Rainwater Harvesting

An ancient technology—cisterns—is reconsidered.

BY DANIEL WINTERBOTTOM

As aquifers are depleted and municipal water supplies are treated with chlorine and other chemicals, an old technique, rainwater harvesting in cisterns and on roofs, is being looked at with renewed interest. For landscape architects, rainwater collection as a means of irrigation offers many advantages, including lower water costs over the lifetime of the system, no withdrawal of groundwater, and a better quality of water for cultivation and for the maintenance of water-using equipment. A few landscape architects are using rainwater harvesting in demonstration projects; as water costs continue to rise, the building of collection systems is likely to accelerate.

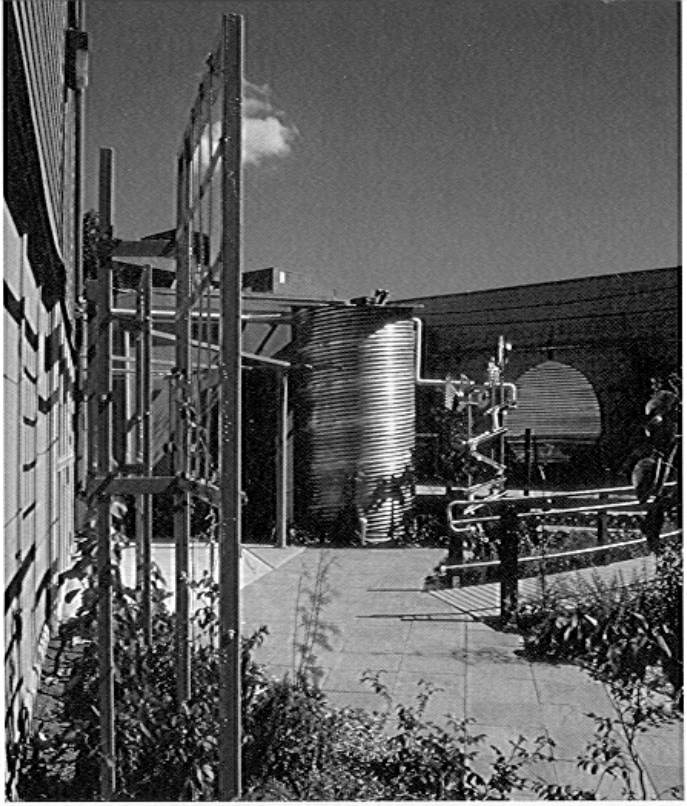
Cisterns range from the simplest systems, in which an excavated hole provides simple storage of ground-level sheet flows, to roof collection systems with storage in a constructed cistern. Historically, many cultures, including those of Meso-America, the Middle East, and ancient Rome, used captured rainwater. Examples can be found in rural Yemen, where the water was used for consumption and to irrigate the fields, and in urban Rome, where rainwater was collected from the roofed peristyle (covered walkway) and conveyed to a small pool (impluvium) in an open garden—there to be used as an aesthetic focal point and for irrigating the plantings. In Meso-American cities such as Xochicalco, in central Mexico, water was collected from the plazas and rooftops within the city and stored in an underground cistern for human use and irrigation. In the United States in the nineteenth and early twentieth centuries, small concrete cisterns were common storage structures serving families settling the high plains. The systems ranged from large civic infrastructures to small cisterns for individual homes. Even today in Yemen, paths and roads are laid out to drain into

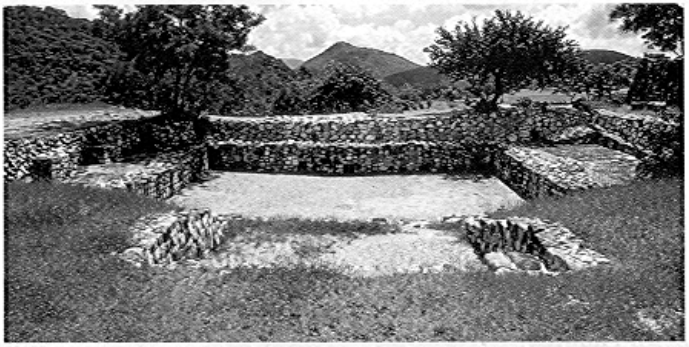
At the Colonia de Santa Ursula in Mexico, rainwater, *top*, is conveyed to the orange cistern. Overflow at the Garden of Eat'in, *above*, is conveyed through a sculptural system.

large circular masonry cisterns that serve as civic meeting places for women coming to collect water for washing and for consumption. The scale of many of the ancient systems dwarfs today's cisterns. Deep in the bedrock beneath the old temple of Jerusalem lies a cistern with a capacity of two million gallons, and beneath a large plaza in the complex of the Church of Santo Domingo in Oaxaca, Mexico, lies a 200,000-liter capacity cistern that has recently been excavated.

Today, in all new construction in both Bermuda and the U.S. Virgin Islands, rainwater harvesting systems are required. The state of California offers a tax credit for rainwater harvesting systems, and financial incentives are offered in cities in Germany and Japan. Systems have been installed in skyscrapers in Hong Kong. An estimated 200,000 cisterns are now in use in the United States, storing rainwater for both consumption and irrigation.

Probably the most extensive contemporary example of rainwater collection is found at the Lady Bird Johnson Wildflower Center near Austin, Texas. Since the center's establishment in 1992, rainwater has been harvested from 17,000 square feet of roof area with an estimated 300,000 gallons collected and used per year. The project, designed by Overland Partnership with Robert Anderson, landscape architect, incorporates four cisterns and two 25,000-gallon fiberglass storage tanks, supplying water for subsurface and pop-up irrigation systems and a series of native Texas demonstration gardens. The largest of the cisterns, the 10,000-gallon Tower Cistern, is veneered in limestone and collects water from the cafe and visitor gallery. A lift system pumps water to the storage units that feed the larger site irrigation units. Smaller cisterns and collection devices collect additional water that is recirculated and used for aesthetic displays.





The galvanized steel cistern at the Garden of Eat'in waters a demonstration garden, *above*. Stone-lined cisterns, *below*, were traditional in the highlands of Mexico.

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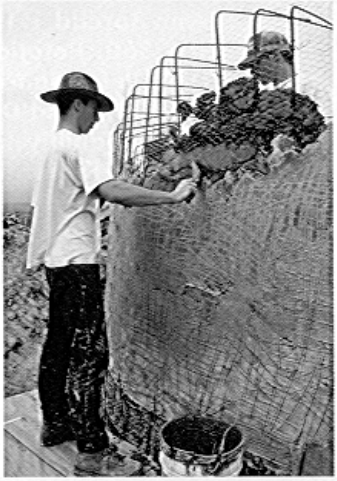
Most people living outside the Northwest would scoff at the seriousness of water shortages there, but in western Washington for three months of the year there is virtually no rainfall. When students in the landscape architecture program at the University of Washington in Seattle discussed their goals for a small courtyard next to a recently renovated community design center, they decided to address ecological issues by harvesting rainwater for irrigating an edible garden. Fifteen students, under the direction of lecturer Luanne Smith and me, designed and built the Garden of Eat'in in a ten-week spring studio in 1998. The thirteen-foot high, six-foot diameter cistern, fabricated from galvanized steel culvert

pipe, is similar to residential collection tanks used in rural Alaska. Its storage capacity of 4,500 gallons will provide approximately one-third to one-half of the irrigation needs of the garden. The underground drip system is gravity fed, and a valve allows the ground crew to switch to a pressurized system when the cistern runs dry. The water is gathered from the metal roof through a conventional gutter and conveyed to a six-inch PVC roof-wash system. The clean water is carried to the cistern through a four-inch PVC pipe, and the overflow is channeled into a sculptural conveyance system and released into a conventional storm system. Given the small site and its use both as a demonstration garden and as a gathering area, it was determined that the cistern should be vertical instead of a wider form, thereby reducing the impact within the garden. The tower has become an unexpected design amenity, serving as an icon for both the park and the west campus area. While the cost of the tank was high ($1,700, including fabrication and delivery), it will recoup its cost in seven years given current water prices—while keeping more water on site, thus facilitating groundwater recharge and reducing discharges into the storm system.

The use of cisterns for rainwater capture has a long tradition in the highlands of central Mexico. A small cistern about four feet square and six feet in height often precedes the building of a house, providing water for construction and irrigation. Because of the lack of municipal water in the Colonia of Santa Ursula, a small rural community of ninety families southeast of Mexico City, the women hiked more than three miles to the closest river to wash clothes. The trip was often difficult, but the river suffered from pollution caused by detergents and from compaction of riparian vegetation. In fall 1998, fifteen University of Washington students and I joined with a Mexican nonprofit group, Accion y Desarrollo Ecologica, to work with the community to design and build a rainwater harvesting system and *lavanderia* (outdoor public laundry).



Students from the University of Washington built the ferrocement cistern at Santa Ursula.

The resulting *lavanderia*'s galvanized metal butterfly roof provides shade to the women using the wash basins below and collects and conveys water to a twenty-foot-diameter, ten-foot-high ferroconcrete cistern anchoring the structure on the north side. The water is then gravity fed, or pumped, once it falls below grade, into a smaller stone-clad open cistern from which the women take it for use in the washing sinks. The dirty wash water is then piped to a grease separator and to a biofiltration channel; the cleaned water is used to irrigate an orchard. Filtration between the cistern and the roof catches any particulates. The built cistern, part of the first phase, will provide one-third to one-half of the water needed during the dry season. The second phase includes plans for a larger thirty-foot diameter cistern to be added to deliver water throughout the dry period. The project serves as a demonstration model, one that can be widely carried out, relieving the natural systems of contamination and providing sustainable amenities to the community.

Design

A rainwater harvesting system includes up to six primary components depending on the degree of water quality required. These components include a catchment area, a roof-wash system, a rainwater conveyance system, a cistern or storage containment, a delivery system, and water treatment systems. The most common contemporary catchment areas are roofs. (Paved areas can also function as catchment surfaces, but greater contamination by oils, salts, and particulates requires increased filtration, and the delivery system typically requires a pump.)

Water quality should be considered when designing the roof. First, a roof built of organic materials such as wooden shakes, clay tiles, or concretious materials supports the growth of algae and molds and is not advisable if the rainwater is to be used for drinking.

A second concern is the wash of dry pollutants into the system. Porous or rough roofing materials (asphalt shingles or rolled roofing) are more likely to hold particulates, including bird feces or heavy metals, than are smooth, impervious surfaces. One solution is a roof-wash system, which captures the first ten to twenty gallons of water in a separate pipe that takes away the first flush, allowing the heavier solids to fall to the base so that the water flowing into the collection system is relatively free of particulates. Porous materials also hold water, reducing collection efficiency; asphaltic roofing, for example, has an absorption rate of 15 percent, while

enameled steel absorbs only 5 percent of the rainfall it collects.

A third issue is the material's leachate capability. Of particular concern are metal surfaces treated with zinc, wood shakes treated with preservatives, and asphaltic materials releasing petrochemicals. The use of lead flashing or solders should be avoided if the plants irrigated are to be ingested. The best roofing materials for rainwater collection are stainless steel or galvanized steel with a baked-on enamel, lead-free finish. Whatever the material, the roof should be sited away from overhanging branches, reducing the risk of contamination from leaves, bird droppings, and insects.

The rainwater is conveyed from the catchment area to a filtration or storage unit via gutters, downspouts, and piping. The piping is constructed of roll or channel-formed copper, aluminum, stainless steel, galvanized steel, or plastic (PVC). Lead-based solder should be avoided in all metal-to-metal connections. A rule of thumb for sizing downspouts is to design the orifice to handle 1.25 inches (32 mm) of rain in a ten-minute period. Leaf screens are commonly installed at downspout inlets, and thrust points should be firmly secured.

Probably the most costly component is the cistern or storage unit. It is also the most limiting element, because its size dictates how much water will be available for use. In areas with a long dry season, units sized for total watering needs will be expensive and will require a great deal of space. Cisterns can range from small individual drums, to a series of fifty five-gallon drums, to large structures storing thousands of gallons. The most common shape is cylindrical, because it provides the greatest strength-to-weight ratio. Covers are necessary to prevent sunlight (which supports algae growth) or animals from entering, and to eliminate evaporation. In cold climates, the unit will need to be insulated, typically buried underground to prevent freezing. In hot climates, at least twelve inches of water should remain inside a concrete structure to prevent the shell from drying out and cracking. In addition to the inlet, an overflow should be located at the desired water level, allowing excess water to be released from the cistern. Many designers also opt to install a drain at the base of the cistern, allowing any standing water to be drained for cleaning or maintenance. Many of the earliest cisterns in ancient Rome and the Middle East were carved into the bedrock. Today, a variety of materials are used, depending on cost, volume of water being contained, and availability of the materials.

Galvanized steel is one of the most common cistern materials found on farms and in rural areas. If edible plantings are to be watered, a sealer or liner is recommended. Many off-the-shelf sizes are available, and larger sizes can be custom ordered, as was done for the Garden of Eat'in.

Concrete tanks are typically cast on site, but there are also precast units available in relatively small capacities. Often these tanks are located below grade, allowing a reduced thickness of the walls. Once roofed, the tanks can support small structures and live loads above, serving either as building additions or as independent free-standing structures.

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Ferrocement (see "Ferrocement and Shotcrete: New Applications," December 1993) is a form of thin-wall cement construction relying on steel reinforcing that provides high strength, ease of use for building, and relatively low cost, making this an increasingly common cistern material.

Mortared stone has been used in many cultures. Construction and material costs are relatively high, but the cistern can be highly attractive, functioning as a focal point of the design, as in the Lady Bird Johnson Wildflower Center.

Fiberglass is inexpensive, readily available, and lightweight.

Polyethylene tanks are readily available in sizes up to several thousand gallons. They are lightweight and easily transported.

Wood stave tanks were common atop buildings in our older cities. When properly built they are highly durable and, if made of redwood or cypress, preservative treatments are not required.

Polyethylene liners, used inside an excavated hole and placed over a nonwatertight frame, offer the lowest cost, although their longevity is relatively short, ranging from ten to fifteen years. The liners should be UV stabilized, with a thickness of twenty to thirty mils.

If the storage structure is located uphill from the planting beds, gravity flow can be used. Otherwise, a pump and pressure tank will be required for delivery. In some situations where the tank is partially submerged, a combination of gravity and pumping may be employed.

For collection systems used solely for irrigation, preliminary filtration (leaf screens) and a roof-wash system may be adequate. A third method of filtration, sometimes used in lieu of the roof-wash device, is a gravel filter. The rainwater is deposited at the base of a small tank containing pea gravel or lava rock and, as the water rises, the particulates are left at the base of the tank so that (as with the roof-wash system) the water entering the cistern is relatively clean of particulate matter.

If a higher level of quality is required, a number of filtration systems are available. The simplest is a microfiltration process employing gravel, sand, and charcoal to achieve potable water quality standards. Two other treatments—UV sterilization and ozonation—are also used when the water will be consumed. The microfiltration system is relatively low in construction cost, but UV sterilization and ozonation each require an additional cost of $1,000 per system.

Probably the largest limiting factor restricting rainwater collection is the high construction cost when compared with the low cost of municipal water supplies. A common rule of thumb is one dollar of construction cost per gallon of water stored. Systems incorporating expensive materials or custom-built systems can cost considerably more. As water costs rise, however, rainwater collection will become more economically feasible. **LA**

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RESOURCES: See page 137.