Residential Rainwater Collection

by Chris Maxwell-Gaines, P.E.

Water for household use is within easy reach, but you have to filter and disinfect it first

I developed an interest in rainwater collection during a two-year Peace Corps stint in Suriname, a small country north of Brazil, because rainwater was the main source of drinking water in the village where I lived. After moving back to Texas, I worked for an engineering firm, and then started a company that designs and installs rainwater-collection systems.

Most of our work is in and around Austin, a hotbed of green building in a part of the state that is frequently short of water. Green-building point systems — such as LEED — grant credit for collecting rainwater, and in a growing number of municipalities rainwater collection is actually required by law. In Tucson, Ariz., and Santa Fe County, N.M., for example, rainwater collection is mandatory on new commercial buildings and on new homes above a certain size.

My company installs both potable and nonpotable systems. Nonpotable systems (**see Figure 1**) are most often used to supply irrigation water in areas where municipal water is available; potable systems provide drinking-quality domestic water and are typically installed in place of a drilled well. Both contain the same basic components: a collecting surface (usually a roof), gutters, downspouts, inlet filters, first-flush diverters, and one or more storage tanks. Most systems also include a pump of some sort. In addition, potable systems (**Figure 2, page 3**) provide for water filtration and disinfection.

Sizing Rules of Thumb

In our area, potable systems can legally be installed only in buildings that are not connected to municipal water. That requirement stems from concern by regulators that improperly purified rainwater could be drawn into the municipal system and contaminate it. Although safeguards like backflow preventers and separate color-coded pipes for rainwater can prevent that, the plumbing codes have not caught up with technology in this area.

As a result, the potable systems we install — primarily on rural or suburban lots with plenty of room — have between 10,000 and 40,000 gallons of storage. That's a lot of water, but a large amount is necessary because the homeowner doesn't have the luxury of switching back to the municipal water supply if the tank runs dry. The idea is to begin the summer with the tanks full and make it through to the rainy winter months without ever hitting empty. In an emergency, the homeowner can have a water-hauling company send a 2,000-gallon tanker truck to the site — which costs about $200 around here — but with a properly designed system, such deliveries may never be necessary.

Calculating storage needs. A quick rule of thumb for our area is 5,000 gallons of storage per occupant. That's enough to provide 50 to 55 gallons per day per person during June, July, and August — the driest months of the year. People who are serious about conserving can get by on 30 gallons per person per day.

The more precise way to size systems is by performing a water balance calculation, which compares the expected monthly inflows and outflows to estimate

Dry-Pipe System for Nonpotable Water

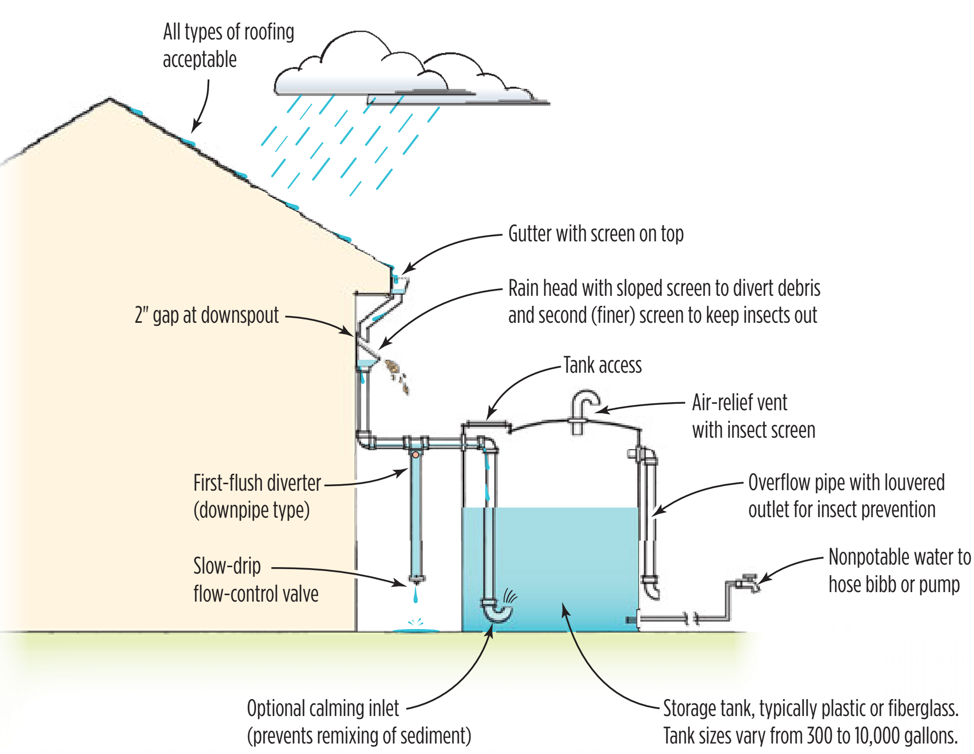

Figure 1. In a dry-pipe system, the tank is placed close to the house and the rainwater flows straight down and in through the tank inlet. Shown in the photo above is a custom steel tank with a rain head and a tall diverter pipe.

Wet-Pipe System to Remote Tank for Potable Water

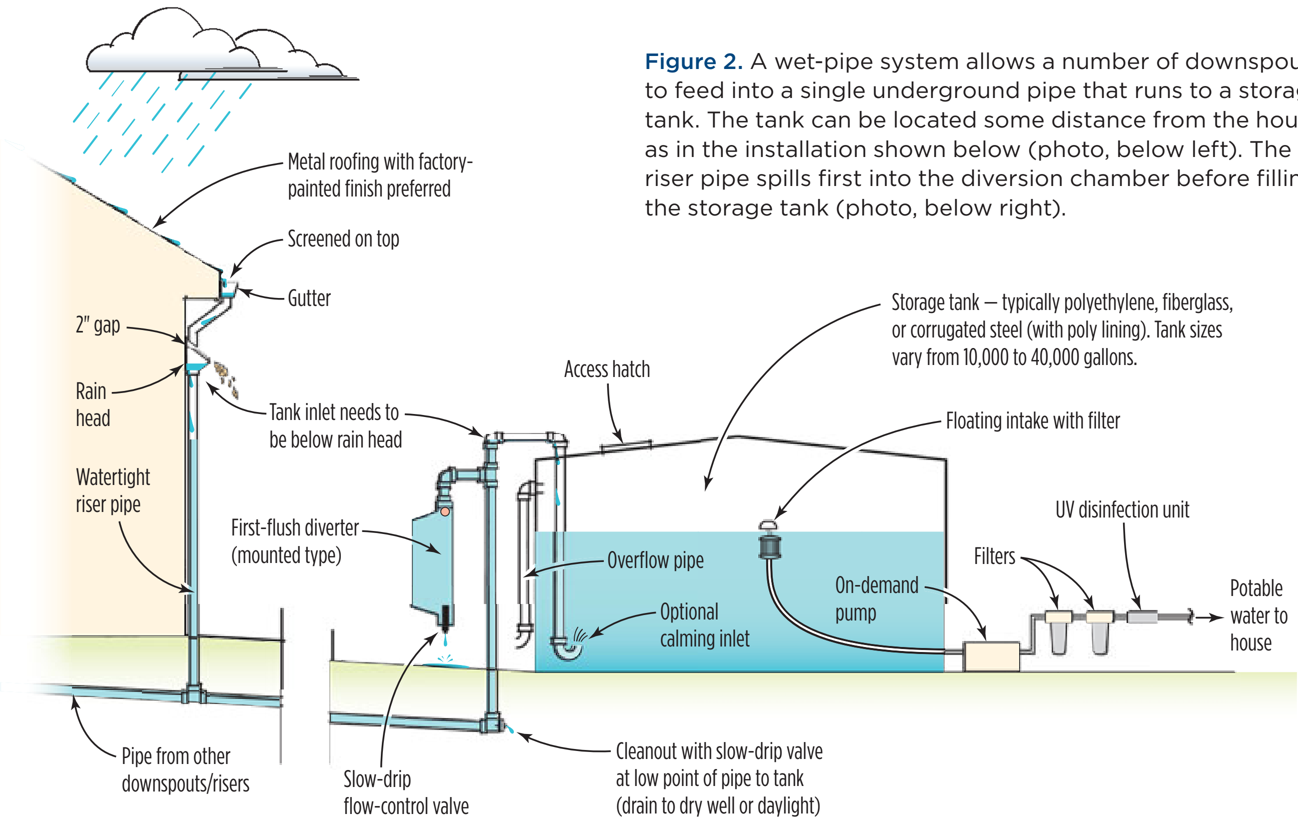

Figure 2. A wet-pipe system allows a number of downspouts to feed into a single underground pipe that runs to a storage tank. The tank can be located some distance from the house, as in the installation shown below (photo, below left). The riser pipe spills first into the diversion chamber before filling the storage tank (photo, below right).

how much water will be in the tank during any given time of year. The inflow figure is determined by the size of the collecting surface and the amount of rainfall, minus an allowance for water lost to absorption and roof cleaning.

For example, weather records tell us that Austin averages 4.78 inches of rain in May. Each inch of rain deposits 0.62 gallon of water on a one-square-foot horizontal area, so a 2,000-square-foot house that collects 85 percent of the water that lands on its roof — a conservative rule of thumb — can be expected to collect 5,038 gallons in the course of the month (2,000 square feet x 4.78 inches per month x 0.62 inch per square foot x .85).

When we design a system, we use an adapted spreadsheet from the Texas Rainwater Development Board, which combines the average local monthly rainfall with various combinations of consumption, roof area, and storage to provide a water-balance estimate. The spreadsheet can be adapted to other areas by altering the rainfall data and is available as a free download at www.twdb.state.tx.us/iwt/rainwater/resources.asp.

Sizing nonpotable systems. We install nonpotable collection for homeowners who are on municipal water but prefer to irrigate with rainwater, either to reduce their environmental footprint or because the utility restricts irrigation usage. When we first meet with them, new customers usually tell us they want a system large enough to cover all of their irrigation needs. In most cases, though, that's not an option. Few city lots have space for more than 2,000 to 5,000 gallons of aboveground storage, which is not enough to cover irrigation during the driest months of the year. While it's possible to bury larger tanks, the cost is often prohibitive. Homeowners with very small yards and drought-tolerant plantings can sometimes get by with stored rainwater alone, but most others will have to supplement their irrigation with municipal water.

Fortunately, size is not critical on nonpotable systems, because the owner can switch to municipal water if the tank runs dry. Nonpotable systems are also simpler and cheaper to install; any roof surface will do as a collector and there's no need to filter or disinfect the stored water. And as long as none of the pipes go into the house, nonpotable systems are exempt from the plumbing code. Just the same, it's a good idea to check with the local water utility, because some municipalities require a backflow preventer at the meter whenever rainwater collection is present on the site, even if it isn't used for domestic water.

Figure 3. Solid debris such as leaves and twigs are kept out of the system by screening the tops of the gutters (above) and installing a rain head (right) in the downspout. The sloped screen of the rain head diverts debris into the yard while allowing water to pass through. A second, finer screen underneath prevents mosquitoes and other insects from getting into the tank.

Collection and Prefiltration

Rainwater is most efficiently collected from a smooth, impervious surface that drains quickly. Our first choice for collecting potable water is a standing-seam galvanized steel or aluminum roof with a factory-applied finish, such as Kynar. Copper and raw galvanized steel should not be used in potable systems because they can release heavy metals into the water. Clay and concrete tile roofs are acceptable for potable systems, but less desirable than metal because they tend to hold dirt and absorb water. Asphalt shingles should not be used in potable systems, because they can leach hydrocarbons.

Any common roofing material is okay for collecting nonpotable water.

The water that comes off the roof receives an initial filtering to keep things like leaves, acorns, and the occasional dead bird from getting into the system. This can be done either by screening the tops of the gutters or by installing a rain head in the downspout. We like the Leaf Eater rain head, which we get from an Australian company called Rain Harvesting (rainharvesting.com/content/default.asp). The Rain Eater incorporates a sloped screen that ejects debris into the yard; a finer screen below prevents mosquitoes and other insects from entering the tank (**Figure 3**).

Cleaning the roof. The first flush of rainwater that flows off a roof after a dry spell carries a heavy load of dissolved solids from dirt and bird droppings. To keep this contaminated water out of the tank, we divert it to the ground. (Not until the roof has been washed clean does the system begin saving the water it collects.) This requires a device called a first-flush diverter, which is installed between the gutters and tank. It consists of a plumbing tee with a large capped pipe, called a diversion chamber, at the bottom. When dirty water flowing from the roof has filled the chamber, a ball float seals it off from the tee and allows the clean water that comes after to flow directly to the tank

First-Flush Diverters

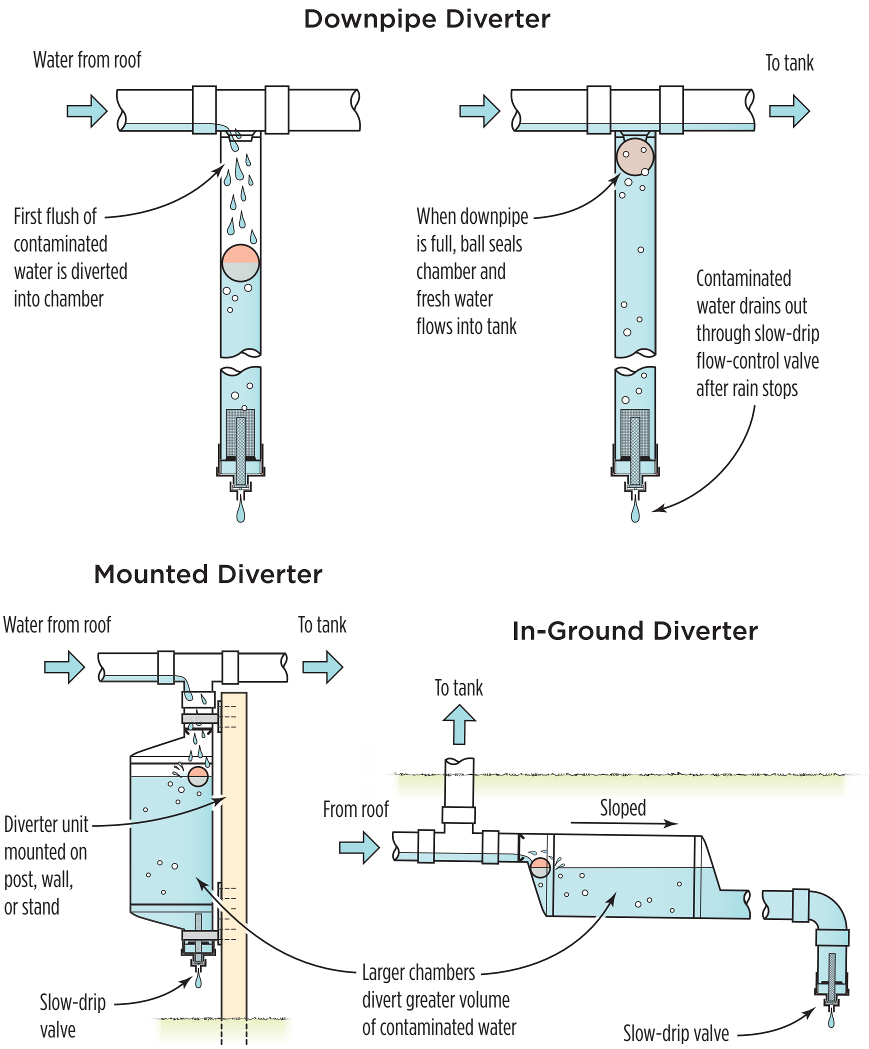

Figure 4. A first-flush diverter keeps dissolved dirt and bird droppings from getting into the tank. It does this by discarding the first water that flows off the roof in a storm, diverting it to a chamber that slowly drains onto the ground. The diverter kit includes everything except the pipe for the diversion chamber, which is sized by the installer based on roof area. Shown here are a small diverter pipe for a single-tank dry-pipe system (photo, top right) and a large diverter chamber on a wet-pipe potable system (photo, right).

(**Figure 4**). A slow-drip flow-control valve in the bottom of the diversion chamber slowly releases the diverted water onto the ground, leaving the system ready for the next rainfall. The flow-control valve comes with a set of interchangeable bushings that can provide different drip rates; typically, the diverter will empty out within a day after a rain event. We get our flush diverters from Rain Harvesting, which offers kits for both large and small diverters, as well as a diverter designed for use underground.

Diverter sizing. In a properly designed system, the volume of water diverted is proportional to the roof area — it's up to the installer to fabricate a diversion chamber of adequate capacity. But this isn't a particularly exact science. I've seen a number of academic studies on the subject, each of which came up with a different diversion rate. In potable systems, we rely on a rule of thumb that calls for diverting between .05 and 0.1 gallon per square foot of roof area, or 100 to 200 gallons for a 2,000-square-foot house.

Like most rules of thumb, this one is

Figure 5. Tucked away behind the garage, these two plastic tanks (A) provide 6,000 gallons of storage. Custom-fabricated steel tanks (B) are more attractive, so there is less need to hide them away. Some tanks are designed to fit an available space — under a deck, say, or in a narrow side yard (C). Because there was no place to hide it in an urban lot, this plastic tank (D) was clad with cedar and given a metal top. Some tanks (E) are designed to be buried and thus kept out of sight.

somewhat flexible. If the house is next to a gravel road and there are trees and birds overhead, for example, we lean toward diverting more. While they're an essential part of a potable water system, flush diverters are sometimes omitted from nonpotable systems because they reduce the amount of water collected.

Piping and Storage Tanks

The simplest way to channel water from the downspouts to a storage tank is with a dry-pipe system, in which the collected water is piped into an opening in the top of a storage tank. With this method, the pipes contain no water unless it's actually raining. Dry-pipe systems are simple to set up but have the disadvantage of requiring a separate tank for each downspout.

Wet-pipe systems, on the other hand, make it possible to use a single large remotely located tank. A series of individual PVC downspout risers lead to a common underground fill pipe, which emerges next to the tank and enters it near the top. The underground fill pipe works something like a P-trap, filling with collected rainwater until it overflows into the tank.

For a wet-pipe system to work properly, the tank must be sited so that its inlet lies below the top of the lowest riser. To prevent the water trapped in the buried fill pipe from becoming stagnant, we install a slow-drip flow-control valve in the low point of the pipe to the tank, which allows it to drain between storms. A cleanout fitting next to the dripper valve provides access to the pipe should it be needed.

Tank options. Storage tanks are made from a variety of materials — including concrete, wood, and even a waterproof fabric like that used for waterbeds — but the three most common are food-grade polyethylene, fiberglass, and corrugated steel lined with plastic.

Polyethylene tanks are the least expensive option; they can hold up to 10,000 gallons. Fiberglass tanks cost more but have the advantage of being paintable and easily repaired if damaged. They are readily available in sizes up to 15,000 gallons. Many of our customers opt for costlier corrugated steel tanks, which look better than polyethylene or fiberglass and can be made to hold as much as 60,000 gallons (**Figure 5, page 6**).

In cases where aesthetics trump cost, we'll have a local company custom-fabricate smooth steel tanks, coated with epoxy on the inside to prevent rust. Although freezing is not a problem in our area, we occasionally bury tanks to keep them out of sight.

An overflow pipe near the top of the tank prevents overfilling (**Figure 6**) and provides a measure of air relief as the water level rises and falls. On fiberglass and polyethylene tanks larger than 5,000 gallons, we install a U-shaped relief vent to prevent the inrush of water from a large roof area from overwhelming the overflow, compressing the air in the tank, and blowing the top off. Air-relief vents are not necessary on corrugated tanks because their loosely fitted tops are not airtight.

Figure 6. The overflow pipes on this nonpotable system terminate at louvered vents (designed for clothes driers), which open as the water escapes, then close to keep insects out. The black fitting to the right of the louver (above) is the dripper valve that drains the first-flush diverter. This simple system has no pump; water is drawn by gravity from the hose bib between the tanks.

Using Stored Water

While bare-bones systems may draw irrigation water through a gravity-fed hose, most installations require a pump to pressurize the stored water (**Figure 7, page 8**). For nonpotable systems, we ordinarily use a centrifugal pump, sized to meet the flow requirements of the irrigation lines. The pump only runs when the irrigation is on, and can be activated manually or wired to the start circuit of the irrigation controller. A small expansion tank can be installed after the pump to reduce short-cycling.

A potable system must supply pressurized water for immediate use. The conventional way to do this is by installing a pressure tank after the pump, but we prefer to save space and simplify the installation by using an on-demand pump that combines a pump, a controller, and a pressure-tank function into one small package. When a valve in the domestic-water side of the system is opened, a small bladder built into the unit provides pressure until the controller activates the pump's motor.

Filtration. In a nonpotable system, water is ordinarily drawn from the bottom

Figure 7. For nonpotable applications, the author uses an inexpensive centrifugal pump activated by either an irrigation timer or, as shown here (A), an inline pressure switch. A potable system typically uses an on-demand pump (B), a compact unit that houses the motor, the controls, and a small bladder that performs the function of a pressure tank. In this potable system (C), the pump pushes water through a pair of filters followed by a UV disinfection unit — the silver canister on the right. The filters remove sediment and particles down to 5 microns in size, and the UV unit kills viruses and bacteria.

of the tank, even though it contains sediment and may be somewhat stagnant due to a lack of air exchange with the surface. In a potable system we want to use the best water first, so we use a floating filtered intake that pulls water from about 6 inches below the surface. As the season progresses, the water nearer to the bottom of the tank will eventually get used.

All potable water — unlike nonpotable water, which can be used straight from the tank — must be filtered and disinfected before being used. On our systems, the pump pushes water first through a 10-micron sediment filter, then through a 5-micron carbon filter. We recommend replacing filters every six months, but the actual time between filter changes depends on the amount of water used and the volume of particles in the rainwater. If the filters are not replaced often enough, they will become clogged and restrict the flow.

Disinfection. The filters remove even very fine particles, but not the viruses and bacteria that may be present in the water. To eliminate the risk of waterborne illness, some form of disinfection is also necessary. We prefer ultra-violet (UV) disinfection because it's the easiest system to install and maintain. The disinfection unit is a tubular chamber with a long UV light inside. The light, which is always on, kills any viruses or bacteria that pass by. The unit must always be installed downstream from the filters, because suspended particles can block UV light. Some models contain a sensor that alerts the homeowner if the bulb isn't working. We recommend replacing the bulb once a year.

Cost

Nonpotable systems vary greatly in price because there so many options in terms of size, type of tank, and whether or not a pump is needed. As an example, the installed cost of a 1,000-gallon nonpotable system is between \$2,000 and \$3,000. As storage volume increases, the cost per gallon goes down. A 20,000-gallon system, suitable for a household of four, costs about \$20,000. In the areas surrounding Austin, this is in line with the cost of a well.

Chris Maxwell-Gaines, P.E., *co-owns Innovative Water Solutions in Austin, Texas, with Blake West.*