HARVESTING THE RAIN

Considering Rainwater Catchment as a Domestic Water Source.

By E.W. Bob Boulware, PE

Worldwide groundwater contamination and loss are growing environmental calamities. The United Nations estimates that one-fifth of all people currently lack access to safe drinking water and more than half lack adequate sanitation, which pollutes the existing fresh water. By 2025, the United Nations predicts that 35 percent of the world will face serious water shortages.[1] Even with the highest feasible water use efficiency and productivity, many countries will not have sufficient water resources to meet their agricultural, domestic, industrial, and environmental needs.[2] Closer to home, water shortage issues now plague the seven Western states relying on the Colorado River for their water needs, according to a recent front-page article in the *New York Times*.[3]

Photo: David Ropinski

It is easy to overlook the fact that the Earth contains the same amount of water now as when dinosaurs roamed and Homo sapiens were just beginning to make their presence known. However, of all the existing water, 99.7 percent is locked in oceans, ice, and the atmosphere. Even much of the remaining 0.3 percent, comprising groundwater, lakes, and rivers, is too deep to easily access or increasingly becoming polluted from poor sanitation.[4] Due to increasing demand from worldwide population growth and the decreasing supply of accessible water sources, the outlook for potable fresh water availability looks grim. Clearly, extending the supply of potable fresh water is one of the most critical challenges facing plumbing engineers today.

However, many traditional methods of obtaining fresh water are becoming increasingly impracticable. Wells are limited by the water supply depth and substrata composition. Evaporation farms require large amounts of space and base infrastructure construction—space that is often not available and infrastructure that is too costly to build. Reverse osmosis systems, while very successful for creating potable water by desalinating seawater, require high energy amounts and maintenance. Also, reverse osmosis systems cannot be used with polluted water without seriously fouling critical components. Furthermore, in less developed countries and even in remote locations in the United States, such systems' construction and maintenance costs are not affordable.

Yet there is one cost-effective and energy-efficient option that reinvents a thousand-year-old methodology: the harvesting of natural rainfall. Rainwater catchment is widely applicable, environmentally friendly, and renewable. It encourages water conservation, as individual users are responsible for operation and maintenance. Plus, the concept requires only three simple components: a surface where rain can be captured and collected, a storage device, or cistern, to store the water, and piping for moving the collected water. The key challenge for engineers designing rainwater catchment systems is matching water demand with the amount of stored rain.

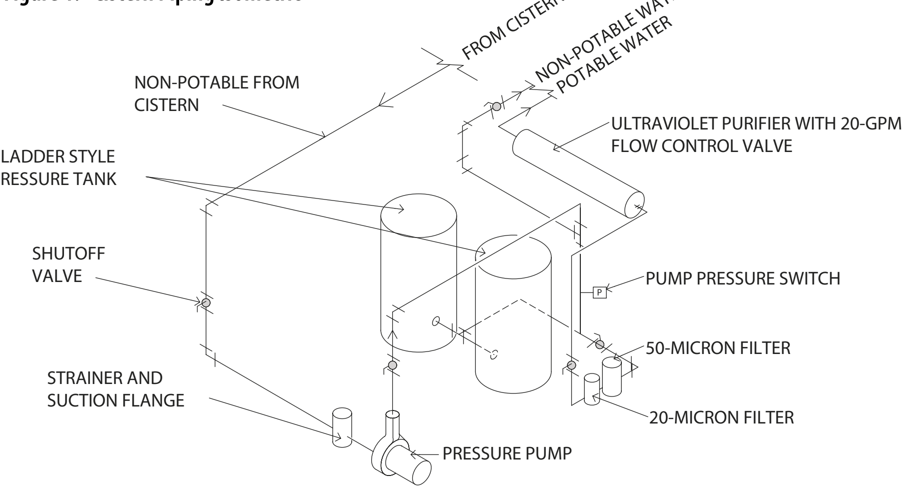
Demand: How Much Water Does a Person Need?

The average U.S. citizen uses an estimated 100 gallons (378 liters) per day for drinking, bathing, waste removal (i.e. toilets), and washing clothes. By comparison, United Kingdom citizens use 87 gallons (329 liters) per day; Asians use 22 gallons (83 liters) per day; and Africans use 12 gallons (45 liters) per day.[5] At a minimum, we need about ⅔ gallons (2.4 liters) of water per day to survive, which represents a vast gulf between water needs and water usage. How much water is the correct amount to provide?

The engineer's challenge is to calculate a water demand estimate that integrates a cost/benefit analysis with a facility's minimum water needs. With a rainwater catchment system, you can exercise some control over water usage. Rather than depending on standardized tables that imply an unlimited water supply, you can perform your own demand calculations that reflect the use of low-flow fixtures and your specific application's usage patterns. This begins by understanding the facility's usage and occupancy.

Using a commercial building as an example, you can eliminate drinking water from the calculation if it comes from a bottled-water provider. The statistical inclusion of ultra-low-flush water closet fixtures, urinals with electronic flush valves that control flush frequency and amount, and kitchen water needs (if applicable) creates a more manageable estimated load than provided by traditional calculation techniques.

Figure 1. Cistern Piping Isometric



Special-purpose facilities such as hotels add some complexity to the calculations due to the inclusion of showers in the water demand load. When you add laundry needs, spas, swimming pools, landscape irrigation, and other recreational options, accurate water demand calculations become more challenging. However, remember that these latter loads can use lower-quality water and can be separated from the facility's domestic water system. It also is important to remember that water demand must be matched with the corresponding seasonal rain pattern.

It is not crucial to collect water for 100 percent of demand if replacement water from an alternative source (well, water delivery service, utility) is available. The actual safety factor is a judgment call that depends on replacement water availability and the consequences of running out of fresh water. Due to a number of factors, it may not be feasible to provide for 100 percent of demand without water rationing during periods of low rainfall.

Estimating the Rainwater Supply

The next step is to determine the amount of rainwater that potentially will be available to supply a catchment system. Two excellent sources of rainwater data are the National Oceanic and Atmospheric Administration's National Climatic Data Center (www.ncdc.noaa.gov/oa/ncdc.html) and National Weather Service (www.nws.noaa.gov).

As a rule of thumb, you should analyze at least seven years of monthly rainfall records at a location close to the project site. While average and median rainfall amounts provide some guidance, rainwater availability extremes are most important.

After determining the available rainwater density, you can calculate the water that can be collected by multiplying rainfall density (in inches) by the collection surface area (in square feet). A 35 percent buffer commonly is added to this amount to account for evaporation and system leakage.[6]

Using this simple equation, you can estimate the expected amount of water supply per month. Since the rain is assumed to be a given, the only variable under your control is the collection surface area. The calculation to size the collection surface is:

$$\text{Collection surface area (feet}^2\text{)} = 2.2\ \text{(conversion factor)} \times [G \div R]$$

where

2.2 = (12 inches/foot) × (1 cubic foot ÷ 7.48 gallons) × 1.35 (leakage/evaporation factor)
G = Water to be harvested (gallons)
R = Precipitation density (inches)

Sizing the Storage Tank

You then must size the storage tank, or cistern. The tank's size is calculated as:

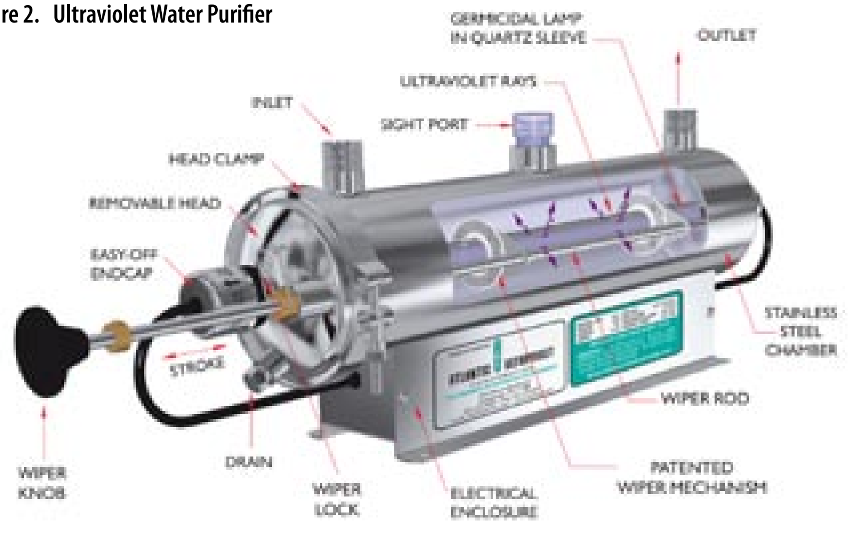
$$V = D - G + L$$

where

V = Tank volume (gallons)
D = Water demand out
G = Available rainwater in
L = Leakage of tank

The maximum storage tank size depends on the consequences of the cistern running dry. As previously mentioned, other available water sources are a factor. For example, if the facility is near a utility water loop to which the cistern can be connected, you can use an automatic float valve to maintain a minimum water level. If no nearby water supply is available, trucking in water to supplement a dry cistern may be an option. This water is often the same rainwater you are trying to collect, billed at the local utility rate with freight added. If no alternative sources exist, the tank size must be increased accord-

Figure 2. Ultraviolet Water Purifier



Source: Atlantic Ultraviolet

ingly. However, if the tank is oversized, the water can become stagnant if not regularly replaced. Balancing these two extremes—running out or causing stagnation—is the art in the engineering.

In some applications, multiple storage tanks enable the use of different quality water. For example, in tropical resort hotels, separate cisterns hold overflow water from swimming pools. This chemically treated water is then available to supplement pool evaporation losses. Reclaimed water from parking lots or other less sanitary areas possibly can be reused as landscape irrigation water by first passing it through an oil separator.

Fiberglass tanks, with capacities of approximately 2,000 gallons or less, are usually the most economical and easily maintained tanks available. Concrete, used for larger tanks, is generally more expensive. One way to greatly reduce a cistern's cost is to integrate it into the building's design rather than construct it as a separate additional system.

ASPE Data Book Volume 2 briefly describes cistern construction requirements. Below-grade tanks need surrounding surfaces graded so surface water runoff will not contaminate the water supply. Cisterns must be watertight and have washable surfaces, with a low point for residue (mud) to collect for easy cleaning. A thorough cleaning with a chlorine solution should be part of the final installation before putting the cistern to use. Furthermore, you should recommend that your client clean the tank on an annual basis.

Collecting It Clean

Any collection surface will have dirt and other undesirable substances, such as precipitated salt and leaves. To prevent this contamination from entering the cistern, you can use a roof washer to filter the initial rain volume. A number of field-constructed and commercial roof washers are available with varying techniques for filtering pollutants. Roof washers clean the collection surface by wasting the first of the rainwater collected. The roof washer tank should be sized to catch about 15 to 30 minutes of rain time, or approximately 10 gallons for every 1,000 square feet of collection surface. When the roof washer tank is full, thus the collection surface and piping system presumed to be clean, rainwater overflows from the roof washer into the cistern. A small (3/8-inch) bleed hole in the bottom of the roof washer collection tank allows the collected dirty water to slowly drain, thus emptying the tank and carrying most of the debris to waste.

Water Distribution Design Inside the Building

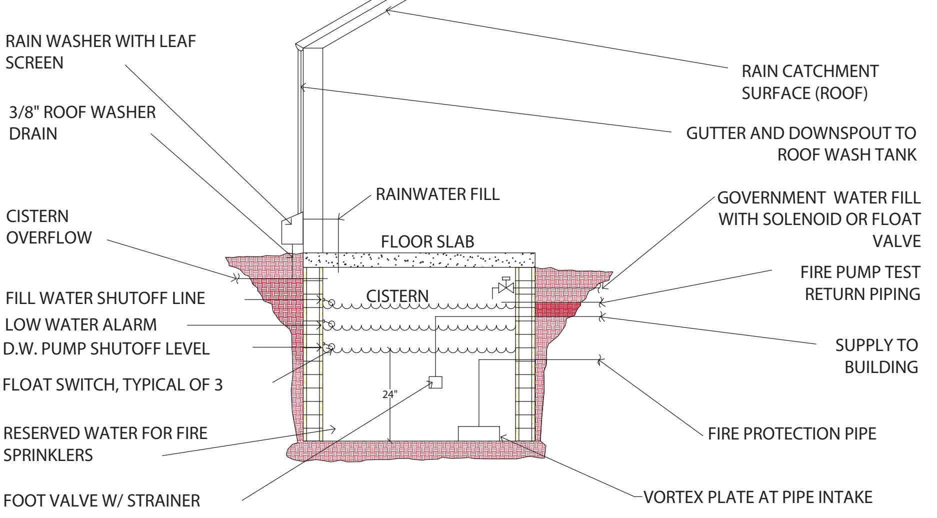
The final step in creating a rainwater catchment system is designing the building distribution system. For a cistern installed below floor grade, a shallow-well pump system commonly is used to pressurize the system. Of course, this presumes that a ready source of electricity is available. For remote locations where power is not reliably available, you may wish to include a manual hand pump to get water out of the cistern.

To avoid sucking accumulated mud from the tank's low point into the water distribution system, locate the pump suction inlet slightly above the low point in the cistern. A vortex breaker, essentially a two-by-two-foot flange around the pump intake, provides protection against the system sucking air into the pump when the water level gets low.

The water next passes through a strainer to remove solids such as mud and leaves. For higher-quality potable water, 50- and 20-micron filters in a series help eliminate cloudiness and clarify the water (see **Figure 1**). This level of water filtration is adequate for most plumbing applications.

For higher levels of purification, such as for personal consumption, you can use an ultraviolet water purifier to kill bacteria. To minimize this purifier's size and resultant cost, run the potable water line intended for human consumption separately from the water to plumbing fixtures. An example of an

Figure 3. Cistern Piping With Fire Reserve



ultraviolet water purifier can be seen in **Figure 2**.

Fighting Fires with Rainwater

Dual use of a cistern is commonplace in many areas. For example, in the close quarters of a historic town such as Charlotte Amalie, U.S. Virgin Islands, a fire in one building could devastate an entire area. To provide for fire protection, a fire reserve is needed in addition to the calculated domestic water demand. This reserve is drawn from the lowest part of a tank and pumped into the sprinkler system with a fire booster pump. Therefore, you need to design the tank so the domestic water is drawn from a level above the designated fire reserve. It is important, and highly recommended, that you consult the local fire authorities regarding the necessary fire reserve requirements.

To accommodate regular fire pump testing and avoid waste, you should design a provision for recirculating the test water back into the cistern. Since fire pumps typically draw from a tank's lowest part, you also should design an additional discharge to a sanitary waste system to provide a method for pumping mud out of the tank. **Figure 3** shows a typical cistern piping configuration with a fire reserve.

Photo: Alan Mars

Cistern Maintenance

Cistern maintenance requires a regular system of inspections. Opinions are mixed regarding the ongoing use of chlorine to occasionally treat the water supply. Concerns include health problems associated with possible chlorine overdosing and chlorine-tolerant bacteria development. In practice, omitting chlorine use and following a regular maintenance and cleaning schedule has been shown to be adequate.

Like any standing body of water, a cistern is often a source of mosquito breeding and attendant mosquito-born diseases. One anecdotal remedy to the mosquito problem is putting a pair of guppies in the tank. The fish eat the mosquito larvae and, because the fish themselves are cannibalistic, will help keep the fish population in equilibrium after the mosquitoes are eliminated. Floating a piece of wood on which an occasional mosquito-eating frog can perch is another rumored solution for abating mosquitoes.

Always a Need for Clean Water

The increasing need for potable water free of water-borne disease is a growing problem worldwide. Less developed countries use rainwater catchment as a low-tech method of water supply as a matter of necessity, but rainwater catchment is still somewhat of a novelty in countries relying on utility-provided water. With the increasing demand for and decreasing supply of clean water, the anticipated potable water shortage will become a bigger issue. Rainwater catchment is a viable option that should be part of every plumbing engineer's design toolbox. ■

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