CHAPTER 1

# The Importance of Rainwater Harvesting



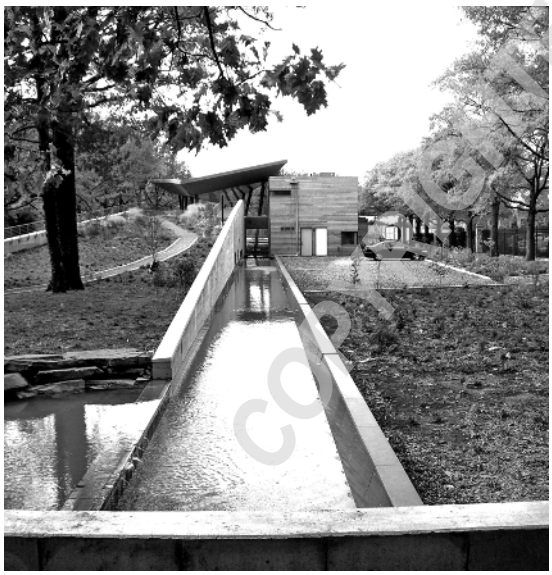

**Figure 1.1** Queens Botanical Garden Visitor and Administration Center is an example of integrated rainwater harvesting system design.

Rain water harvesting and conservation aims at optimum utilization of the natural resource that is Rain Water, which is the first form of water that we know in the hydrological cycle and hence is a **primary source** of water for us. The Rivers, Lakes, and Ground Water are the secondary sources of water. In present times, in absence of Rain Water harvesting and conservation, we depend entirely on such secondary sources of water. In the process it is forgotten that rain is the ultimate source that feeds to these secondary sources. The value of this important primary source of water must not be lost. **Rain water harvesting and conservation means to understand the value of rain and to make optimum use of Rain Water at the place where it falls.**

—India: Rain Water Harvesting and Conservation Manual[1]

## WATER CAPITAL

Water is the only commodity on Earth for which there is no economic substitute. Seventy-five percent of the Earth's surface is covered in water, yet only 2.5 percent of it is suitable for human consumption. Of that 2.5 percent, most is locked in polar ice caps or hidden beyond the reach of commercial technologies.[2] All life forms on the planet depend on water to survive. Simply stated, water is the basis for all life on Earth.

The more technologically advanced humans become, the more water is consumed on a per capita basis. Electricity use within a typical home requires 250 gallons (almost 1,000 L) of water per day per person; the manufacturing processes of computer chips, televisions, and cell phones require water, and the production of a half-gallon (roughly 2L) bottle of soda can take over 1.3 gallons (5 L) of pure water.[3] Even the production of food requires tremendous amounts of water, as producing 1 pound (0.5 kg) of chicken and 1 pound (0.5 kg) of beef requires over 1,600 gallons (6,000 L) of water![4] Historically, an abundance of water, as well as water scarcity, has affected both the growth and decline of every civilization. History teaches that finite water resources need to be managed with the utmost care.

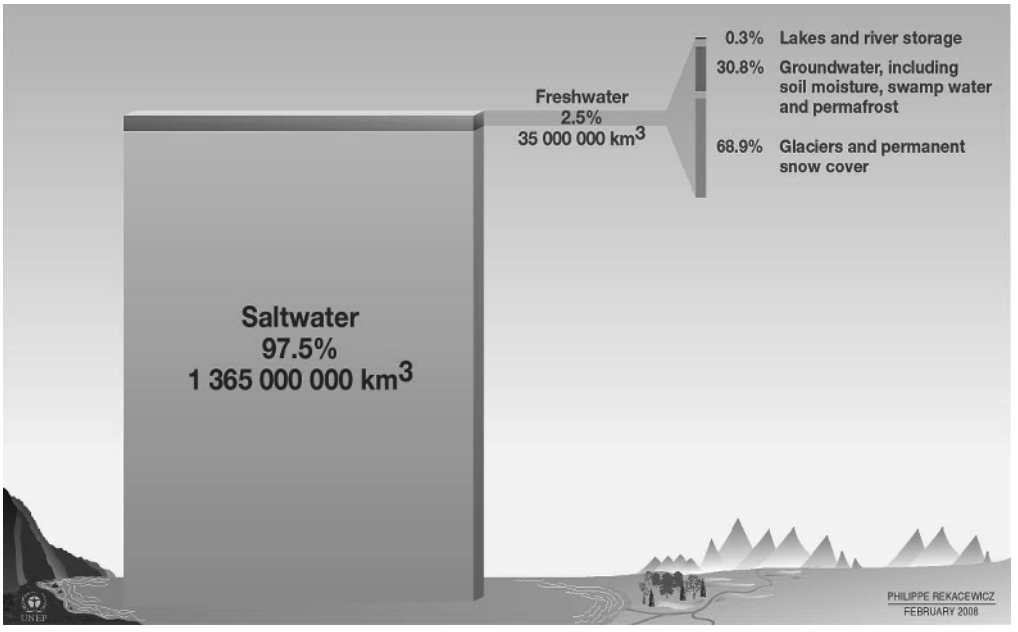


**Figure 1.2** EARTH A Graphic Look at the state of the world[5] (*Source: Igor A. Shiklomanov, State Hydrological Institute (SHI, St. Petersburg) and United Nations Educational, Scientific and Cultural Organisation (UNESCO, Paris), 1999. Image courtesy of UNEP.*)

As profound as our dependence on water is, there is an equally profound lack of knowledge concerning where water comes from and how it is best and most efficiently used as a public and private resource. According to the Environmental Protection Agency (EPA), the following statistics underscore the challenges faced by architects, engineers, and public policy makers as they face looming freshwater shortages:

- The average American directly uses 80 to 100 gallons of water each day, but supporting the average American lifestyle requires over 1,400 gallons of water each day.
- Agriculture is the largest consumer of freshwater: worldwide, about 70 percent of all withdrawals go to irrigated agriculture.
- Only 1 percent of the world's freshwater is accessible to humans.
- Forty percent of America's rivers and 46 percent of its lakes are too polluted to support fishing, swimming, or aquatic life.
- Power plants in the United States use 136 billion gallons of water per day, more than three times the water used for residential, commercial, and all other industrial purposes.[6]

In addition, scientists and researchers are describing a "peak water" crisis for water use throughout the world. As a response to these issues, professionals are developing new strategies to conserve and effectively use water resources.

## Peak Water

The planet is getting thirstier as a growing worldwide population is using fresh water resources. Dr. Peter Gleick, president of the Pacific Institute, has coined "peak water" as a description for the world's water crisis. This concept describes the lack of sustainably managed water throughout the world, just as "peak oil" refers to the lack of oil reserves globally. According to Dr. Gleick, there are three major definitions for peak water. These are:

- *Peak Renewable Water:* The limit reached when humans extract the entire renewable flow of a river or stream for use.
- *Peak Non-Renewable Water:* Groundwater aquifers that are pumped out faster than nature recharges them—exactly like the concept of "peak oil." Over time, groundwater becomes depleted, more expensive to tap, or effectively exhausted.
- *Peak Ecological Water:* The point where any additional human uses cause more harm (economic, ecological, or social) than benefit. For many watersheds around the world, we are reaching, or exceeding, the point of "peak ecological water."[7]

The design challenge is to reverse the direction of peak water so that it is not a linear loss of water, but a regenerating system that allows humans to participate in the continuation of the hydrologic system.

One response to the water supply challenges is the re-creation of one of the world's oldest water supply systems: *rainwater collection*. Rainwater collection, or rainwater harvesting, involves the capture of water from roofs and/or impervious/pervious surfaces. The roofs of buildings, schools, offices, large data distribution centers, and agricultural buildings can serve as the contributing drainage area for a given system. Once captured within the rainwater harvesting system, the quality of the runoff water may be improved via physical and biological processes including filtration, disinfection, and other treatment strategies. New approaches in plumbing design are using site-collected rainwater/stormwater to provide all or part of a building's and its site-related water needs. This results in a reduction of stormwater runoff volumes leaving a site, while at the same time providing a new source of water to reduce the burden on potable water supplies.

Water conservation and stormwater management are two of the most effective sustainable design practices available to architects and engineers. Rainwater collection conforms to the goals and objectives of low-impact development, which aims to mimic the predevelopment site hydrology by using site design techniques that store, infiltrate, evaporate, and detain runoff.[8] Reducing the runoff from storm events via rainwater harvesting strategies provides benefits to property owners, including lower municipal fees and larger developable site area, and contributes to the big-picture goal of reducing the impact of urbanization on receiving water bodies.

Rainwater collection is becoming one of the many tools used by sustainable design professionals. Sustainable building rating methods and performance guidelines are influencing the development of rainwater harvesting systems. Projects throughout the world are demonstrating that rainwater collection systems can solve some of our water-related problems. Rainwater systems are meeting the challenges of water conservation while demonstrating the effectiveness of alternative nontraditional water supplies. There are numerous benefits to this approach for the conservation of the world's most valuable natural resource.

**Figure 1.3** At the Queens Botanical Garden, rainwater is a valuable resource. (*James Wasley/Atelier Dreiseitl*)

## Low Impact Development

Until the 1960s, the philosophy of stormwater management was to dispose of the water as quickly as possible from urban areas to the nearest receiving water.[9] Extensive underground piping networks were used to convey runoff from parking lots, roadways, and buildings and discharge it into the closest stream or river. As the negative impacts of discharging stormwater runoff and wastewater into surface waters became apparent, the focus shifted to encompass water quality concerns as well, initiating what is now considered traditional stormwater management.[10] The major components of a traditional stormwater system are concrete curbs and gutters, drop inlets (catch basins), underground pipe networks, and detention/retention basins. The majority of modern developments, both residential and commercial, utilize curb and gutters to convey stormwater runoff from impervious surfaces (such as parking lots and roadways) to drop inlets, which are connected to extensive networks of underground pipes that carry the water to large detention or retention basins.

The use of retention and detention basins addresses some water quality and quantity concerns; however, there are detriments associated with their implementation. While retention ponds can reduce peak flows to some extent, recent research has shown that the outflow is often released at rates exceeding that, which can be absorbed by receiving streams, resulting in erosion of the streambed and banks.[11] Furthermore, basins are designed to release outflow longer than the duration of the storm event, thereby causing a prolonged state of erosion within the stream.[12] Detention and retention basins can also increase the temperature of captured stormwater due to exposure to sunlight and the shallow pool depth. The introduction of this warm water to cold-water streams can be detrimental to biota, especially trout.

The optimal approach to minimizing hydrologic impacts from an urbanizing watershed (as opposed to traditional stormwater management) is through the implementation of low-impact development (LID) principles and practices during the planning and construction phases of development. The overall goal of LID is to "mimic the predevelopment site hydrology by using site design techniques that store, infiltrate, evaporate, and detain runoff.[13]" Unlike the traditional stormwater management paradigm, the LID approach encompasses all aspects of watershed hydrology, including runoff peak flows and volume as well as the temporal and spatial distribution of runoff events.[14]

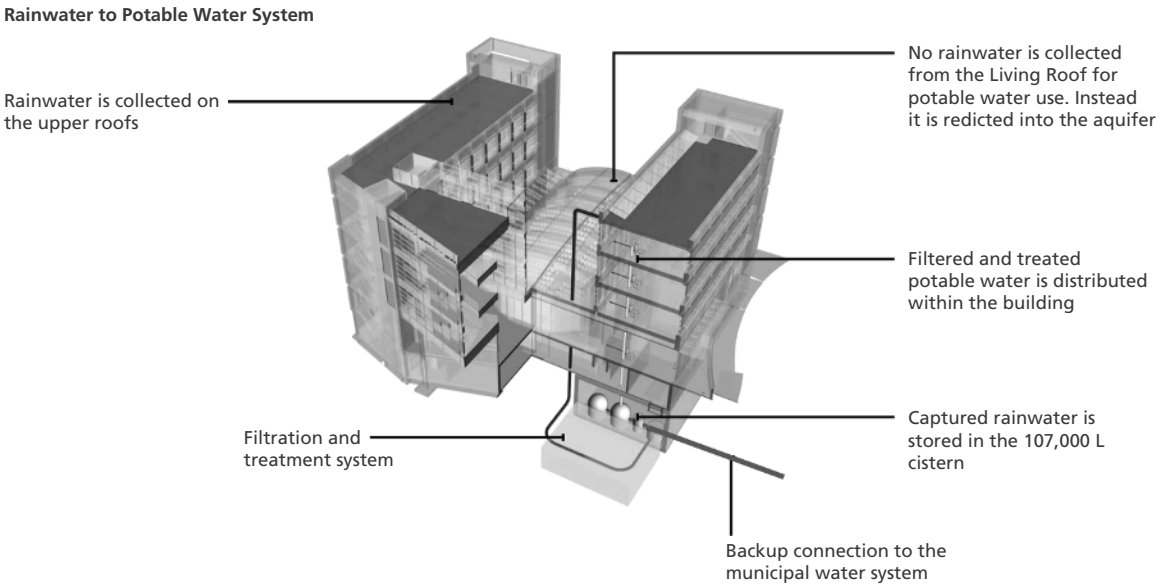


**Figure 1.4** Designed by Perkins+Will, the Centre for Interactive Research on Sustainability integrates rainwater collection, graywater reuse, and water treatment for building potable water to meet the Living Building Challenge™. (*Diagram Courtesy of Perkins+Will*)

## A BRIEF HISTORY OF CENTRALIZED WATER SYSTEMS

Most conventional water sources include groundwater from shallow or deep wells, rivers, and lakes (natural and manmade). Humans depend on these sources and their replenishment via the hydrologic cycle. Through the input of energy from the Sun, water moves from the Earth's surface to clouds and back to the Earth's surface again. Water is in constant motion in the hydrologic cycle.

Populations have always grown where there is adequate water. In addition to gathering water from surface sources and wells, the use of cisterns has been documented in many cultures. As far back as 3000 BC, stone structures for capturing rainwater have been found in India.[15] Large cisterns and canals carved in rock for transporting roof-collected rainwater are found in Petra, Italy, dating from roman times.[16] Aqueducts constructed by the Romans were also early efforts at providing centralized water systems to concentrated populations. Other examples are found worldwide, including irrigation strategies for agriculture.

Over the centuries, small and large communities have faced continual successes and failures in securing adequate sources of clean freshwater for daily activities. Problems in securing these sources include:

- Overuse, as populations and uses increase;
- Contaminants from human waste as well as commercial/ industrial/agricultural activities.

The effect of poor sanitation, lack of control over purification systems, and major health


**Figure 1.5** Tang Dynasty leader Li Jing (571–649 AD) praised this cistern as being a "Smart Spring." It was "full of water when drought came and it was dry when the flood came."[17] (*Celeste Allen Novak, Architect*)

crises of waterborne diseases in the 19th century, particularly in urban environments, led to the current centralized water systems. Along with the need to provide water for the increased demand associated with the industrial boom, population growth demanded even more water for human needs.

In the early 1900s, the development of successful chlorination methods for disinfection of water led to further expansion of controlled water supply in the United States.[18] Centralized systems in use today throughout the developed world provide a standard level of safe, treated drinking water through a continuous loop that extracts water from lakes, rivers, and aquifers and then treats and distributes the water to the end users.

As described in a recent publication on climate change, "Urban water systems have evolved into large highly engineered systems in which water is imported from surrounding catchments and aquifers, distributed through extensive pipeline networks and used just once. Most of the used water is then collected in large sewerage systems, treated to remove contaminants and nutrients and discharged back to rivers and oceans."[19]

Once in place, that water infrastructure is largely taken for granted by the public and policy makers alike. Over the decades, the focus has been primarily on expanding the infrastructure to accommodate growth at the expense of maintaining the aging original infrastructure. According to the EPA, the aging water infrastructure is one of the United States' top water priorities.[20] The impacts of delayed maintenance, budget cuts, and disinvestment in aging infrastructure have become a 21st century political, economic, and social crisis.

The original water infrastructure in many urban centers (in the United States and worldwide) is more than 100 years old. Lisa Jackson, former EPA administrator, highlights the current state of deterioration of this infrastructure. In "Water Infrastructure" (October 2010), she writes: "An issue we face is deferred maintenance in our [water] infrastructure, which in too many communities is over-worked and

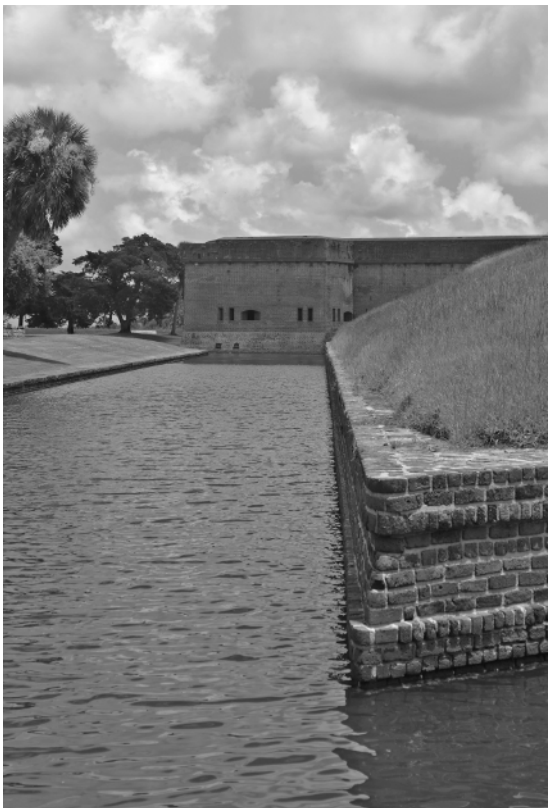

**Figure 1.6** Fort Pulaski National Monument in Georgia provides an example of a historic rainwater collection system. Ten brick subterranean cisterns incorporated into the structure of the fort were capable of storing 200,000 gallons of fresh water. After the capture of the Fort, in 1862, Union soldiers supplemented the natural supply with a steam condenser which converted the moat's saltwater into freshwater. (*Eddie Van Giesen*)

under-budgeted. Our system is deeply stressed, our financial and our natural resources are limited and our needs are not negotiable."[21] This report defines one of our current national problems: We are facing costly upgrades and repairs to an aging water infrastructure that includes drinking water and wastewater treatment facilities.

In the last 100 years, with the exponential increase of manmade impervious surfaces, the hydrologic cycle has been interrupted and impacted by industrialization, mechanization, and population growth. The result is an alarming increase in stormwater discharge velocities and volumes, causing a paradoxical shortage of freshwater resources. This shortage is caused not by a reduction of the amount of water, but rather contamination and pollution of the available water due to floods, erosion, and sewage overflows.

Some alarming statistics in the EPA report include an estimated 240,000 water main breaks per year and up to 75,000 sanitary sewer overflows per year in the United States, resulting in the discharge of 3 to 10 billion gallons of untreated wastewater into our waterways.[22] Each leak wastes water and increases the costs associated with treatment and distribution. Sanitary sewer overflows discharge polluted water downstream, causing environmental damage. At the same time, pollution compromises downstream community water supplies.

Nevertheless, new regulations and policies that promote centralized water distribution are still being encouraged to the exclusion of all other decentralized approaches in many parts of the world. One of the barometers of the economic health of a country is the degree to which centralized drinking water and sewer systems are present. Countries that lack functioning centralized water distribution systems continue to look to the developed world as a source for inspiration and technical knowledge. Inadvertently, the developed world is leading their technological disciples toward their own water shortages. However, some countries, like India, Singapore, Australia, and New Zealand, are rethinking their policies toward centralized water systems and developing new approaches to water use and reuse.

### New Approach to Centralization—Decentralized Rainwater Systems

U.S. cities with hundred-year-old utilities are beginning to address the creation of new municipal water systems. For example, the City of Chicago has slated over $1.4 billion in investment into fixing the leaks in aging water mains and eroding sewer systems. Chicago's improvements include the replacement of 900 miles (1,450 km) of century-old water pipes, repairing 750 miles (1,200 km) of sewer lines, reconstructing 160,000 catchbasins, and modernizing Chicago's water filtration plants. The upgrades could save an estimated 170 billion gallons (645 million $m^3$) of water by 2020, or close to all the water that Chicago households consume in two years, according to Chicago's Mayor Rahm Emanuel.[23]

A recent vision for a new Chicago water system was provided by UrbanLab, the winner of the City of the Future Competition in 2011. UrbanLab described a city that could become a "holistic living system that would multiply and intensify Chicago's 'Emerald Necklace' of parks, boulevards and waterways; and saving, recycling and 'growing' 100 percent of its own water."[24] Water infrastructure (drinking and waste) is being viewed as part of a living system.

## Eco-Boulevard by Martin Felsen, AIA

### Chicago, Illinois

Chicagoans discard over 1 billion gallons of Great Lakes water per day. This "wastewater" never replenishes one of the world's most vital resources. As a remedy, this project re-conceives the Chicago street-grid as a holistic Bio-System that captures, cleans, and returns wastewater and storm-water to the Lakes via "Eco-Boulevards."

The Eco-Boulevard transforms existing roadways, sidewalks, and parks (the "public-way"), which comprise more than a third of the land in a city such as Chicago, into a holistic, distributed, passive bio-system for recycling Chicago's water. Treated water is returned to the Great Lakes, closing Chicago's water loop.

Eco-Boulevards are ecological treatment systems that make use of natural bioremediation processes to remove contaminants from storm-water and wastewater sources. In the proposal, two types of bio-systems are at work: Type A and Type B. Type A is a hydroponic bio-machine that uses aquatic and wetland ecological processes to treat wastewater naturally. These processes are carried out in reactor tanks in enclosed greenhouses. Type B is a wetland bio-system that uses constructed wetlands and prairie landscapes that use low energy processes to biologically filter storm-water naturally.

Re-designing Chicago's non-sustainable water infrastructure will have a profound impact because the Great Lakes are a global resource holding 21% of the world's, and 84% of North America's, fresh surface water. Water availability is becoming a key global issue as water scarcity/pollution and climate change bear down on the planet. Even in the comparatively water-rich Great Lakes region, global warming could ultimately create urban flooding, frequent droughts and a scramble for water. Implementing blue/green infrastructure that safeguards ecosystem health

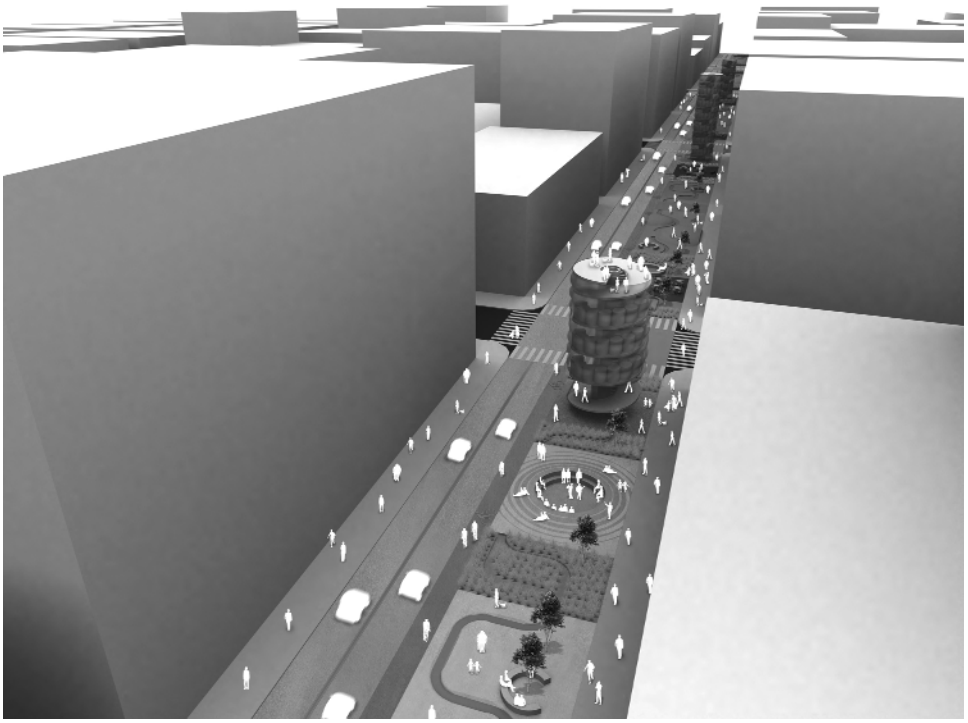

**Figure 1.7** Eco Boulevard, a conceptual proposal for Chicago by UrbanLab Architecture + Urban Design. (*UrbanLab Architecture + Urban Design*)

and drives sustainable development is imperative. This is especially the case for cities adjacent to the Great Lakes because the Great Lakes Region is a $2 trillion/year economic juggernaut.

The Eco-Boulevard concept re-conceptualizes current roadway designs on a case-by-case basis (over time) to create a preferred breed of performance-based infrastructural landscapes. Integration and connectivity between ecological and social systems is the key breakthrough toward the cultivation of a healthy ecosystem.

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A modern decentralized water infrastructure can include site-collected rainwater, graywater, stormwater, and blackwater systems. These alternative water sources may never totally replace centralized systems. They *do* help manage and store water and treat it to various levels of quality for use in buildings and the sites upon which they stand. By designing the site and building as a complete system for water storage and use, designers can conserve water resources, save energy, and reduce the cost to community treatment facilities.

New technologies and a better understanding of these "new water sources" allow the designer to use these natural resources as part of the integrated design of commercial

buildings. India, Malaysia, Germany, Australia, New Zealand, Bermuda, and many countries in the Caribbean are and have been harvesting rainwater for both potable and nonpotable water sources. The following projects in India, Germany, and the United States are just a few of the case studies that will be explored as examples of successful rainwater collection systems throughout the world.

## EXAMPLES FROM AROUND THE WORLD

### India

The following example is a project that exemplifies the use of rainwater in a public memorial both inside and outside the building by the Indian firm of Mathew & Gosh Architects.

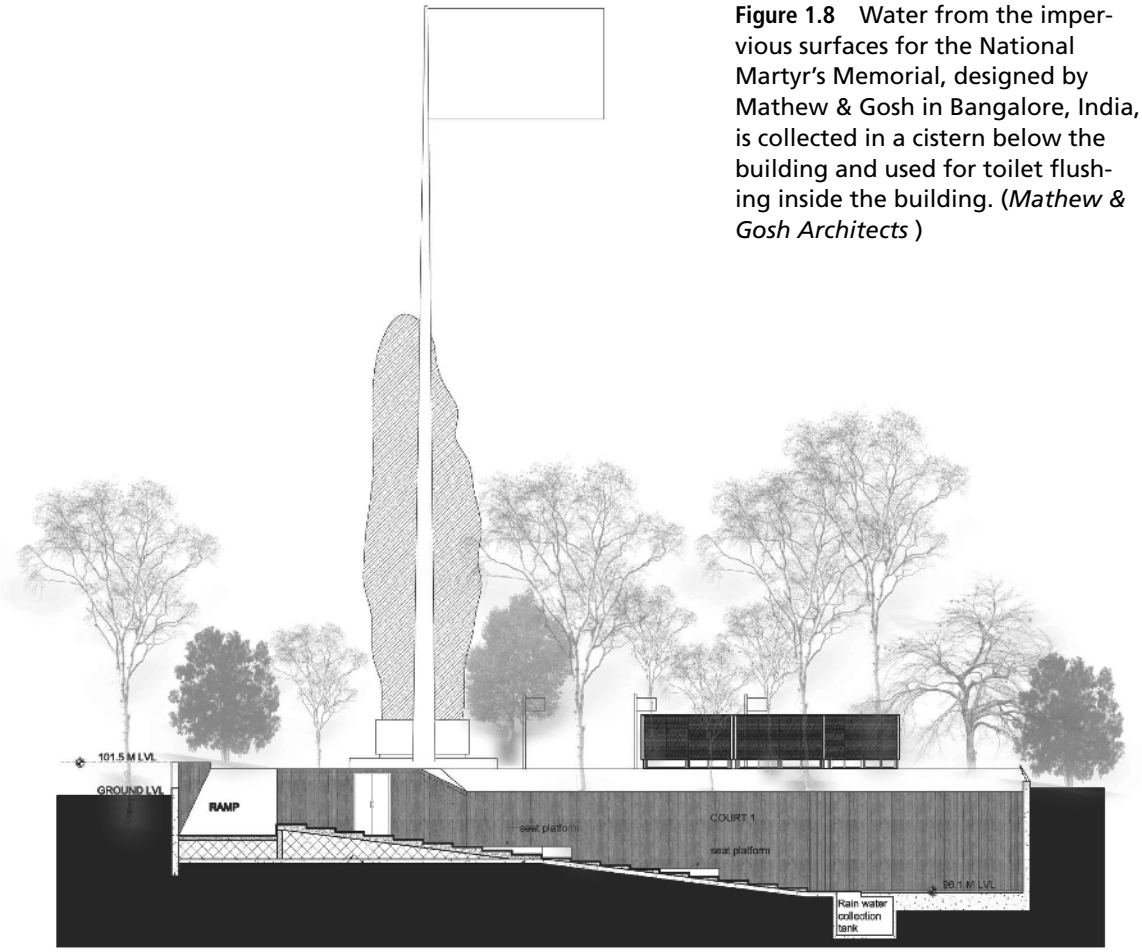


**Figure 1.8** Water from the impervious surfaces for the National Martyr's Memorial, designed by Mathew & Gosh in Bangalore, India, is collected in a cistern below the building and used for toilet flushing inside the building. (*Mathew & Gosh Architects* )

# National Martyr's Memorial

## Bangalore, Karnataka, India

Designed by Mathew & Gosh Architects, this project was conceived as a place to remember those who gave their lives for the country since India's independence in 1947. The client was the Bangalore Development Authority and the building is located at the site of the Rashtriya Sainika Smaraka in Bangalore.

Located on an arterial road of the city, the site gains visual prominence amidst busy thoroughfares. In addition to isolating the site from the noise and pollution, the dense vegetation becomes

**Figure 1.9** Triangular skylights animate the memorial space through the day at the National Martyr's Memorial. (*Mathew & Gosh Architects)*

the foundation for the design of the National Martyr's Memorial. The Memorial is conceived as a place of quiet remembrance and homage.

The ceremonial path of commemoration begins at a series of plaques with the physical marking of 21,763 martyrs' names. Water from the roof of this underground space flows through the site and is collected in a cistern below the building to be used for toilet flushing.

Intended to retain an important green space within the city, the built form of the motivational hall was designed to disappear into the ground. The structure below ground meanders between the roots of the trees to preserve a large part of the vegetation. Of the 324 trees at the site, only 4 eucalyptus trees were removed to accommodate the structure while 40 trees were newly planted.

The entrance to the motivation hall through a large open court is the first of five courts that serve to provide ventilation and daylight into the underground structure. In addition to the open courts, triangular skylights animate the space through the day.

This project is designed to be a "light touch on the ground" within the trees. The concept by the architect is to create a memorial that remembers the untimely loss of precious life and absence of these heroes. The design is to simulate a "lovingly mount of earth patted in a cemetery."

## Germany

The work of Atelier Dreiseitl is known worldwide and has influenced numerous architects to rethink the use of water in urban environments. Prominent landscape designers have included parks, fountains, and elegant stormwater designs as part of architectural site design. Similarly, many collaborations have included urban designs that used water primarily for stormwater management. By using water resources as part of a system that included aesthetics, human interactions, and the naturalization of the urban environment, Atelier Dreiseitl paved the way for a new approach to rainwater collection and management.

A **biotope** is an area of uniform environmental conditions providing a living place for a specific assemblage of plants and animals. Biotope is almost synonymous with the term **habitat**, which is more commonly used in English-speaking countries. However, in some countries these two terms are distinguished: the subject of a habitat is a species or a population; the subject of a biotope is a biological community.[25]

Potsdamer Platz, in Berlin, Germany, was one of the first integrated urban rainwater systems using water as art and public engagement. It created a cleansing, manmade biotope and

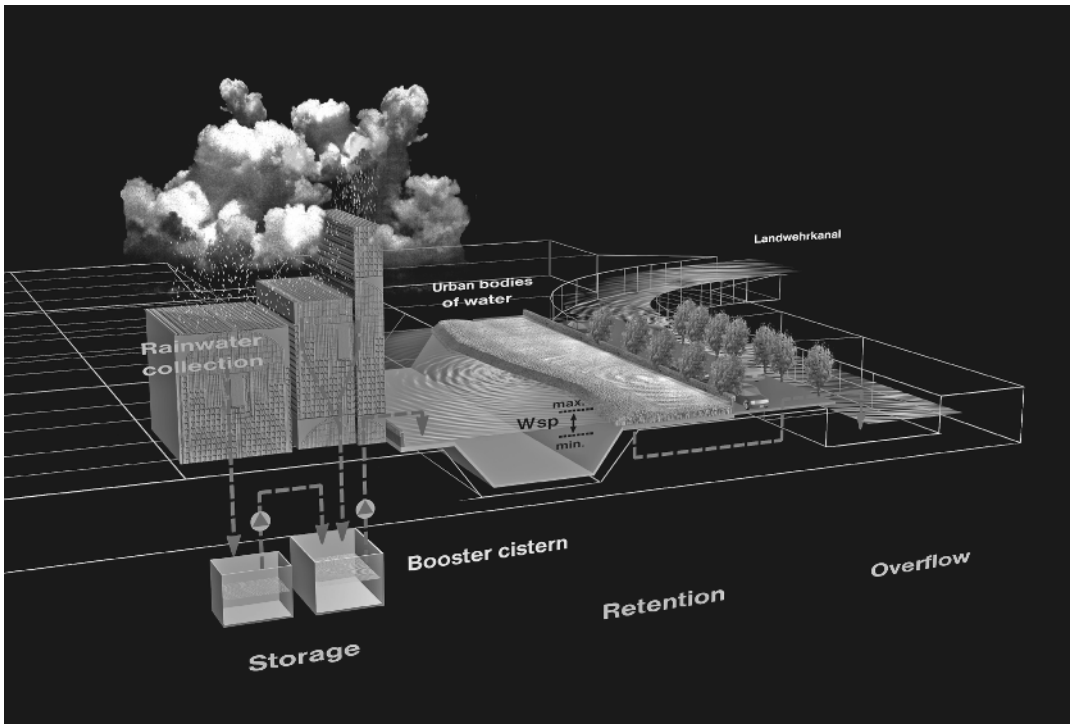


**Figure 1.10** At Potsdamer Platz in Berlin, Germany, Atelier Dreiseitl collaborated with numerous architects to design an integrated water system that adds to the vitality and energy of the City as well as providing stormwater. (*Atelier Dreiseitl*)

used stormwater from the buildings and site for toilet flushing. Since this project, this firm has designed water systems worldwide. Their latest is a project in Indonesia that will take all roof rainwater and turn it into a potable water source for an entire community.

# Potsdamer Platz

## Berlin, Germany

The redevelopment of Potsdamer Platz provided an opportunity for designers to utilize numerous sustainable water management strategies to add to the vitality of the city. A three-acre lake helps create a place that brings nature into the heart of central Berlin.

Rainwater falling on 11 acres of surrounding rooftops makes its way into huge underground cisterns. Thirty-seven percent of the contributing rooftop area employs green roofs, which provide a first line of filtration for runoff entering the rainwater harvesting systems. The cisterns function in two ways:

1. Providing irrigation and toilet flushing water to an adjacent high-rise (50 percent of the toilet flushing water). Technical filters are used as needed to treat water to appropriate levels.
2. Providing makeup water for the lake (the stormwater retention area).

The stormwater in the lake is biologically cleansed using vegetated sand filter beds (biotopes). At its peak, typically during periods of high biological activity—approximately four times per year—close to 4 million gallons of water are re-circulated through the filtration beds. The lake and its watercourses are a unique and innovative response to urban stormwater management and plaza design. These features were designed together to promote a natural drainage progression. When soil moisture capacity is reached, water outflow to a nearby canal is equivalent to that of a naturally vegetated area.

Some of the waterways reflect a formal design to mirror the surrounding architecture; others are more naturalistic and incorporate vegetated cleansing biotopes. At the Marlene-Dietrich-Platz the water reverberates with the city's bustling activities. Water flows to the deepest point of the plaza, forming floating images shaped by flow steps and water cascades. The Potsdamer Platz project is a model for integrating energy and water conservation, biologically based stormwater management, and aesthetics in an urban setting.

**Figure 1.11** Potsdamer Platz integrates various water system designs to create a vibrant natural area in the heart of Berlin. (*Judy Lee/Atelier Dreiseitl*)

**Figure 1.12** Designed as a welcoming gateway to the city, as well as an active hub for large cruise ships, Pier 27 Terminal is built on the impervious surface of a large San Francisco pier. Rainwater harvesting was employed as a means to provide flushing for toilets in the building designed by KMD Architects with Pfau Long Architecture. (*KMD ARCHITECTS + PLA,& PFAU LONG ARCHITECTURE, a Joint Venture*)

### The United States

Many architects, landscape architects, engineers, and planners are working on the development of rainwater collection systems throughout the United States. Some of these projects are driven by the prospect of meeting green building codes and some to meet federal requirements for stormwater management. The Port Authority of San Francisco developed a new primary cruise terminal and gateway to the City at Pier 27 to replace an existing facility. From the beginning, the design of this building included a variety of stormwater management strategies, including rainwater harvesting.

## James R. Herman Cruise Terminal—Pier 27

### San Francisco, California

Designed as a welcoming gateway to the city, as well as an active hub for large cruise ships, this two-story facility is built on the impervious surface of a large San Francisco pier. Architects for the facility, KMD Architects & Pfau Long Architecture (KMD + PLA), are committed to a holistic approach to sustainability. They were challenged to manage stormwater runoff in the design of

**Figure 1.13** Three aboveground rainwater collection tanks are sized to meet both the monthly demand for toilet flushing and for irrigation at Pier 27. (*KMD ARCHITECTS & PFAU LONG ARCHITECTURE, a Joint Venture*)

this 88,000-square-foot cruise terminal facility and an adjacent 2.5-acre public plaza. As part of the ongoing protection of San Francisco Bay waters, KMD + PLA included the utilization of rainfall from the roof for onsite use.

A report by the Port Authority outlined the existing runoff conditions: "The existing pier deck includes the Valley between the Pier 27 shed and the Pier 29 shed, the North Point area, and the Eastern Apron. The existing deck in these three areas consists of approximately 1-1/2 inches of asphalt paving over a 16-inch thick reinforced concrete slab, supported by concrete piles. Stormwater runoff from the Valley and the North Point area is discharged to the Bay through 4-inch diameter drain holes that are distributed on a grid of about 25 feet. The eastern apron drains as sheet flow over the edge of the deck directly into the Bay."[26]

A siphonic roof drain system collects rainwater from a roof area of 48,790 square feet. A vortex filtration system separates debris from the runoff, which travels through a downspout inline filter. Filtered rainwater then travels into a series of aboveground tanks and is used for both toilet flushing and irrigation systems.

The monthly demand for toilet flushing is approximately 15,000 gallons per month. One group of tanks are sized to meet this need, and the water is filtered and treated with an ozone system to remove contaminants, and provide disinfection and deodorization. Two additional tanks with a capacity of 1,300 gallons each are used to collect water for irrigation. The rainwater used for irrigation is not required to be treated, and it is used to water new planting beds that act as biofilters.

# Rainwater Retrofit: Perkins+Will

## Atlanta, Georgia

Retrofitting existing buildings with dedicated water lines for each end use is not always practical. Re-plumbing an entire school or office building to create a dedicated water supply line to the toilets is often infeasible, as it is expensive to open up wall cavities and make the necessary plumbing changes to accommodate a rainwater harvesting system unless it occurs during a major renovation. This is why outdoor irrigation is so often chosen as a relatively cost-effective method for utilizing rainwater in an existing structure.

The following case study of the Perkins+Will office renovation in Atlanta, Georgia, demonstrates a successful use of rainwater for both indoor and outdoor applications.

Architect Paula McEvoy, AIA, LEED Fellow, Associate Principal and Co-director of Sustainable Design Initiatives at Perkins+Will, considered the firm's concerns for water resiliency when renovating their new headquarters. Atlanta was in the midst of a long drought in 2008, and

**Figure 1.14** Concerns for water resiliency and the promotion of sustainable design practices were key drivers for the Perkins+Will Atlanta, Georgia, office renovation, which uses captured rainwater for toilet flushing in tenant spaces. (*Photo: Eduard Hueber/Courtesy: Perkins+Will*)

the reservoir providing the majority of Atlanta's water was at record low levels. This major U.S. city had only seven days of water reserves for most of the summer.

The drought was a wake-up call for businesses in the city as well as throughout the state. Since then, Georgia has adopted rainwater harvesting policies and guidelines in the United States. "The Georgia Rainwater Harvesting Guidelines"[27] manual is available on the Internet and was published in 2009 to demystify the use of rainwater in the residential and commercial sector. This manual outlines the strategies, components, and processes of rainwater collection for the state. Georgia's adoption of Appendix I, "Rainwater Recycling Systems of the 2009 Georgia Amendments to the 2006 International Plumbing Code," was the beginning of a new chapter in policy development for rainwater harvesting in the state. The title of Appendix I has been amended and now reads "Rainwater Harvesting Systems" to accurately describe the source of water.

As a partial response to the drought, the city of Atlanta increased commercial water rates significantly to encourage conservation. The state of Georgia also passed legislation mandating automatic triggers for outdoor watering bans in 2009. Atlanta also initiated improvements to aging infrastructure that contributed to leaks, high energy costs, etc.

Perkins+Will is a firm committed to sustainability and the winner of numerous American Institute of Architecture (AIA) Committee on The Environment (COTE) Top Ten Awards.

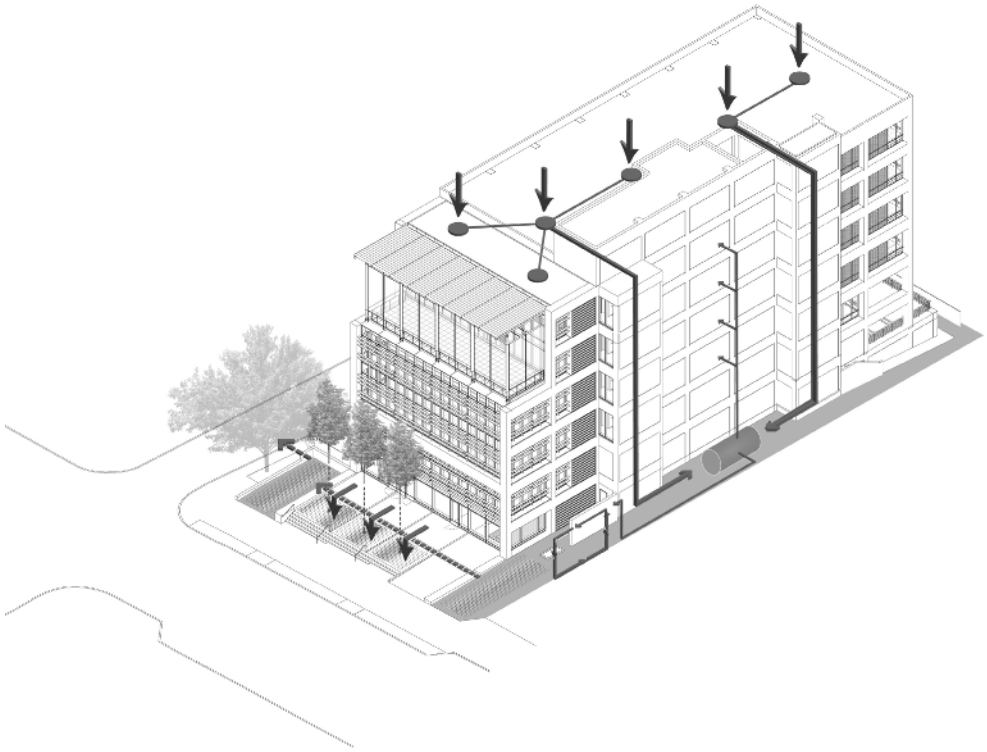

**Figure 1.15** Rainwater system diagram for the renovated Atlanta offices of Perkins+Will. (*Diagram: Courtesy: Perkins+Will*)

The renovation of an existing 1985 high-rise for their new offices included the reduction of energy use by 58 percent.

The firm wanted to display its commitment to the environment and the transformative power of sustainable design by incorporating building re-use and renovation efforts into the concept of sustainability. In addition to LEED Platinum, the project is already a recipient of the Urban Land Institute's Development of Excellence Award. Their Atlanta Office is the highest-scoring Platinum LEED® project in the Northern Hemisphere and the design showcases numerous environmental strategies, including rainwater harvesting.

Rainwater is collected from the roof of the building and a 5th-floor terrace and is stored in a 10,000-gallon cistern. Rainwater is filtered, treated, and utilized for landscape irrigation, low-flow urinals and toilets. This water is used for the firm's headquarters and a museum in the lower floors of the building.

The firm first calculated an economically feasible amount of roof surface from which to collect not the maximum amount of rainwater that was available. The owner realized that more rainwater was available for collection if more surface area (roof and terrace) was employed and a larger cistern was utilized. However, the amount of roof area utilized for rainwater collection and space limitations for the main storage cistern ultimately determined the portion of the toilet flushing that the rainwater system would provide.

Water conservation initiatives and the use of rainwater have cut municipally supplied potable water use by 78 percent from the pre-renovation levels.[28] This project demonstrates the importance of the consideration of all means available (efficient fixtures, alternative water sources, etc.) to achieve water conservation.

Ongoing problems with the city water supply and increasing water and sewer rates influenced the decision by Perkins+Will to include rainwater harvesting as a part of the sustainability strategy for this building. Part of the challenge for all design professionals is to identify the different amounts and uses of water in projects and then to implement appropriate applications of rainwater harvesting, efficient plumbing fixtures, piping design, and treatment.

## POLICY ISSUES AND SUSTAINABILITY

There are numerous policy issues related to the distribution and protection of the world's water systems. These include:

1. The effect on energy savings through water conservation and the water-energy nexus.
2. The response to water scarcity in times of drought and the ability to add resiliency to the water system.

Decentralized rainwater harvesting systems can be part of the solutions to these difficult problems.

### Water and Energy Savings

The design of an efficient water system impacts energy efficiency. There is a symbiotic relationship between water and the energy needed to make it usable to humans. According to the EPA, energy is used in five stages of the water cycle:[29]

1. Extracting and conveying water: From streams, mountain runoff, or aquifers, pumping and conveying water takes energy. Example: According to EPA estimates, the State Water Project (SWP) uses 2 to 3 percent of all electricity consumed in California to pump water over the Tehachapi Mountains for use in Los Angeles.[30]
2. Treating water: Water treatment facilities use energy to pump and process water.
3. Distributing water: Transporting through pumps and piping.
4. Using water: Treatment, pressurization, pumping, heating, and cooling.
5. Collecting and treating wastewater.

According to research by the Sandia National Laboratory in *Energy and Water in the Western and Texas Interconnects*, "water and energy are co-dependent. Water is used directly in hydroelectric power generation and is used extensively for thermoelectric power plant cooling and air emissions control. Water is also needed for energy-resource extraction, refining, and processing. Altogether, the energy sector accounts for approximately 41 percent of daily freshwater withdrawals and 49 percent of total overall daily water withdrawals in the U.S. Likewise, significant energy is expended to extract, convey, treat and deliver water and wastewater."[31]

One of the objectives of this research is to develop an "Energy-Water Decision Support System." This system will facilitate planners to analyze the potential implications of water scarcity and evaluate future policies for water transmission and resource conservation. This regional analysis of the energy-water relationship is a coordinated initiative by federal and state agencies, the power industry, nongovernmental organizations (NGOs), and other stakeholders. Studies like this initiative will influence local, state, and federal water policies in the future as the country works to balance the need for drinking water with other water-intensive uses.

Water and energy conservation and protection of freshwater sources is not only a means for saving natural resources; strong evidence suggests that it has a positive impact on national security. The effects of climate change, increased atmospheric and point source pollutants combined with the increase in world population is causing water scarcity around the world. Policy makers are struggling to balance the need for economic growth with responsible environmental management.

For example, farm subsidies that funded more efficient irrigation techniques were intended to decrease water use. Instead, they have had the unintended consequence of *increasing* water use. The subsidies allowed more crops to be planted using more efficient irrigation equipment, thereby resulting in more water use. This is not a criticism of effective agricultural techniques; however, the stress on aquifers and rivers by inefficient, as well as efficient, techniques is an issue that must be balanced responsibly.

Senator Tom Udall of Oregon is just one of many legislators who hope to encourage farmers to seek the implementation of "new practices that increase quality production through sound management of our precious resources."[32] The federal government has recognized dwindling water resources as a major national security threat. Not only does an eminent shortage of water affect public drinking resources, record-setting droughts in the South, Southwest, and Western United States have impacted agriculture production and food costs.

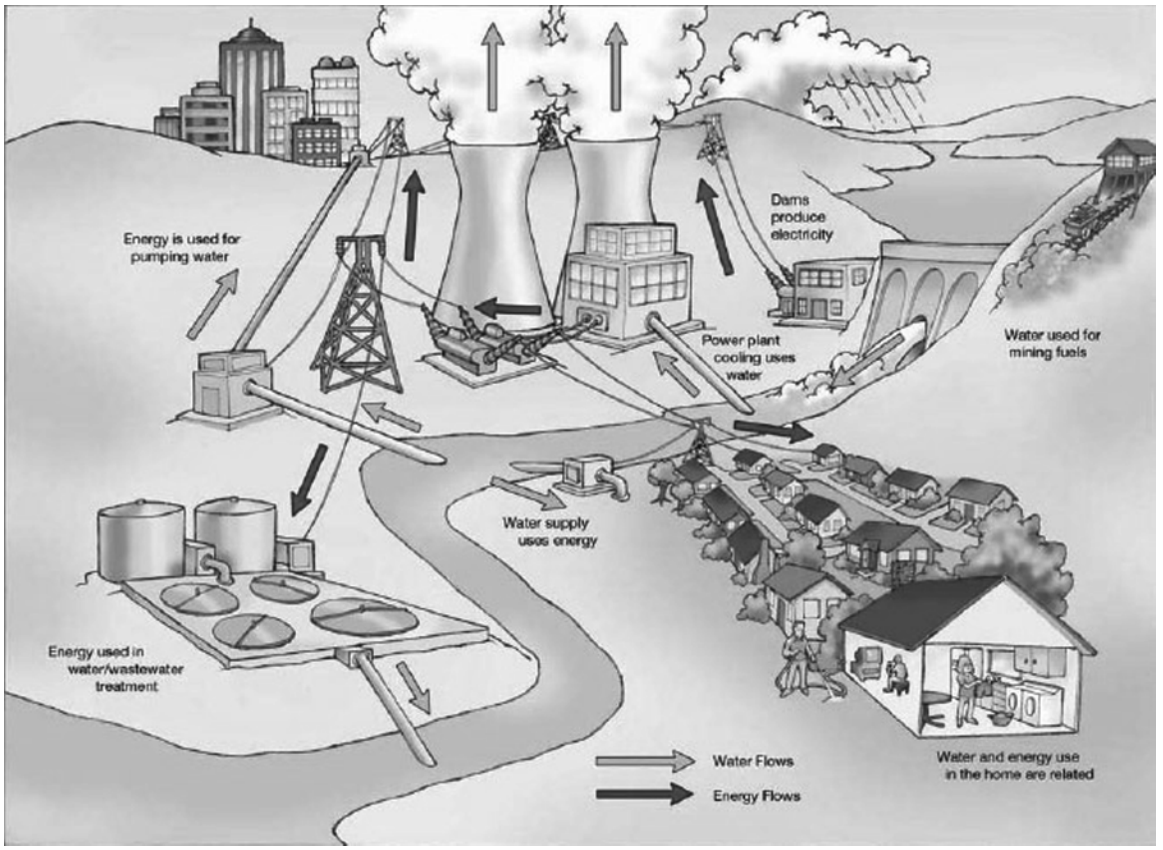


**Figure 1.16** Image from "Energy Demands on Water Resources." (*U.S. Department of Energy, 2006*)

In 2009, the EPA developed an implementation plan for Net-Zero, High Performance Green Buildings. Among the goals for this plan were the development of the scientific and technical bases for significant reductions in water use and improved rainwater retention. The EPA is promoting a 50 percent reduction in domestic water use and maximization of water recycling and rainwater harvesting.

According to Robert Goo, Office of Water at the United States EPA (USEPA), EPA rainwater harvesting policies and programs are part of federal plans for water resilience during climate change. The EPA promotes rainwater harvesting for the following reasons:

1. Reduced detrimental stormwater impacts
2. Combined sewer overflow abatement
3. Integrated water resource management
4. Increased water supplies
5. Reduced energy consumption and greenhouse gas emissions
6. General sustainability goals
7. Climate change resiliency.

According to the Energy Independence and Security Act of 2007, Section 438: Storm Water Runoff Requirements for Federal Development Projects, "All Federal development projects that exceed 5,000 square feet shall use site planning, design, construction, and maintenance strategies for the property to maintain or restore, to the maximum extent technically feasible, the predevelopment hydrology of the property with regard to the temperature, rate, volume, and duration of flow."[33]

The various branches of the U.S. military (Army, Navy, Air Force, Marines) have a two-fold interest in sustainable building and operating practices. They have initiated net zero water as well as net zero energy programs on many new projects to preserve the environment as well as save money. The military is aware of how the increasing use of nonrenewable resources may be the source of armed conflicts by the year 2025.[34]

## Response to Drought Conditions

News reports of water scarcity and record droughts due to climate change are becoming increasingly common. The National Resources Defense Council maintains an interactive map that provides a record of the extreme weather. "In 2012, there were 3,527 monthly weather records broken for heat, rain, and snow in the US, according to information from the National Climatic Data Center. That's even more than the 3,251 records smashed in 2011—and some of the newly-broken records had stood for 30 years or more."[35] The National Drought

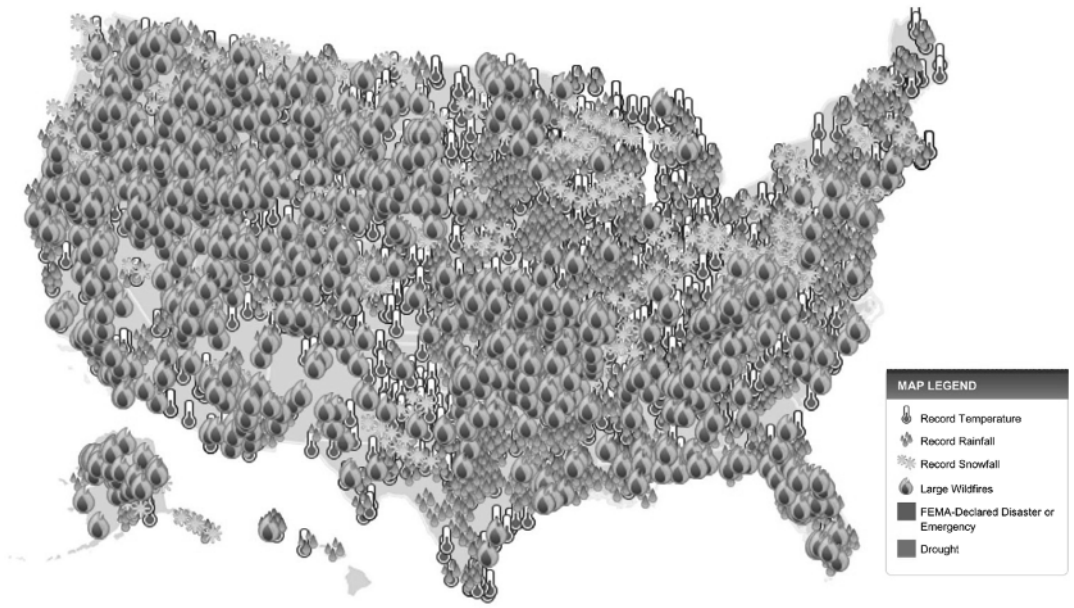


**Figure 1.17** Extreme Weather Map showing thousands of weather records broken in the U.S. in 2012. (*Natural Resources Defense Council*[37] *ww.nrdc.org/health/extremeweather/*)

Monitor records areas of the United States that are impacted by this new normal, which has increased the cost of food production.[36]

According to the United Nations, climate models point to the drying and lowering of both lake and river levels throughout North America. An extended hot, dry period starting midway through 2012 has made these trends worse for numerous U.S. cities. More and more regions of the United States are finding that records continue to be broken for cooling as well as heating degrees in almost every climate zone. Unusual storms, lack of rain, or too much rain adds complexity to budget planning and policy directives. As suggested in a 2009 United Nations Report,[38] rainwater harvesting can be used as a local intervention with benefits on the ecosystem and human livelihoods. The introduction of rainwater harvesting systems should always be compared with **conventional infrastructure** investments.

## Resiliency in Australia

Rainwater harvesting can increase the resiliency of a city's water supply. Studies by P.J. Coombes and ME Barry of Australia describe the advantages of designing a resilient system. The following excerpt from an article by P.J. Coombes and ME Barry illustrates this point.

"The majority of water applied to Australian cities has, until recently, been sourced from rainfall runoff collected from inland catchments. Australia experiences a highly variable climate that has required the construction of large dams to provide a secure water supply to cities. The future reliability of urban water supplies dependent on single centralized sources of water is uncertain due to the combined pressures of population growth, a highly variable climate and the potential for climate change."

"It is now recognized that multiple sources of water from centralized and decentralized locations, in combination with a diverse range of water conservation strategies, can increase the resilience and reliability of a city's water supply (PMSEIC, 2007). Nevertheless, the water available in our cities from rainwater, stormwater and wastewater sources is not fully exploited."

"It was postulated by Coombes (2002) and Coombes & Kuczera (2003) that the efficiency of the water supply catchments is considerably less of the water supply catchments feeding rainwater tanks in urban areas. It has also has been shown that in dry years (rainfall < 500 mm) the annual runoff in water supply catchments is insignificant. In these years, water losses to the soil and atmosphere balances most of the rainfall, and as a result water supplies to cities are almost totally dependent on water stored in dams from more bountiful years and from aquifers. In contrast, the roof catchment, being impervious, only experiences a small loss at the commencement of each rain event and is able to harvest the majority of rainfall, up until storage overflow. As a result, a rainwater tank can harvest beneficial volumes of water even during drought years. This result suggests that rainwater harvesting in cities can supplement the performance of dams, providing an overall improvement in the resilience of urban water supplies."[39]

## Privatization and Relocation

The impact of the privatization of water resources is also a worldwide human rights and social justice issue. A new threat to the public's access to freshwater is the rapid relocation of water supplies throughout the globe.

Poorer areas of the world are becoming destabilized by the extraction and relocation of their water resources. Charles Fishman, author of *The Big Thirst: The Secret Life and Turbulent Future of Water*, keynoted the American Society of Landscape Architects 2012 annual meeting and challenged the landscape architects to become "water revolutionaries."[40] According to Fishman, more water is exported out of Fiji than is available to the residents of Fiji, as water resources are being redistributed around the globe.[41] Rainwater harvesting systems with proper design and maintenance can aid in the redistribution problems being experienced around the world. The Millennium Development Goals published in 2009, by the United Nations,[42] outline the role of rainwater harvesting as a technology that can help alleviate numerous problems for drinking water in developing countries.

# VALUING WATER RESOURCES

## History and Early Codes

As populations grew and civilizations developed, codes and regulations were written to organize trade, monitor social interactions, and direct the built environment. Regulations describing the use of water were among the first codes recorded, as seen in the following excerpt from Babylonia.

The Hammurabi Code of Laws, noted by many ancient history scholars as one of the most noteworthy pieces of the Hammurabi records, is a body of laws carved in stone during the reign of the ancient king Hammurabi of Babylonia (1795–1750 BC). It describes how an ordered society is maintained, and details the rules and punishments for those who do not abide by the code. A provision in this code on the subject of water is found in Section 55.

> "55. If anyone open his ditches to water his crop, but is careless, and the water flood the field of his neighbor, then he shall pay his neighbor corn for his loss."[43]

As described thousands of years ago, uncontrolled flows of stormwater had the same devastating effects on property as they do now. Early water codes were developed predominantly to safeguard property owners and neighbors from the upstream effects of water storage, use, diversion, and quality. The basic premises of these ancient laws apply to water directives today. Modern stormwater regulations represent a continuum of thought that has its roots thousands of years ago.

Water purity was also an issue to early humans. As cities grew, the contamination of the water supply by waste and improper storage led to the modern centralized water systems. Today in the United States, the federally legislated Safe Drinking Water Act (1974) regulates the quality of water in public water supply systems. According to the EPA, public systems are defined as those that serve more than twenty-five individuals (or at least fifteen connections) for at least six months per year. The EPA has enforcement agreements with individual states and normally does not enforce the provisions of the Safe Drinking

Water Act directly. The responsibility falls on the shoulders of states and local governmental authorities to do the actual enforcement.[44]

The solutions for providing safe and adequate water supplies for the built environment will be a combination of public and private, centralized and decentralized water systems, for both the residential and nonresidential sectors. Rainwater harvesting is not a new concept, rather it is a different way of looking at the water supply in a modern context.

## Source

Generally, urban water supply collected from various sources (i.e., lakes, rivers, springs, and groundwater, which are fed by rain). Collected water is then treated and distributed through centralized water piping systems. All water withdrawn for public use is required by law to be treated to potable drinking standards by the Safe Water Drinking Act. This distribution model is based largely on 19th-century engineering and requires an expensive and extensive municipal treatment and underground community infrastructure. These centralized systems depend on continuous extraction from the various sources described above.

Although all water on Earth originates from precipitation either in the form of rain or snow, we rarely gather it at the source. Water is extracted once it is in the ground or in a river or reservoir. Often a dam is built at the lowest part of a watershed and water is pumped to a treatment plant and then pumped back to the user. Once it is used, the water is piped back to a treatment station as sewerage and after some level of treatment/improvement is allowed to flow downstream where the next community can use it. Recent concern over the amount of trace chemicals and chemical pollutants found in even treated water is drawing more and more attention of policy makers and the public alike.

Meanwhile, the rainwater that hits the roofs and paved surfaces (keep in mind that this water has reached the site with no human-produced energy) is channeled to the stormwater gutter and quickly funneled to the nearest river or ocean.

These one-directional pathways depend on one crucial reality: continued influx of water from upstream sources or present in underground aquifers. Much of California, for example, depends on water derived from reservoirs that are fed by snow packs in the Sierras and other surface reservoirs from other states. The massive population in Southern California would not exist without the influx of water from the Sierra Nevada Mountains as well as the Colorado River. The Rainwater Capture Act of 2012 addresses this issue by promoting smart water conservation measures and rainwater capture for indoor and outdoor use.

As simple as it may seem, catching and using water near its origin represents a paradigm shift in the way we value water. According to a report on urban water sustainability, "Water is very heavy, at one ton for every kiloliter. Sourcing water close to its end use has definite energy benefits."[46] Those energy benefits mean energy savings. Decentralized water collection is much more direct and affords the end user an intimate connection between the local climate and the built environment. With a rainwater harvesting system the end user now becomes the owner and takes responsibility for the collection, treatment, and maintenance of the water supply from that decentralized system.

### AB 1750, Solorio. Rainwater Capture Act of 2012.

***PART 2.4. Rainwater Capture Act of 2012***

**10570.** This part shall be known, and may be cited, as the Rainwater Capture Act of 2012.

**10571.** The Legislature finds and declares all of the following:

(a) As California has grown and developed, the amount of stormwater flowing off buildings, parking lots, roads, and other impervious surfaces into surface water streams, flood channels, and storm sewers has increased, thereby reducing the volume of water allowed to infiltrate into groundwater aquifers and increasing water and pollution flowing to the ocean and other surface waters. At the same time, recurring droughts and water shortages in California have made local water supply augmentation and water conservation efforts a priority.

(b) Historical patterns of precipitation are predicted to change, with two major implications for water supply. First, an increasing amount of California's water is predicted to fall not as snow in the mountains, but as rain in other areas of the state. This will likely have a profound and transforming effect on California's hydrologic cycle and much of that water will no longer be captured by California's reservoirs, many of which are located to capture snowmelt. Second, runoff resulting from snowmelt is predicted to occur progressively earlier in the year, and reservoirs operated for flood control purposes must release water early in the season to protect against later storms, thereby reducing the amount of early season snowmelt that can be stored.

(c) Rainwater and stormwater, captured and properly managed, can contribute significantly to local water supplies by infiltrating and recharging groundwater aquifers, thereby increasing available supplies of drinking water. In addition, the onsite capture, storage, and use of rainwater for nonpotable uses significantly reduces demand for potable water, contributing to the statutory objective of a 20-percent reduction in urban per capita water use in California by December 31, 2020.

(d) Expanding opportunities for rainwater capture to augment water supply will require efforts at all levels, from individual landowners to state and local agencies and watershed managers.[45]

## Value and Water Rates

*We pay to bring water in, we pay to get rid of it, and the water that is free, we pay to channel it away as fast as possible through costly stormwater infrastructures.*

—Georgia Taxpayer, 2013

There are many intrinsic values to rainwater collection. The larger implications to society and the environment typically are not the only motivators for implementing rainwater harvesting systems. Owners are beginning to realize that the installation of these systems have a public relations benefit due

to an increasing awareness of environmental issues. Public policy makers and elected officials are considering rainwater harvesting as another method for achieving not only increased water supplies but also for improving water quality downstream. Knowledge of these environmental benefits by policy makers is critical when forming new codes, regulations, and financial incentives that encourage rainwater harvesting by both private and public entities.

Water rates in the United States vary significantly from region to region. Consider the following: "A family of four using 100 gallons of water in Phoenix, Arizona will pay about $34.29 per month compared to $65.47 for the same amount in Boston Massachusetts. . . . The irony is that there is approximately five times more rainfall in the Boston area as compared to the Phoenix area. . . . A family of four using 100 gallons per person each day will pay on average $32.93 a month in Las Vegas compared to $72.95 for the same amount in Atlanta, which has more than ten times the amount of average annual rainfall as Las Vegas, according to National Weather Service statistics."[47] How can water rates be lower in the dryer part of the country while rates are higher in the wetter parts? Part of the answer is linked to the role that government subsidies play and the complexity of U.S. water policy.

In 2012, Circle of Blue, an international nonprofit affiliate of the think tank The Pacific Group, reported that water rates have risen 18 percent overall since 2010 and at least 7 percent in 30 major U.S. cities.[48] Although per capita water use is declining primarily due to user conservation efforts, the rates charged to customers continue to rise. It is difficult for the public to understand how lower consumption can equal higher cost. Even though there may be a lesser volume of water flowing through the pipes, much of the cost for maintaining and upgrading this infrastructure does not decrease and the cost for maintenance continues to rise.

To make matters worse, the decreased flows (due to user conservation) through the existing sewers can cause problems with the sewers' ability to move solids downstream as plumbing engineers size sewerage drain pipes based on providing an adequate amount of liquids to move solids effectively in an engineered drainage system.

As water utility managers and design professionals encourage the public to conserve and use less water, the result is a decline in revenues. Water rates have risen due to rising operational and maintenance (chemicals, repairs, labor, and so forth) costs as well as the need to account for lost revenues because of lesser water consumption. It is important to note that in most jurisdictions in the United States sewer rates are based on water consumption volumes. Therefore, there are also corresponding declines in sewer revenues because of lower water consumption. The unintended consequence of the increase in water conservation is an increase in taxes and/or fees to replace the declining revenues.

## RETURN ON INVESTMENT

The perception that rainwater harvesting systems are not economically feasible is rooted in the fact that their cost is weighed against one single item: the cost of municipal water over a certain period. In the past, a simple return on investment (ROI) calculation included the amount spent on the rainwater harvesting system (tanks, pumps, treatment, and the like)

versus the cost of municipal water. The formula generally used was as follows:

$$\text{Cost}_{\text{RWH}} - \text{Cost}_{\text{MW}} = \text{ROI}$$

where

$\text{Cost}_{\text{RWH}}$ = cost of rainwater harvesting system ($)

$\text{Cost}_{\text{MW}}$ = cost of municipal water over time ($)

ROI = return on investment ($)

The belief that water is free and unlimited needs to change to one that places an intrinsic value on water and its inextricable relationship to the built environment. A key component in calculating the ROI on rainwater harvesting systems is the cost of municipal water ($\text{Cost}_{\text{MW}}$). Water rates, by and large, do not reflect the total infrastructure replacement costs. Using traditional water rates is not the best way to measure the $\text{Cost}_{\text{MW}}$. There are infusions of grant money and local options sales taxes that are not accounted for in what is charged to the water consumer. Thus, using $\text{Cost}_{\text{MW}}$ as the way to measure the ROI of a rainwater harvesting system is an inadequate way of valuing these systems.

According to Mr. Jason Peek, formerly with the City of Athens Public Utilities Department, the federal government heavily subsidized water infrastructure in the United States before 1980. As water rates were developed (prior to 1980), they did not factor in the initial infrastructure costs and the depreciation of the infrastructure. They largely reflected only operations and maintenance. Since this time, local and state water-related infrastructures have been funded at the local level. As is widely acknowledged, the decaying infrastructure across the United States is seen as a looming tsunami on the not-so-distant horizon. If water rates are not modified to reflect the actual costs of pending or ongoing upgrades and additional infrastructure, it is unclear from where the revenue will come to cover these expenses.

New water infrastructure expenses are paid largely by new customers and municipalities via connection fees, impact fees, and bond issues, which are not built into actual water rates. During economic downturns, revenue is not generated by new customers and must come from somewhere, either in the form of taxes, fees, or rate hikes to the public.

Stormwater management infrastructure and its associated costs are now compulsory in commercial development and increasingly common across a wide array of residential construction. To a large degree, stormwater infrastructure is designed and built to prevent loss of life and property from devastating floods resulting from impervious surfaces. There is no ROI on municipal stormwater infrastructure and the costs are buried in taxes and fees.

Rainwater harvesting has the potential to reduce the cost of water supply and manage stormwater runoff through the application of a dual-purposed infrastructure. Whenever rainwater/stormwater can be captured onsite for either indoor or outdoor uses, some of the effects of impervious surfaces are mitigated. More water managed onsite equals less water to be managed offsite and downstream.

Rainwater harvesting systems reduce flows to an overburdened stormwater drainage network and represent a "real savings" that is not included in the traditional $\text{Cost}_{\text{MW}}$. Municipalities are beginning to develop policies that encourage storage and treatment of the initial amount, or the first flush, of rainwater in a storm event, in order not to overwhelm existing drainage infrastructure. Reduction

of erosion to banks on rivers and streams are additional benefits.

Some developers are finding that rainwater harvesting systems, as part of a stormwater management plan, can actually increase the developable area on a site. The case study for Markets at Colonnade is an example of how one developer increased the buildable area by 50 percent by incorporating this methodology. Given the economic and environmental benefits of rainwater harvesting, future development projects that include rainwater harvesting systems may become financially and ethically viable.

In conclusion, with rising water rates, potential water scarcity and new policy directives to improve urban runoff water quality and quantity, current ROI calculations must include the benefits that rainwater harvesting affords. *Rainwater harvesting systems enhance the resiliency of centralized water supply and drainage systems*. A better formula for a rainwater system ROI calculation should include, in addition to the $Cost_{MW}$, the costs listed below.

$$Cost_{RWH} - Cost_{MW} - ED - PP - RR - SI - HT - MF - BA - MB = ROI$$

where

$Cost_{RWH}$ = cost of rainwater harvesting system ($)

$Cost_{MW}$ = cost of municipal water over time ($)

ED = costs associated with environmental degradation ($)

PP = costs associated with pollution prevention ($)

RR = costs associated with river restoration ($)

SI = costs associated with stormwater infrastructure ($)

HT = increase in tax rates ($)

MF = municipal fees ($)

BA = costs associated with the increase in buildable area ($)

MB = costs associated with market branding ($)

# Market at Colonnade

## Raleigh, North Carolina

Located in a highly desirable part of Raleigh, North Carolina, this small parcel was considered prime real estate for a commercial development. Numerous developers and design firms investigated build–out scenarios using conventional stormwater techniques, but could not make the numbers work or satisfy the community zoning requirements. This site became even more difficult to develop because of the latest state and local stormwater requirements that required additional treatment and reduction of peak discharge from larger rainfall events. Located in an area with roughly 43 inches average precipitation, maximizing the site development using traditional methods drastically reduced the possible building envelope.

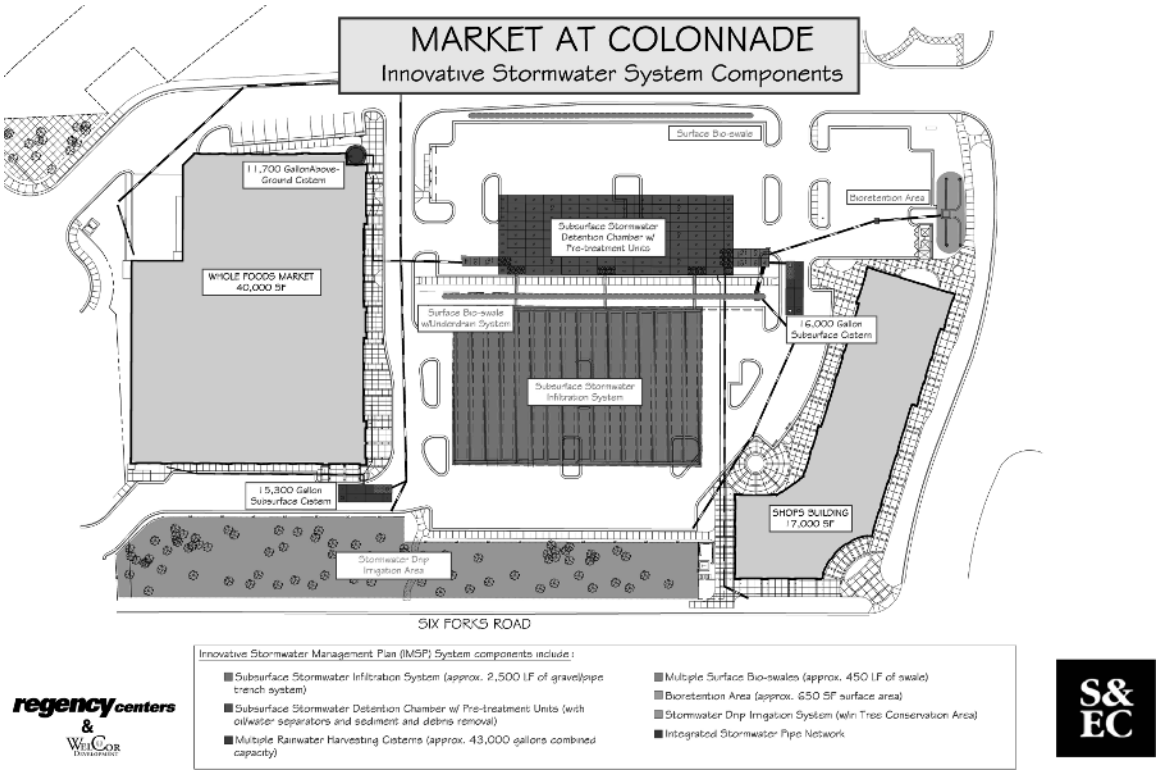


**Figure 1.18** Site plan diagram. (*Soil and Environmental Consultants, PA)*

The Market at Colonnade is representative of an ever-increasing number of in-fill projects within the City of Raleigh and the greater Research Triangle area. In these cases, limited site area and high land costs demanded higher density and maximum yield to support development alternatives. On conventional development sites, typical stormwater best management practices (BMPs) such as wet detention ponds, infiltration basins, and stormwater wetlands often require significant surface area when designed in accordance with current standards. On large development tracts, such conventional applications are possible; however, on smaller sites or in-fill development projects like Colonnade, land costs alone may make the use of conventional BMPs prohibitive to achieving project density necessary to make the project financially viable.

Regency Centers (Regency), Colonnade's developer, desired to lead the way in sustainability by creating the first-of-its-kind stormwater management system while at the same time still maximize the site's building potential. To do so Regency turned to a local engineering and environmental consulting firm, Soil & Environmental Consultants, PA (S&EC) to analyze alternatives for onsite stormwater treatment, retention, and detention. Patrick Smith, PE,

LEED®AP and Mike Ortosky, LSS, ASLA, both of S&EC, collaborated to integrate a variety of rainwater harvesting and low-impact stormwater management practices. This solution provided increased utilization of the 6.25 acres of land. It allowed for the 57,000-square-foot retail development (anchored by a 40,000-square-foot Whole Foods Market) in an area that was not considered large enough for a shopping center, required parking, and a traditional surface stormwater system.

Colonnade is unlike any other project within the State of North Carolina with regard to its approach to stormwater management with an Innovative Stormwater Management Plan (ISMP). This unique application utilized proven wastewater treatment and infiltration technology, in conjunction with the use of select conventional devices, such as underground detention, rainwater harvesting systems, surface bio-swales, and a bioretention area. These applications serve to showcase the value of a more comprehensive stormwater management approach. At a time when the conservation of resources, such as potable water and groundwater, is essential, the various elements at Colonnade bring much needed attention to the harvesting, reuse, and infiltration (and return to groundwater) of stormwater runoff. The project team, including a nationally recognized developer, a local municipal stormwater utility, a stormwater consultant and designer, and a major area university, combined to form a true public-private partnership.

The Innovative Stormwater Management Plan (ISMP) captures the first one-inch of runoff from paved surfaces and infiltrates this volume utilizing a subsurface gravel and pipe trench system approximately 2,500 feet in length. A combination with three cisterns (one aboveground and two underground), captures approximately 43,000 gallons of rooftop runoff and results in near zero site discharge from the one-inch storm, providing the overall reduction of annual runoff volumes. All surface runoff from the center's paved surfaces beyond the one-inch storm is similarly captured, pretreated (removing oil, sediment, and debris), and stored in the 185-foot by 65-foot by 4-foot-high underground detention chamber, estimated to hold approximately 350,000 gallons of water. Site stormwater discharge is released from a single 15-inch diameter outlet to the adjacent municipal stormwater system.

Post-development 2-year and 10-year stormwater peak discharges are reduced by over 65 percent and over 50 percent, respectively, when compared with the pre-development condition by ISMP's enormous detention capacity. The system's retention and infiltration of runoff from the first one- inch of rainfall drastically exceeds regulatory standards by providing nearly 100 percent removal requirements of Total Suspended Solids (TSS) and Total Nitrogen (TN) from the one-inch storm. By comparison, conventional stormwater devices typically provide just 85 percent and 35 percent removal of TSS and TN, respectively. In addition, as roughly 90 percent of the rainfall events in this portion of North Carolina are one- inch or less, site infiltration promotes groundwater recharge in an unprecedented fashion.

Harvested rainwater from part of the Colonnade's roof on the Whole Food's store is stored in an 11,700-gallon aboveground cistern and used inside the store for toilet flushing. Additional rainwater stored in two underground cisterns (totaling 31,300 gallons) is used for site landscape irrigation and to promote infiltration through drip irrigation within an onsite tree conservation

area. Surface bio-swales and a bioretention area provide additional treatment of stormwater while providing additional localized infiltration to support groundwater recharge.

Colonnade's ISMP serves to educate both the public and private sectors (regulators, developers, land planners, designers, and the general public) on innovative stormwater management approaches. A North Carolina Clean Water Management Trust Fund (CWMTF) grant recipient, the project incorporates site monitoring by a major area university for a 12-month period. Project monitoring results and performance data will be evaluated to allow for the development of necessary design guidance for similar future stormwater management plans. Project results have been made available to the public and private sectors through presentations at various professional and educational venues and various publications.

Both retail buildings at Colonnade are LEED Silver Core and Shell Version 2.0 Certified. The Whole Foods Market is LEED Gold Commercial Interiors Certified. The project has also been recognized with a variety of awards for its innovative and precedent setting approach to stormwater management.

Due to the holistic approach to stormwater management the developable area of the site was increased by 50 percent. The ISMP helped to expedite the permitting for the 40,000-square-foot Whole Foods' building. It also allowed for the development of an additional 17,000 square feet used for a small strip shopping center on the site.


**Figure 1.19** Project sustainability is showcased by this exterior rainwater harvesting cistern that stores water for toilet flushing in store restrooms. *(Regency Centers)*

## CHALLENGES, EDUCATION, AND PARADIGM SHIFTS

There are many challenges to the development of a rainwater collection system. These include:

- Removing stereotypes and preconceptions as to the uses of rainwater
- Conflicting standards, codes, regulations, and guidelines
- Conflicting water quality testing protocols and procedures

Overcoming these challenges will result in the paradigm shift necessary for the wider spread implementation of this technology. System planners/designers will need to respond to these and other challenges as they join the many pioneer architectural and engineering firms and research centers who are using rainwater harvesting in their practices.

### Stereotypes and Preconceptions

Unfortunately rainwater harvesting is often equated with small rain barrels attached to gutters to collect water for outdoor plant irrigation. The fact is that rainwater harvesting systems can be large and complex depending on the end use and the type of controls employed, particularly for nonresidential applications. The degree of complexity is ultimately determined by the programmatic needs of the end user.

### Rainwater Technical Standard

The American Rainwater Catchment Systems Association (ARCSA) and The American Society of Plumbing Engineers (ASPE) have published the ARCSA/ASPE 63 Standard as a technical standard for the rainwater harvesting industry. The following is an excerpt from the Foreword: "The purpose of this Standard is to assist engineers, designers, plumbers, builders/developers, local government and end users in safely implementing a new rainwater catchment system. This standard is intended to apply to new rainwater catchment installations as well as alterations, additions, maintenance and repairs to existing installations. This standard is intended to be consistent with, and complimentary to, nationally adopted codes and regulations. However, designers/installers are advised to consult with the authority having jurisdiction regarding local conditions, requirements and restrictions."[50]

> A technical standard is an established norm or requirement in regard to technical systems. It is usually a formal document that establishes uniform engineering or technical criteria, methods, processes and practices.[49]

The rainwater industry generally falls into two groups: one whose focus is on smaller-scale commercial and residential systems and the other whose focus is on larger-scale commercial systems. What works on a small-scale system may be impractical if not impossible to achieve on a larger-scale building or on a high-rise building. Much of the component selection is based on scale.

Rainwater harvesting systems are not inherently experimental, but *are* new for most designers. These systems are often overbuilt primarily due to the lack of conceptual understanding of the practice of rainwater collection. By following some of the key guiding principles and fundamentals outlined in ARCSA/ASPE 63 Standard and this book, rainwater systems need not be excessively expensive or complicated. A well-designed system will follow sound mechanical engineering practices and provide the least

amount of technology necessary to accomplish the task. These systems are capable of producing high-quality water for most nonpotable applications as well as potable ones.

## Water Quality

One of the barriers to the introduction of rainwater harvesting systems in almost any community is the perception that rainwater is not safe. Rainwater, as well as the source water from most municipal systems, has to be treated before it is used. Even municipal water extracted from lakes, streams, and aquifers contains unsafe levels of contaminants until it is treated to appropriate levels for domestic water use. It is no different with rainwater. Rainwater *can* and *is* being treated successfully for both potable and nonpotable water uses worldwide.

Another issue is the lack of a standard testing protocol. Drinking water provided by municipal systems is treated to established federal standards. Drinking water from private wells is usually tested on a one-time basis when the well is first drilled. Ongoing testing is up to the individual owner. In many parts of the world, including the United States, no testing is required for deep wells when they are not connected to a public drinking water supply. If a municipality uses well water as a source, the water quality at the well is monitored regularly *and* the well water is treated continuously so that it meets established standards for drinking water. When it comes to decentralized rainwater collection, there is a lack of established treatment protocols, both for potable and nonpotable uses. As a result, rainwater that is collected for use onsite is unnecessarily restricted in many jurisdictions.

One of the main challenges to rainwater harvesting is in the realm of public policy, particularly in the permitting of a rainwater harvesting system. Permitting officials (building and public health) have to be confident that the site-collected water is being treated properly for the end use. Specific treatment strategies must be planned and communicated to the authority having jurisdiction so that the rainwater is treated appropriately for the intended end use. Treatment requirements are directly related to the end use. Rainwater for use in indoor nonpotable application, such as toilet flushing and evaporative cooling, may require much less treatment than rainwater for indoor potable use.

## Paradigm Shift

Any time water is collected onsite and is brought into the footprint of a building and onsite storage, pressurization, and treatment is required, the responsibility for the water supply is shifted from the local municipal utility to the building owner. Building owners will assume the construction and maintenance of the alternative water supply. In many cases the alternative water supply will have a connection to the municipal water supply. This is a paradigm shift from one that assumes that all water will be supplied by a municipal water source to one that allows the municipal water supply to be supplemented by decentralized onsite collected water. When a rainwater harvesting system fails or is low on water and it is supplying critical functions of a building, then the backup switching mechanism becomes even more critical. System designs in urban settings must be carefully planned with appropriate backflow prevention strategies incorporated to prevent co-mingling of potable water with nonpotable rainwater sources.

In the United States, water is expected to be available regardless of where we live and to be used in the same ways whether

the location is in the water-rich East or the drought-prone West. Often people conscientiously choose the location of their cities and towns based on sunny climates and lack of rain, but expect that the water will always be there to support their water-rich lifestyle. They assume that technology will provide solutions that allow the habitation of areas that lack the environmental resources for large populations. According to Neal Shapiro, Watershed Program Coordinator for the City of Santa Monica, "a lot of people want to have green lawns year round, and they are transplanted from the East coast where they can have a green lawn most of the year because it rains year round. They come to Southern California, where you can grow things year round due to the mild climate. They are used to seeing green all the time. That doesn't work, you can't transplant East coast watershed mentality to Southern California where there is a Mediterranean climate. That's not how nature works."[51]

The final challenge to designers of rainwater harvesting systems is in the integration of all of the components, materials, construction methods, and space constraints within the parameters of a particular site and building program. Rainwater harvesting should be viewed as a distinct system, and not merely a collection of parts. In order to create a successful rainwater harvesting system, the designer needs the input from the architect, engineer, landscape architect, owner, and the code authorities having jurisdiction.

A sustainable design includes rainwater harvesting as a critical environmental strategy that contributes to the conservation of potable water and aids in stormwater management.

**Figure 1.20** The 2001 Philip Merrill Environmental Center, designed by SmithGroup for the Chesapeake Bay Foundation, was the first Platinum LEED® building. This project demonstrates that a design that includes a number of sustainable strategies including rainwater harvesting can save energy and water resources. (*Photo courtesy of the Chesapeake Bay Foundation/www.cbf.org*)

Site-collected rainwater should not only be used for outdoor irrigation but also for uses inside the building envelope. The challenge for the 21st century will be how to harness site-collected rainwater so that buildings can be a beneficial part of the hydrologic cycle.

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