Chapter 8: Water Conveyance

Conveyance systems move roof water from precipitation collection surfaces to cisterns. In a roof-reliant landscape, a typical conveyance system will perform five functions:

1. **Concentration**
2. **Vertical drop**
3. **Horizontal run**
4. **Filtration**
5. **Delivery**

Concentration

Figure 8-1: Gutters collect water from a pitched metal roof.

Conveyance begins where roof water is first concentrated in specific places, such as in a roof gutter, a canale or a roof drain. All concentration points require regular monitoring and occasional maintenance.

Gutters, which are almost always associated with pitched roofs, are open channels, or troughs, that direct roof water along roof lines usually toward downspouts. Typically, gutters are made of either aluminum or galvanized steel; custom-made copper and stainless steel gutters are also available at a higher cost. A common size for residential applications is a five-inch-wide gutter that drops a minimum of one inch for every 16 feet of roof line (1/16 inch per foot of slope).[11] A gutter with more slope can handle a greater volume of water. Wider gutters are also available, and these are recommended for use in many steep roof and commercial applications.

[11] Source: Uniform Plumbing Code (UPC) provided by Construction Industries Division (CID), of the NM Regulation and Licensing Dept.

Since gutters can require maintenance, be prepared to climb a ladder to clean out debris from time to time. If your building is situated next to one or more mature trees, you will likely have to remember to clean your gutters every fall. If you do not have mature trees in your current landscape, you may not have to clean your gutters for years, although annual monitoring would still be wise.

A canale is a short, narrow trough that protrudes through the parapet of a flat roof and directs water onto the ground below. A typical canale, according to the City of Santa Fe building code, should not be responsible for draining more than 400 square feet of roof. Canales on the north sides of roofs (especially northeast corners) should be avoided because the parapet can shade them during the shortest days of the year, which can cause ice blockage and freeze-thaw damage.

Before water harvesting became popular, an architect (or builder) could place canales virtually anywhere (except over a walkway or patio) as long as the precipitation never puddled on the roof. However, if you plan to include roof-reliant landscaping in your new construction project, it pays to let your architect and/or builders know this so they can most efficiently place the canales. It is much easier and less expensive to locate canales near your cistern instead of on the opposite side of your house.

Roof drains are sometimes used on flat-roofed buildings. These drains are typically connected to

Figure 8-2: Photo of a roof drain. Note the canale opening, which is required for secondary drainage.

pipes fitted within the wall of the structure. Roof drains, as shown in Figure 8-2, can work well if properly designed, installed and maintained. (For more information, see the "In-Wall Drainpipes" section later in this chapter.)

However, expensive mistakes can result if any one of the three links in the designer-builder-owner chain is weak. If the designer underestimates the size of the drain, the roof may not be able to withstand the inevitable backup of water. Similarly, if the builder makes a mistake during construction, leaks can occur inside the walls of the building, and these can be difficult to detect. Additional problems with roof drains can occur whenever regular monitoring, cleaning and maintenance of the drain are neglected.

Vertical Drop

Figure 8-3: Photo of a downspout. Downspouts funnel water from gutters along a vertical drop.

In most water harvesting systems, there is at least one place in the conveyance system with a sharp vertical drop. From pitched roofs, this is typically a downspout. From flat roofs, this is usually the arc of projected precipitation off of the edge of a canale. Harvesting water that free-falls from a canale imposes a need to efficiently direct the runoff. This manual offers three methods to deal with the vertical-drop issues associated with canales: funnel drains, downspout-canale connections and in-wall drainpipes.

Most roofs have more than one vertical-drop point. If, however, you can limit the number of these points in your design, you often can save money in the installation process. This of course assumes that your roof can handle the limited number of vertical-drop points during large storm events.

Downspouts

Downspouts are the pipes that direct water vertically from gutters toward cisterns. It is recommended that your downspouts be made of the same material as your gutters and that you affix them to your structure, as in Figure 8-3. Connections between gutters and downspouts should be monitored periodically for leaks and blockages.

Downspouts are highly efficient at conveying water along a vertical drop. They are also very precise at directing runoff, so the water they convey is less expensive to control than the water associated with canale drains (see next section). Aluminum, galvanized steel and vinyl downspouts normally come in two-inch by three-inch or three-inch by four-inch rectilinear sizes, but downspouts can also be cylindrical pipes made of polyvinyl chloride (PVC), steel and corrugated metal.

For the do-it-yourselfer, vinyl is a good downspout choice since it comes in manageable lengths with an assortment of parts that can be fit together quickly and easily. Aluminum gutters and downspouts are economical and relatively easy to install. Wood gutters are used primarily in special applications, such as historic preservation, due to their extra expense and fire-hazard potential.

Funnel Drains

A funnel drain catches water that falls from a canale. It does this by directing roof water through a rubber or vinyl liner (such as EPDM pond liner, which is a highly flexible synthetic rubber material that is commonly used to line decorative ponds) into a below-grade box drain. A top dressing of gravel or river rock covers the liner to protect it from degrading in the intense New Mexico sun and hides the drain from view. Most importantly, the gravel prevents mulch, soil and other particulate from being conveyed toward your cistern. This gravel becomes the first step in the filtration of the captured water.

Figure 8-4. An above ground demonstration of how a funnel drain works. Materials, shapes and proportions of funnel drains can vary.

When determining the location for a funnel drain, take into account the fact that roof water can arc far away from a structure (especially during intense storm events). Other times—at the beginning and the end of storm events, during light storms and when snow melts off of a roof—significant quantities of roof water drip straight down from the canale along what is called the drip line. In storm events that are associated with gusty winds, the collected roof water may be blown against your building, away from your building, or sideways, out of range of your funnel drain.

To combat the variable nature of the trajectory of the water, funnel drains are located in the ground at least four inches below grade and about 12 inches out from the drip line of the canale. The edge of the liner should start against the house and protrude at least three feet from the drip line, the point directly below a canale where it literally drips tiny amounts of water. Different liner materials come in different widths; standard five-foot-wide liners are typically sufficient for one-story structures, while a minimum of a six-foot-wide funnel should be used for two-story structures. Make sure that your funnel drain is pitched in such a way that water does not settle against your building, particularly in the case of adobe structures.

How to Install a Funnel Drain

After determining that your funnel drain is properly sited so that it will capture the optimal amount of water, you can install it by completing the following steps:

1. Double-check to make sure that there are no utility lines in the vicinity of your trenches. (Call 1-800-321-2537 before you dig!)
2. Place a piece of liner where you intend to install the drain.
3. Draw a line with a pick or shovel around the edge of the liner.
4. Remove the liner.
5. Determine the level of your existing grade.
6. Starting from the lines you drew, gently excavate a shallow hole that gets gradually deeper until the hole is four inches deeper in the center.
7. In the middle (and at the bottom) of this hole, dig another hole that is 12 inches by 12 inches by 12 inches. The total depth of this hole below grade will be 16 inches.
8. Dig a trench for the horizontal run pipe in the direction that you expect the pipe to go. This trench should be at a depth of 12 inches from the original grade.
9. Place some pipe in the trench and a drain box (available at landscape supply stores and home centers) in the second hole that you dug.
10. Connect the pipe to the drain box.
11. Backfill and tamp over the pipe and around the drain box.
12. Place the liner in the hole and cut out an 11-inch by 11-inch square piece of liner directly over the drain box.
13. Remove the grate on top of the drain box and then squeeze the grate back onto the box in a manner that locks the liner in place over the box.
14. Using standard landscape staples (purchased at your local garden/hardware center), tack down the liner with staples at 18-inch centers.
15. Cover the grate and the liner with gravel, round river rocks, smooth pebbles, etc.

See Figure 8-4 for a depiction of a funnel drain. This aboveground demonstration shows how a funnel drain can collect and filter water. The filtered water exits from the bottom of the drain.

Important Tips
Drainage mistakes close to the foundation of a wall should be avoided no matter what the cost. When installing your funnel drains:

- Be sure water flows away from buildings. When water collects against a wall, it can create expensive structural damage and mold problems.
- Do not cut corners by eliminating the liner. Without it, you will harvest much less water, and the roof water that you do not harvest may soak into the soil at the foundation of your home.
- Ensure that the connections between parts and materials are tight and secure. Although conveyance piping does not technically move water under pressure, the force under a canale can be substantial.

Downspout-Canale Connections

Figure 8-5: A toilet flange can connect a canale to a downspout.

For many people, all of the work described in the previous section about constructing a funnel drain may seem like too much labor and too much expense for a system that cannot capture all of the rainwater during high winds and/or large storm events. An alternative to a funnel drain is directly connecting downspouts to the bottom of canales.

There are a number of ways to direct roof water from a canale toward a storage tank. One common way, shown in Figure 8-5, is to install a toilet flange in the bottom of the canale, seal the flange, connect the flange to a downspout and partially dam up the outer edge of the canale. (Shown in Figure 8-6). The partial dam helps direct

Figure 8-6: Partial dams installed on both sides of a drain directs the flow of rainwater.

water into the drain at the top of the downspout. In the event that the drain gets clogged with debris, however, water can spill over the dam and flow off the canale to the ground below. This reduces the chance of creating a potentially damaging standing pool of water on the roof.

There are other potential risks in connecting a downspout to a canale. A weak connection between canale and downspout can leak into the roof and walls of your structure. If undetected or neglected, significant structural and/or mold damage can occur. In addition, ice, especially on the north side of a structure, can prevent snowmelt from running off of buildings. Standing water and heavy icicles, along with the freeze-thaw conditions associated with winter weather, can cause significant damage either to a roof or its associated walls.

Another common method of directing roof water from a canale, presented in Figure 8-7, is to use a rain chain to direct water downward.

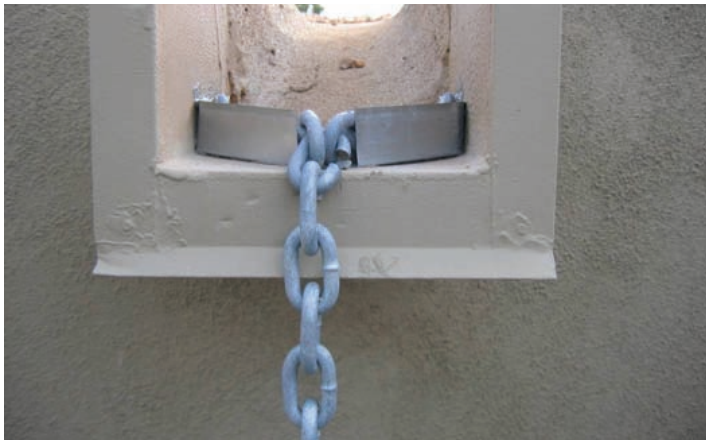

Figure 8-7: A rain chain is a simple but effective way to direct water downward from a canale.

In-Wall Drainpipes

Some downspouts, especially those associated with roof drains, are built into the walls of structures and are called "in-wall" drainpipes. Such systems are often installed for aesthetic reasons to keep the downspouts out of sight.

In-wall drainpipes are not only more difficult to fix, but also problems are more difficult to detect because they are so well hidden. Even small, undetected leaks can cause major damage to a wall in a relatively short time. In residential applications, these in-wall systems are relatively uncommon. However, in commercial applications, especially for tall buildings with flat roofs, roof drains associated with in-wall drainpipes are currently a typical method for controlling roof-water runoff at the vertical-drop point.

Horizontal Run

Figure 8-8: Conveyance pipes being installed, which will carry water to a cistern.

Almost all cistern systems require conveyance pipes that run perpendicular to the system's vertical-drop line. To maintain positive drainage toward the cistern, however, these pipes only appear to be horizontal and, in fact, must not be level. The horizontal runs should drop a minimum of one-quarter inch per linear foot until they connect with your storage area.

There are two kinds of horizontal runs: aboveground pipes and underground pipes. Aboveground runs are generally associated with aboveground and partially buried cisterns. Underground runs are typically used with underground cisterns.

Horizontal runs should be installed at least three feet away from any building or wall. Assuming sufficient depths and compacted soil between lines, your trenches for these conveyance runs can also be used for other conduits such as drip irrigation tubing and pressurized distribution pipes, as well as low-volt and high-volt electric lines. (Check local building codes to verify required burial depths.)

An important job for every cistern system designer is the proper sizing of the diameter of horizontal run lines.[12] Pipes that are too small will not be able to harvest the entire system's potential and will cause flooding wherever the flow is constricted by an excess volume of water. Pipes that are too large will cost more money than is necessary for both the materials and labor.

Before installing the pipes, it is critical to determine that there are no buried utilities anywhere in the vicinity of your proposed trenches and that the pipes will not be placed in the way of any other future landscape feature. You are required to call New Mexico One Call (also known as the toll-free Buried Cable Locating Assistance Hotline) at 1-800-321-2537 or New Mexico One Call at 811. Information is also available online at www.nmonecall.org to locate existing utilities.

To install an underground horizontal run, complete the following steps:

- Double-check to make sure that there are no utility lines in the vicinity of your trenches.
- Excavate along the lines.
- Lay pipe and fittings with a 1/4" drop per linear foot. Use sanitary tees and other fittings made for drainage. (SDR35 DWV fittings are commonly used in outdoor settings.)
- Connect horizontal run(s) to the vertical-drop point(s).
- Connect horizontal run(s) to the chosen method of prefiltration.
- Connect the final horizontal run to the cistern at the delivery point.

[12] See Appendix 7 (Pipe Sizes and Drainage Capacities). NOTE: Unless you are using an aboveground cistern, you will need underground conveyance piping. Often, four-inch-diameter pipe is sufficient to convey peak flows to the cistern.

- Install cleanouts at every 135-degree or greater bend and at the end of continuous runs.
- Make sure there is a cleanout for every run of more than 100 feet of conveyance pipe.
- Take pictures of the trenches (which include aboveground reference points so you can find the pipes once they are buried). Keep these photos in a file for future reference.
- Backfill and tamp trenches.

Conveyance pipes are typically PVC or ABS plastic pipes. PVC is the most expensive, but it is usually the most durable. ABS, the least expensive horizontal pipe material, is made of a corrugated, flexible plastic material that bends easily around obstacles. This makes the pipe relatively simple to work with. However, ABS is more susceptible to damage than other conveyance materials (it can be punctured with a shovel or a spade), and it has more creases that can collect sediment. Horizontal run piping does not have to be buried below the frost line as pressurized piping does. Conveyance pipes can be placed under the surface of the soil, covered with at least six inches of backfill material. However, conveyance piping along north-facing slopes is prone to freezing, so it is best to bury these runs below the frost line at a minimum of 12 inches deep.

Glue and/or tightly fit all of the pipe connections and install cleanouts for any horizontal runs of more than 100 linear feet. Conveyance pipes that run parallel to the foundation of a structure should be installed at least three feet away from the foundation.

Filtration

The conveyance system presents an easy and effective opportunity to filter the roof water being delivered to your cistern. You will have other chances to filter your water before distributing it to your plants—for example, in your cistern, in your pump house and during distribution through a drip irrigation system—but you should not neglect this first valuable opportunity. Conveyance, or "inlet," filtration is your best defense against preventing particulate from getting into your tank and against the growth of algae inside your tank, both of which can clog drip irrigation systems and cause pumps to burn out.

Note that the kind of filtration described here does not remove toxins, viruses or bacteria. It is possible to eliminate these and other contaminants during the water-distribution process, but this type of filtration is not necessary for landscape irrigation purposes.

The need for precistern filtration increases as the number and size of mature trees around your roof grows. Branches, leaf matter, bird and animal droppings and other natural debris associated with trees can all pose slightly different problems later on if ignored and not effectively filtered out of the system.

The following conveyance filtration systems are neither "high tech" nor particularly expensive. However, replacing a number of drip irrigation emitters because of improperly filtered water can be a frustrating and costly experience. It is recommended, whenever practical, to install precistern filters and a standard particle filter between your system's pump and any irrigation valves. When it comes to filtration, a redundant system means a clean system.

Debris Prevention

For roof-reliant landscapers, the first level of defense against allowing particulate into a cistern is a leaf screen. (Leaf screens are also known as gutter guards, debris traps and leaf catchers.) Typically, leaf screens are placed in gutters at the entrance to a downspout, although some types are designed to be placed at the bottom of a downspout. These devices allow roof water into the conveyance system while preventing some of the larger pieces of debris from being conveyed. Although leaf screens are effective and inexpensive methods of filtration, they are typically not considered adequate by themselves. (See Figure 8-9.)

Even though flat roofs tend to collect more debris than pitched roofs, leaf screens are not recommended for canales because as soon as a

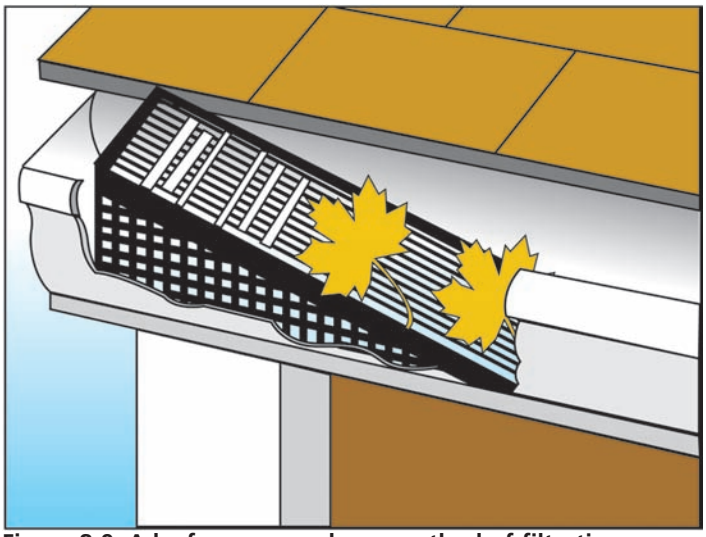

Figure 8-9: A leaf screen used as a method of filtration

small amount of debris collects behind such a screen it begins to prevent roof drainage, which could ultimately cause the roof to leak. Sometimes a layer of gravel is placed in a canale to act as a simple debris filter. Most roof-reliant landscapers working with canales will install funnel drains, which also act as reasonably effective leaf screens.

Small-Particle Removal

There are a number of simple strategies for removing small particles of debris from the roof water entering your cistern. These can be divided into two categories: one type uses some form of filtration, and the other uses a method called the "first flush." Neither type will prevent all particulate from entering your cistern, but each should yield a significant increase in your water quality.

Filters for Small Particulate

Inlet filter. An inlet filter is any of a number of various types of barrels, containing one or more filters, through which roof water is conveyed to a cistern. Inlet filters can be relatively self-cleaning when positioned at a proper angle and if they are sufficiently sized for the amount of water and particulate that will pass through. Many of these and similar products are available online at a reasonable cost.

Sediment trap. For our purposes, a sediment trap is similar to an inlet filter in that it traps sediment.

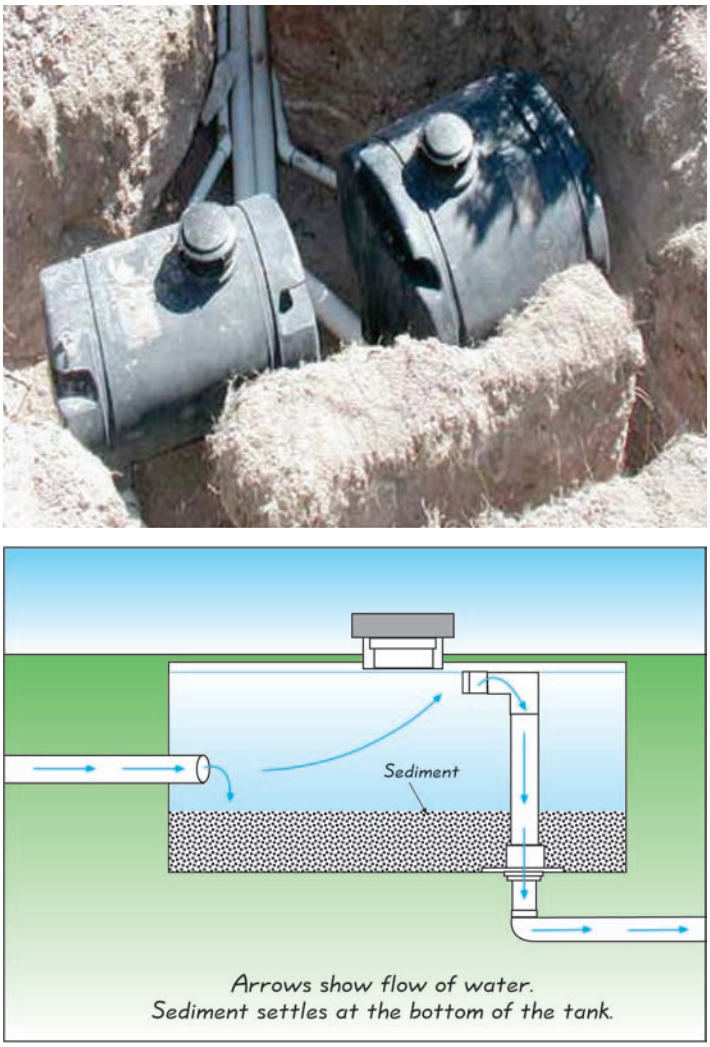

Figure 8-10: Example of a sediment trap. The top photo shows the installation of two traps; the illustration depicts how water flows through a trap.

Unfortunately, much of the water harvesting literature uses terms like sand filters, settling tanks and sediment traps interchangeably. One version of a sediment trap is shown in Figure 8-10.

Settling tank. Like the first-flush devices described in the next section, a settling tank is not actually a filter but serves the same purpose as the particle-filtration devices described above, so they are included in the category of small-particle filtration devices. The basic operation of a settling tank is quite simple: water pours into the tank, debris settles to the bottom and cleaner water flows out the top toward the cistern.

First-Flush Diverters

First-flush diverters are technically not filters, but they perform the same function as any of the devices defined above. First-flush devices cause the initial (dirtier) amount of collected water during a storm event to be directed away from the cistern. Two of the most common types of first-flush diverters are described below.

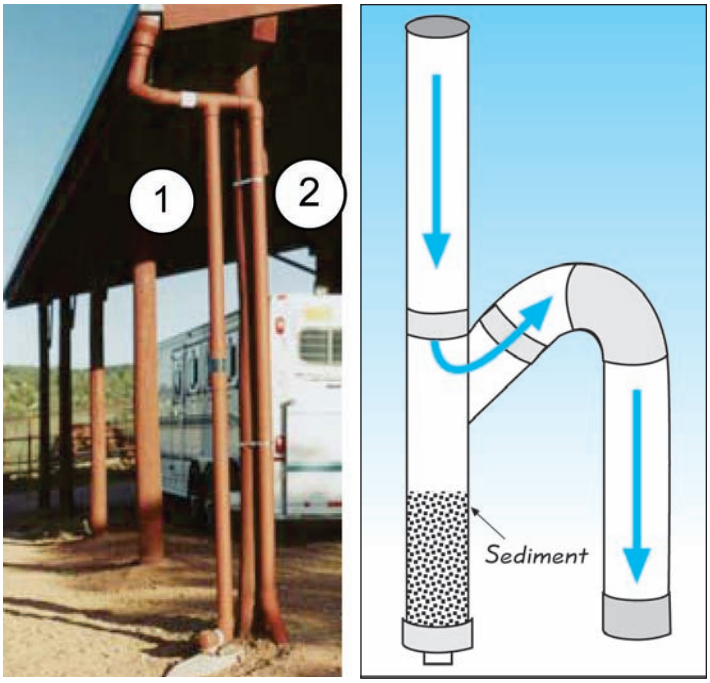

Figure 8-11. Roof water is initially conveyed from the downspout into a pipe (#1) that dead-ends (preferably near a planting bed). After that pipe fills, the cleaner water flows through pipe #2 to a cistern. The cutaway illustration shows how sediment settles in the first pipe.

Dead-end pipe. The most common type is the dead-end pipe. Associated only with downspouts and not canales, these diverters direct the first quantity of water that comes off a roof into a pipe that dead-ends at a removable cap. The remaining roof water, which is always much cleaner than the "first flush," runs straight over the dead-ended water and directly into the cistern via the remainder of the conveyance system.

First flushes serve two purposes: the initial flush of dissolved and suspended solids is diverted and heavier sediments are continuously trapped. After a storm, the cap is removed and the first flush of water and debris drains away from the house (and optimally, into a nearby garden bed). This allows for the debris and particulate matter that was on the roof to be diverted away from the cistern and toward an appropriate place in the landscape. After the dead-end pipe has fully drained, you simply screw the cap back on. If a 1/8-inch hole is drilled in the cap at a "3 o'clock" or "9 o'clock" position, water in the dead-end pipe will slowly drain by itself. Debris in the pipe will still need to be cleaned out periodically.

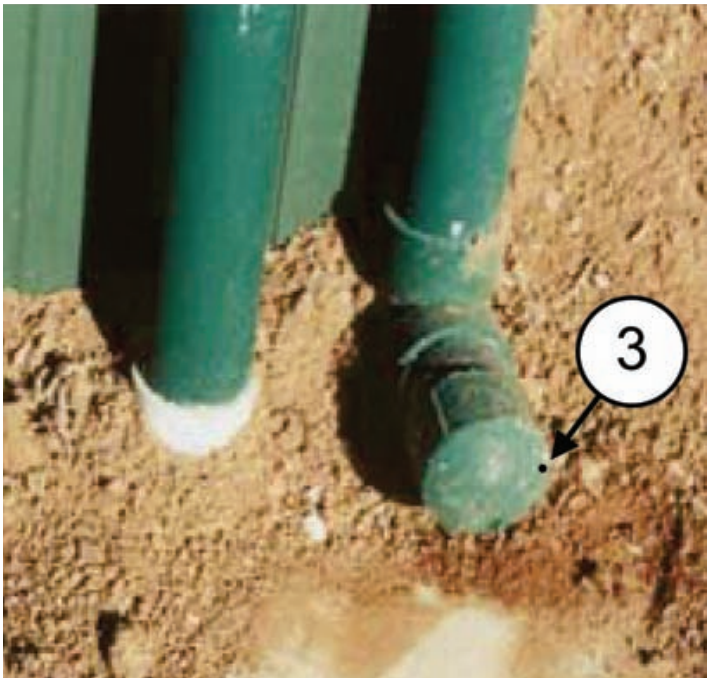

Figure 8-12. The cap on the first-flush pipe has a small hole drilled in the cap. Positioning the hole at the "3 o'clock" position enables water to slowly drain from the pipe while leaving sediment behind. The cap can be unscrewed for cleaning out the sediment.

Pulley pourer. A less common form of diverter, the pulley pourer uses a bucket, a pulley and a counterweight to pour first-flush water into neighboring garden beds. An empty bucket is set under a gutter or downspout with a counterweight equal to the weight of about two-thirds of a full bucket of water. When water pours off the canale, it fills the bucket to the point at which it dumps the first flush into a thirsty garden bed (or some other appropriate place). The system is manually set up between storms so that the counterweight keeps the bucket in a ready position.

Delivery

The last step in the water conveyance process is delivery to your cistern at a supply point (also known as the delivery point), where conveyed water reaches a cistern. Most conveyance systems require only one supply point, but multiple supply points are sometimes cost effective. Instead of cutting additional holes in a cistern for more than one supply point, it is recommended to join the conveyance lines together near the cistern so that a single delivery point can be used.

Landscape design can both influence and be influenced by cistern system design. If you are planning a pitched-roof house with gutters and downspouts, your landscape design should call for some plants that will make good use of your first flush in the immediate vicinity of all of your dead-end pipes. Similarly, if you are planning sediment traps off a flat roof, an effective landscape design might include a convenient place to clean the filter, mesh, sand or gravel.

Figure 8-13: An assortment of water cisterns, clockwise from top left: a metal tank, two 54-gallon rainbarrels stacked on each other, two partially buried tanks, and an assortment of colorfully painted tanks.