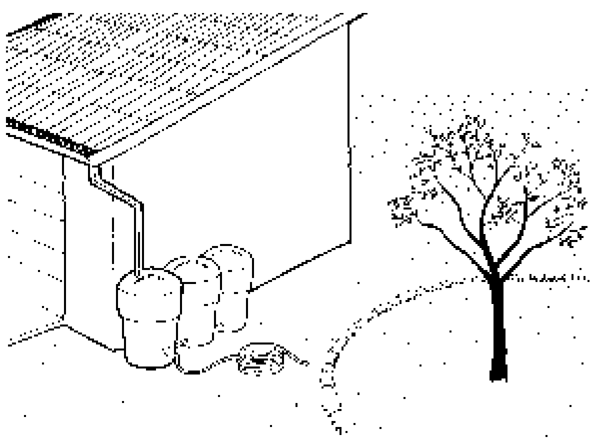
**100 CUBIC FEET (CCF) = 748 GALLONS**

Calculate supply (Tables 5 and 6) - The equation for calculating supply measures the amount of water (in gallons) capable of being harvested from a catchment area.

$$\text{SUPPLY ( Gallons )} = (\text{CATCHMENT AREA ( FT}^2\text{ )} \times \text{RAINFALL ( FT ))} \times \text{RUNOFF COEFFICIENT} \times 7.48\ \text{GAL/CF}$$

The area of the catchment is expressed in square feet, for example a 10 x 20 FT catchment area is 200 SF (square feet). Measure a sloped roof by measuring the area that is covered by the roof, usually the length and width of the building. The catchment area is multiplied by the amount of rainfall converted to feet to get the volume of water which is expressed in cubic feet (Table 3). The runoff coefficient tells what percent of the rainfall can be harvested from specific surfaces (Table 4). The conversion number 7.48 converts cubic feet to gallons. The higher numbers represent a smoother surface that the lower numbers.

Tables 5 and 6 give monthly amounts for 1000 SF of roof area in Tucson or Phoenix. $ET_o$ data for other Arizona locations is available from AZMET (520_621_9742 or http://ag.arizona.edu/azmet/). (All Phoenix data is from the Greenway weather station.)



*Roof catchment with multiple storage cans connected to a hose adjacent to a landscape holding area.*

Table 3 - Average Monthly Rainfall
Tucson and Phoenix (Greenway)

| TUCSON, ARIZONA | | | PHOENIX, ARIZONA | | |
|---|---|---|---|---|---|
| Month | Inches | Feet | Month | Inches | Feet |
| Jan. | 1.2 | 0.1 | Jan. | 1.6 | 0.1 |
| Feb. | 1.0 | 0.1 | Feb. | 0.9 | 0.1 |
| Mar. | 0.9 | 0.1 | Mar. | 1.4 | 0.1 |
| April | 0.3 | 0.0 | April | 0.3 | 0.0 |
| May | 0.3 | 0.0 | May | 0.2 | 0.0 |
| June | 0.0 | 0.0 | June | 0.1 | 0.0 |
| July | 1.3 | 0.1 | July | 1.4 | 0.1 |
| August | 1.8 | 0.2 | August | 1.2 | 0.2 |
| Sept. | 1.0 | 0.1 | Sept. | 0.9 | 0.1 |
| Oct. | 0.7 | 0.1 | Oct. | 0.8 | 0.1 |
| Nov. | 0.7 | 0.1 | Nov. | 0.9 | 0.1 |
| Dec. | 1.4 | 0.1 | Dec. | 1.1 | 0.1 |
| Total | 10.6 | 1.0 | | 10.8 | 0.9 |

\

Table 4 - Runoff Coefficients

| | High | Low |
|---|---|---|
| Roof: | | |
| Metal, gravel, asphal 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 |

Table 5 - Total Monthly Supply
Tucson
Roof Area = 1000 Square Feet                    Runoff Coefficient = 0.90

| Month | Roof SF | Runoff Coeff | Rainfall Feet | Convert Gallons | Yield Gallons |
|---|---|---|---|---|---|
| Jan. | 1000 | 0.90 | 0.1 | 7.48 | 673 |
| Feb. | 1000 | 0.90 | 0.1 | 7.48 | 673 |
| Mar. | 1000 | 0.90 | 0.1 | 7.48 | 673 |
| Apr. | 1000 | 0.90 | 0.0 | 7.48 | 0 |
| May | 1000 | 0.90 | 0.0 | 7.48 | 0 |
| Jun | 1000 | 0.90 | 0.0 | 7.48 | 0 |
| Jul | 1000 | 0.90 | 0.1 | 7.48 | 673 |
| Aug | 1000 | 0.90 | 0.2 | 7.48 | 1346 |
| Sept. | 1000 | 0.90 | 0.1 | 7.48 | 673 |
| Oct. | 1000 | 0.90 | 0.1 | 7.48 | 673 |
| Nov. | 1000 | 0.90 | 0.1 | 7.48 | 673 |
| Dec. | 1000 | 0.90 | 0.1 | 7.48 | 673 |
| Total | | | 1.0 | | 6730 |

Table 6 - Total Monthly Supply
Phoenix (Greenway)
Roof Area = 1000 Square Feet                    Runoff Coefficient = 0.90

| Month | Roof SF | Runoff Coeff | Rainfall Feet | Convert Gallons | Yield Gallons |
|---|---|---|---|---|---|
| Jan. | 1000 | 0.90 | 0.1 | 7.48 | 673 |
| Feb. | 1000 | 0.90 | 0.1 | 7.48 | 673 |
| Mar. | 1000 | 0.90 | 0.1 | 7.48 | 673 |
| Apr. | 1000 | 0.90 | 0.0 | 7.48 | 0 |
| May | 1000 | 0.90 | 0.0 | 7.48 | 0 |
| Jun | 1000 | 0.90 | 0.0 | 7.48 | 0 |
| Jul | 1000 | 0.90 | 0.1 | 7.48 | 673 |
| Aug | 1000 | 0.90 | 0.2 | 7.48 | 673 |
| Sept. | 1000 | 0.90 | 0.1 | 7.48 | 673 |
| Oct. | 1000 | 0.90 | 0.1 | 7.48 | 673 |
| Nov. | 1000 | 0.90 | 0.1 | 7.48 | 673 |
| Dec. | 1000 | 0.90 | 0.1 | 7.48 | 673 |
| Total | | | 0.9 | | 6057 |

**Calculate demand** — The demand equation tells you how much water is required for a given landscaped area. There are two methods you can use — *Method 1* is used for new or established landscapes, *Method 2* can only be used for established landscapes. HINT: Grouping plants with similar water requirements simplifies the system by making the amount of water needed to maintain those plants easier to calculate.

***METHOD 1*** **:**

$$\textbf{DEMAND} = (\,\textbf{ET}_\textbf{o} \times \textbf{PLANT FACTOR}\,) \times \textbf{AREA} \times 7.48$$

The equation for calculating demand for new or established landscapes is based on monthly evapotranspiration ($ET_o$) information. Table 7 provides $ET_o$ information for Tucson and Phoenix. (Evapotranspiration data for other Arizona areas is available through AZMET, the state-wide weather service.) For this equation use $ET_o$ values in feet. The Plant Factor represents the percent of $ET_o$ that is needed by the plant (Table 8). This is determined by the type of plant — high, medium, or low water use. In the example shown, the plants require approximately 26 percent of $ET_o$, the high range of low water use.

These plant factor values are approximate, specific plant values (coefficients) for landscape plants are not available. These values approximate what is needed to maintain plant health and acceptable appearance. Irrigation experience tells us where plants fall within each category. Consult the Arizona Department of Water Resources *Low Water Use/Drought Tolerant Plant List* for the Tucson or Phoenix areas to determine the approximate water requirement of landscape plants common to the area you live in. The irrigated area refers to how much area is planted and is expressed in square feet. The conversion factor 7.48 converts cubic feet into gallons. (Tables 9 and 10).

Table 7 - Average Monthly $ET_o$
Tucson and Phoenix (Greenway)

| TUCSON, ARIZONA | | | PHOENIX, ARIZONA | | |
|---|---|---|---|---|---|
| Month | Inches | Feet | Month | Inches | Feet |
| Jan. | 1.2 | 0.1 | Jan. | 1.6 | 0.1 |
| Feb. | 1.0 | 0.1 | Feb. | 0.9 | 0.1 |
| Mar. | 0.9 | 0.1 | Mar. | 1.4 | 0.1 |
| April | 0.3 | 0.0 | April | 0.3 | 0.0 |
| May | 0.3 | 0.0 | May | 0.2 | 0.0 |
| June | 0.0 | 0.0 | June | 0.1 | 0.0 |
| July | 1.3 | 0.1 | July | 1.4 | 0.1 |
| August | 1.8 | 0.2 | August | 1.2 | 0.2 |
| Sept. | 1.0 | 0.1 | Sept. | 0.9 | 0.1 |
| Oct. | 0.7 | 0.1 | Oct. | 0.8 | 0.1 |
| Nov. | 0.7 | 0.1 | Nov. | 0.9 | 0.1 |
| Dec. | 1.4 | 0.1 | Dec. | 1.1 | 0.1 |
| Total | 10.6 | 1.0 | Total | 10.8 | 0.9 |

Table 8 - Plant Water Use

| Plant Type | Percent Range | |
|---|---|---|
| | High | Low |
| Low Water Use | 0.26 | 0.13 |
| Medium Water Use | 0.45 | 0.26 |
| High Water Use | 0.64 | 0.45 |

Table 9 - Total Monthly Demand
New or Established Landscapes - Tucson
Irrigated Area = 450 Square Feet Plant Factor = .26/ Low Water Use

| Month | $ET_o$ Feet | Plant Factor | Areal SF | Convert Gallons | Demand Gallons |
|---|---|---|---|---|---|
| Jan. | 0.2 | 0.26 | 450 | 7.48 | 175 |
| Feb. | 0.3 | 0.26 | 450 | 7.48 | 263 |
| Mar. | 0.5 | 0.26 | 450 | 7.48 | 438 |
| Apr. | 0.7 | 0.26 | 450 | 7.48 | 613 |
| May | 0.8 | 0.26 | 450 | 7.48 | 700 |
| Jun | 0.9 | 0.26 | 450 | 7.48 | 788 |
| Jul | 0.8 | 0.26 | 450 | 7.48 | 700 |
| Aug | 0.7 | 0.26 | 450 | 7.48 | 613 |
| Sept. | 0.6 | 0.26 | 450 | 7.48 | 543 |
| Oct. | 0.5 | 0.26 | 450 | 7.48 | 438 |
| Nov. | 0.3 | 0.26 | 450 | 7.48 | 263 |
| Dec. | 0.2 | 0.26 | 450 | 7.48 | 175 |
| Total | 6.5 | | | | 5709 |

Table 10 - Total Monthly Demand
New or Established Landscapes - Phoenix(Greenway)
Irrigated Area = 450 Square Feet Plant Factor = 0.26/ Low Water Use

| Month | $ET_o$ Feet | Plant Factor | Areal SF | Convert Gallons | Demand Gallons |
|---|---|---|---|---|---|
| Jan. | 0.2 | 0.26 | 450 | 7.48 | 175 |
| Feb. | 0.3 | 0.26 | 450 | 7.48 | 263 |
| Mar. | 0.5 | 0.26 | 450 | 7.48 | 438 |
| Apr. | 0.7 | 0.26 | 450 | 7.48 | 613 |
| May | 0.8 | 0.26 | 450 | 7.48 | 700 |
| Jun | 0.9 | 0.26 | 450 | 7.48 | 788 |
| Jul | 0.8 | 0.26 | 450 | 7.48 | 700 |
| Aug | 0.8 | 0.26 | 450 | 7.48 | 700 |
| Sept. | 0.6 | 0.26 | 450 | 7.48 | 543 |
| Oct. | 0.5 | 0.26 | 450 | 7.48 | 438 |
| Nov. | 0.3 | 0.26 | 450 | 7.48 | 263 |
| Dec. | 0.2 | 0.26 | 450 | 7.48 | 175 |
| Total | 6.6 | | | | 5796 |

Table 11 - Total Monthly Demand
Established Landscapes - All Locations
Average Winter Use=9 CCF Household Size = 3

| Month | Monthly Use CCF | Winter Ave CCF | Use CCF | Convert CCF Gallons | Use Gallons |
|---|---|---|---|---|---|
| Jan. | 7 | 9 | 0 | 748 | 0 |
| Feb. | 11 | 9 | 2 | 748 | 1496 |
| Mar. | 13 | 9 | 4 | 748 | 2992 |
| Apr. | 15 | 9 | 6 | 748 | 4488 |
| May | 18 | 9 | 9 | 748 | 6732 |
| Jun | 19 | 9 | 10 | 748 | 7480 |
| Jul | 18 | 9 | 9 | 748 | 6732 |
| Aug | 15 | 9 | 6 | 748 | 4488 |
| Sept. | 14 | 9 | 5 | 748 | 3740 |
| Oct. | 12 | 9 | 3 | 748 | 2244 |
| Nov. | 10 | 9 | 1 | 748 | 748 |
| Dec. | 9 | 9 | 0 | 748 | 0 |
| Total | 161 | | | | 41140 |

***METHOD 2*** **:**

This method of determining demand for established landscapes (Table 11) is based on actual water use. Use your monthly water bills to roughly estimate your landscape water demand. With this method we assume that during the months of December, January, and February most of the water is used indoors and that there is very little landscape watering. (If you irrigate your landscape more than occasionally during these months use *Method 1*.) The water company measures water in ccfs (100 cubic feet).To use this method average December, January, and February water use. In the example, the combined average winter monthly use is 9 ccf. Because we can assume that indoor use remains relatively stable throughout the year, you can subtract the winter average monthly use from each month's combined use and get a rough estimate of monthly landscape water use. To convert ccfs to gallons, multiply by 748.

Calculate storage/municipal water requirement (Table 12) — Use a "checkbook" method to determine the amount of irrigation water available from water harvesting and the amount of municipal water needed in case there is not enough stored rainwater. This example is based on the supply and demand numbers from Tables 5 and 9. For simplicity, the calculations are done on a monthly basis. However, in reality the amount of water available fluctuates on a daily basis. The "Storage" column is *cumulative* and refers to what is actually available in storage. This is calculated by adding together the previous month's storage and the previous month's yield. The current month's demand is then subtracted from this. If the amount is positive, the amount left over is added to that month's yield to provide for the following month's demand. If the amount of water available is negative, that is, if the demand is greater than the supply, municipal water would be required to supplement the storage supply. During the first year there will be a *deficit* of harvested water because the year begins with an empty storage container (Table 12). However, beginning with Year 2 the storage has built up and there will always be enough harvested water for this landscape unless a drought occurs. The reason for this is that the winter rainwater is not all used up in winter when evapotranspiration rates are low, so this water can be saved for the "leaner" summer months. You will notice in this example (Table 13) that each year the overall storage numbers will increase slightly because supply will likely exceed demand.

Each site presents its own set of supply and demand amounts. Some water harvesting systems may always provide enough harvested water, some may provide only part of the demand. Remember that the supply will fluctuate from year to year depending on the weather and also which month the rainfall occurs. Demand may increase when the weather is hotter than normal and will increase as the landscape ages and plant sizes increase. Demand is also high during the plant establishment period which requires more frequent irrigation for new landscapes.

To determine storage [3], find the highest number in the Store column under Year 2. This would be the maximum storage requirement. In this example, March will be the month with the most water — 2221 gallons. You will need approximately a 2300 gallon storage capacity to be self-sufficient using harvested water.

Table 12 - Monthly Storage/Municipal
Year 1

| Month | Yield Gallons | Demand Gallons | Cumulative torage Gallons | Municipal Use Gallons |
|---|---|---|---|---|
| Dec | | | 0 | |
| Jan. | 808 | 210 | 0 | 210 |
| Feb. | 539 | 270 | 537 | 0 |
| Mar. | 539 | 429 | 647 | 0 |
| Apr. | 202 | 595 | 591 | 0 |
| May | 135 | 718 | 75 | 0 |
| Jun | 0 | 779 | 0 | 569 |
| Jul | 808 | 691 | 0 | 691 |
| Aug | 1010 | 586 | 222 | 0 |
| Sept. | 337 | 534 | 698 | 0 |
| Oct. | 404 | 420 | 615 | 0 |
| Nov. | 404 | 263 | 756 | 0 |
| Dec. | 808 | 184 | 976 | 0 |
| Total | 5994 | 5680 | 976 | 1470 |

Table 13 - Monthly Storage/Municipal
Year 2

| Month | Yield Gallons | Demand Gallons | Cumulative torage Gallons | Municipal Use Gallons |
|---|---|---|---|---|
| Dec | 808 | | 976 | |
| Jan. | 808 | 210 | 1574 | 0 |
| Feb. | 539 | 270 | 2111 | 0 |
| Mar. | 539 | 429 | 2221 | 0 |
| Apr. | 202 | 595 | 2165 | 0 |
| May | 135 | 718 | 1649 | 0 |
| Jun | 0 | 779 | 1005 | 0 |
| Jul | 808 | 691 | 314 | 0 |
| Aug | 1010 | 586 | 536 | 0 |
| Sept. | 337 | 534 | 1012 | 0 |
| Oct. | 404 | 420 | 929 | 0 |
| Nov. | 404 | 263 | 1070 | 0 |
| Dec. | 808 | 184 | 1290 | 0 |
| Total | 5994 | 5680 | 1290 | 0 |

Table 14 - Monthly Storage/Municipal
Year 3

| Month | Yield Gallons | Demand Gallons | Cumulative torage Gallons | Municipal Use Gallons |
|---|---|---|---|---|
| Dec | 808 | | 1290 | |
| Jan. | 808 | 210 | 1888 | 0 |
| Feb. | 539 | 270 | 2425 | 0 |
| Mar. | 539 | 429 | 2535 | 0 |
| Apr. | 202 | 595 | 2479 | 0 |
| May | 135 | 718 | 1963 | 0 |
| Jun | 0 | 779 | 1319 | 0 |
| Jul | 808 | 691 | 628 | 0 |
| Aug | 1010 | 586 | 850 | 0 |
| Sept. | 337 | 534 | 1326 | 0 |
| Oct. | 404 | 420 | 1243 | 0 |
| Nov. | 404 | 263 | 1384 | 0 |
| Dec. | 808 | 184 | 1604 | 0 |
| Total | 5994 | 5680 | 1604 | 0 |

If there is not enough water harvested for landscape watering, there are several options:

- increase the catchment area,
- reduce the amount of landscaped area,
- reduce the plant density,
- replace the plants with lower water use plants,
- use mulch to reduce surface evaporation,
- use greywater,[4]
- use municipal water.

Final design and construction — Use your site analysis information and your potential supply and demand calculations to size and locate catchment areas. For new construction, if possible, size the catchment area to accommodate the maximum landscape water requirement. If you cannot do this you may want to reduce plant water demand by either lowering planting density or selecting lower water use plants. Roofs or shade structures can be designed or retrofitted to maximize the size of the catchment area. If you are planning a new landscape, create a landscape that can live on the amount of water harvested from the existing roof catchment area. This can be accomplished by careful plant selection and control of the number of plants used. For the most efficient use of the harvested water, group plants with similar water requirements together. Remember that new plantings, even native plants, require special care and will need supplemental irrigation during the establishment period which can range between one and three years. (Use the supply and demand calculations to determine this.) Use gutters and downspouts to convey the water from the roof to the storage area. Consult Table 15 and 16 for tips on selecting and installing gutters and downspouts.

Table - 15 Guidelines
Gutters

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- Select gutters that are 5 inches wide.
- Select galvanized steel (26 gauge minimum) or aluminum (.025 inch minimum) gutters.
- Slope gutters 1/16" per 1' of gutter, to enhance flow.
- Use an expansion joint at the connection, if a straight run of gutter exceeds 40 feet.
- Keep the front of the gutter one-half inch lower than the back.
- Provide gutter hangers every 3 feet.
- Do not exceed 45 degree angle bends in horizontal pipe runs.
- Select elbows in 45, 60, 75, or 90 degree sizes

Table - 16 Guidelines
Downspouts

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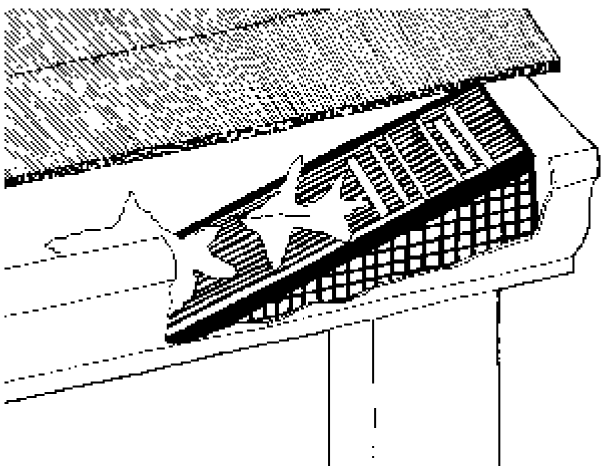
- Space downspouts a minimum of 20 feet apart, a maximum of 50 feet apart.
- Provide 1 square inch of downspout area, for every 100 square feet of roof area.
- Select downspouts in different configurations -- square, round, and corrugated round, depending on your needs.
- Use 4-inch diameter Schedule 40 PVC to convey water to the storage container or filter.



Size your storage container(s) large enough to hold your calculated supply. Provide for distribution to all planted areas. Water collected from any catchment area can be distributed to any landscaped area; however, to save effort and money, locate storage close to plants needing water and higher than the planted area to take advantage of gravity flow. Pipes (Schedule 40), hoses, channels, and drip systems can distribute water where it is needed. If you do not have gravity flow or if you are distributing through a drip system you will need to use a small 1/2 HP pump to move the water through the lines. Select drip irrigation system filters with 200 mesh screens. The screen should be cleaned regularly

## Conclusion

Historically, people relied on harvested rain water to provide water for drinking, landscape watering, and for agricultural uses. Once urban areas started to develop, large, centralized water supply systems replaced the need to harvest water. More recently, people have become reacquainted with water harvesting, using it to provide water for home gardens, parking lot trees, multi-housing lawns, and commercial landscapes featuring desert-adapted plants.

Homes, schools, parks, parking lots, apartment complexes, and commercial facilities all provide sites where rainfall can be harvested. Many methods are available to harvest rain water for landscape use. Some of them inexpensive and easy to construct, for example, storing water in a barrel for later use or constructing small berms and drainages to direct water to a row of trees. All you need to get started is rainfall and plants that require irrigation. Even the most simple methods provide benefits. The water customer benefits from lower bills and the community achieves long-term benefits which reduce groundwater use and promote soil conservation.