

DESIGNING RAINWATER HARVESTING SYSTEMS

Integrating Rainwater into Building Systems

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WILEY

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Additional material that complements this book is available to purchasers of *Designing Rainwater Harvesting Systems*. To view this material, visit the companion website at: www.wiley.com/go/rainwaterharvesting

Preface

G. EDWARD (EDDIE) VAN GIESEN

August 2013

After receiving my Masters in Landscape Architecture from the University of Georgia in 1995, I worked as a self-employed design/build landscape and general contractor and homebuilder in Athens, Georgia. I always incorporated green building practices, and received local sustainable building awards, but I knew that I could do more.

In 2007, we were all on the edge of the deepest economic recession that any of us could remember. I had an eerie suspicion that the housing boom was resting on a foundation of loose sand. By the end of the summer, homebuilding, as I knew it, was over. The profession that I had enjoyed for ten-plus years was not there anymore. I was forty-six years old and suddenly out of business.

At the same time, along with the economic recession, Georgia and much of the Southeastern United States was in the grip of an extreme drought. Due to the State's increasing population, the effects of this drought were significantly amplified. Either we were all going to have to find other sources of water for the region or we would be increasingly vulnerable to water scarcity.

I did a lot of soul-searching in those months. I reflected on a trip made to Northern California in 2001, and a workshop I attended on rainwater harvesting. I read a few books on the subject, but little did I know that in only six years I would embark on the greatest adventure of my life.

I discovered that rainwater harvesting could be an answer to our water woes. It was a no-brainer. Rain falls on the roof; it is collected and utilized. Simple, easy, and sensible. Shortly thereafter, I stumbled upon the American Rainwater Catchment Systems Association (ARCSA). Through ARCSA I came to know people who had experience and generously shared their knowledge. I did not need to reinvent the wheel.

I began to install systems on a small scale and eventually worked with a company in North Carolina. By 2010, that company was bought by Watts and I joined them as the public policy director. Later I became the National Sales Manager and through my travels, I have had the opportunity to see the bigger picture. There is an enormous potential yet to be realized. Two things became abundantly clear: (1) education is essential for all the parties involved in these systems, and (2) plumbing codes need to be developed so that the industry can have a foundation upon which to build.

The opportunity to educate the design community through this book resonated with me when I was approached to be a co-author.

It was a chance to establish and reinforce the fundamental principles of rainwater collection, as well as illuminate the connections between water policies, codes/regulations, and new and existing technologies.

Everyone involved—architects, engineers, landscape architects, mechanical contractors, manufacturers, suppliers, policy makers, code officials, and others—needs to see the importance of their respective roles as part of the practice of wise use of rainwater. It is my sincere hope that this collaborative effort will contribute to an increase in awareness and implementation of successful rainwater harvesting systems.

KATHY DEBUSK

August 2013

It was during a canoe trip along the James River near Richmond, Virginia, that I discovered my true calling in life: stormwater management. While paddling past the heart of downtown Richmond one summer, my father and I were caught in a surprise thunderstorm. The short, yet intense, storm resulted in the discharge of urban runoff into the river just upstream of where we were floating. Not only did this water have a foul odor, but it was filled with a tremendous amount of trash and debris. Then and there, I decided that I wanted to become a part of the effort to decrease the impact of urban runoff on valuable water resources such as the James River.

It wasn't until many years later, after a bachelor's and master's degree in engineering at Virginia Tech, that I was exposed to rainwater harvesting. One of my first design projects as an Extension Associate at North Carolina State University was a rainwater harvesting system for an animal shelter in Craven County. It was love at first sight. I continued to design and research rainwater harvesting systems throughout my stay at NCSU, and even made rainwater harvesting the focus of my doctoral research.

Rainwater harvesting is a unique creature, unlike any other. From a water supply perspective, it challenges our country's largely centralized approach to water supply and use. This brings about many uncertainties and unknowns, which leads to a widespread hesitancy regarding the implementation and use of these systems. From a stormwater management perspective, rainwater harvesting systems are the only best management practices (BMPs) that serve an important supplementary goal—that of water supply. Moreover, rainwater harvesting systems contain more moving parts than any other stormwater BMP currently used. Together, these factors greatly increase the design complexity of these systems, the number of project stakeholders, and the necessary maintenance requirements, thus generating hesitancy within the stormwater industry to exploit the full potential of these systems. The result? Inconsistency, confusion, and a profound lack of knowledge regarding the potential benefits of these systems.

Consequently, it seems predestined that someone would recognize the need for a compilation of current knowledge regarding these practices to serve as an all-inclusive source for any person dealing with rainwater harvesting. Celeste and Eddie recognized that need and had the courage and passion to embrace such a daunting task. My hat goes off to them, and I thank them for including me. I couldn't be more honored and delighted to have been part of this effort, and I sincerely hope that the result is a valuable resource for design professionals. I learned countless lessons the hard way when designing, installing, and utilizing these systems, and if my experiences can help one person avoid the same mistakes, then it was worth every sleepless night.

CELESTE ALLEN NOVAK

August 2013

Water surrounds Michigan and our State motto *Si quaeris peninsulam amoenam circumspice* translates to "If you seek a pleasant peninsula, look around you." It is true; we are surrounded by three of the five Great Lakes. With at least one-quarter of the world's freshwater supply, there are enough rivers, inland lakes, rain, and snow to fill our aquifers and water my garden. So, why am I, a native of Michigan, so concerned about water use and rainwater harvesting?

It is the storage and treatment of waste and stormwater control that drives many of the systems described in this book, not necessarily the lack of freshwater. However, as an architect and advocate for the environment, I know that a growing population largely removed from natural cycles threatens water resources across the world. The notion that we can find new ways to live within the means of the world's environmental envelope appeals to me as a common-sense solution to a growing problem. I also know that there is a gap between policy and practice that restricts professionals from tapping into (pardon the pun) rainwater as a natural resource.

As one of my students asked after being given the simple calculations for schematic planning for rainwater harvesting: "If rainwater design is this easy, how come architects are not doing this on every project?" It's a good question and one that will be addressed in this book on planning for rainwater harvesting in building systems. As also will be discussed, not every project in every community can include rainwater harvesting. Some solutions will require new policy and code changes, some will require new types of community or neighborhood water collection and treatment. Most solutions will require the construction and maintenance of a self-sufficient decentralized water system for part of a building water supply. In some countries, rainwater collection is a strategy that can provide water as part of a disaster assistance program. In the future, it may be possible to design schools, stores, and community centers to collect, store, and treat water in order to provide a resilient water resource in times of drought. It is my belief that future buildings will be designed to collect rainwater and designers will create a new hydrologic system that restores water as it flows through the environment.

Acknowledgments

The authors draw from strong backgrounds on the subject. Celeste Allen Novak, AIA, is an architect, writer, and adjunct professor at Lawrence Technological University who specializes in sustainable design. G. Edward Van Giesen, MLA, National Sales Manager at BRAE/WATTS Water Technologies, has extensive experience in the design and implementation of rainwater systems. He has been instrumental in developing new rainwater codes and standards nationwide. Dr. Kathy DeBusk, PhD, PE, and Assistant Professor of Environmental Science at Longwood University in Farmville, Virginia, has just completed a thorough examination of rainwater quality and treatment, providing one of the first published international overviews of this global resource in communities. Contributing authors include Viviane Van Giesen, Graphic Designer, who along with Dr. Jim Novak, PhD, has offered countless hours of editing, design, and support. Fred Smotherman, BLA, has drawn from his perspective and knowledge of the construction of rainwater systems to provide information on components and maintenance. Many thanks to Cedric, Ian, and Isabella Van Giesen for their patience and hours of work transcribing interviews.

Finally, special contributions by Dr. Diana Glawe, PhD, PE, LEED AP, Associate Professor at Trinity University in San Antonio, Texas, provided the most recent information on the use of condensate; and Nicole Holmes, PE, LEED AP, provided an excerpt describing the factors involved in cistern sizing. In addition, a special thanks to researchers Azubeke Ononye, a graduate student from Lawrence Technological University, and Jacquie McDermott-Kelty, currently at the University of Michigan. Others who were significant in the development of this book include the following: Robert Goo, Office of Water, USEPA, who provided contacts for this book; Dolly Patel and Preeta John, both young architects who provided information and contacts from India. To these and to all of the architects and professionals who provided images, interviews, case study data, and constructive criticism, the authors give thanks.

CHAPTER 1

The Importance of Rainwater Harvesting

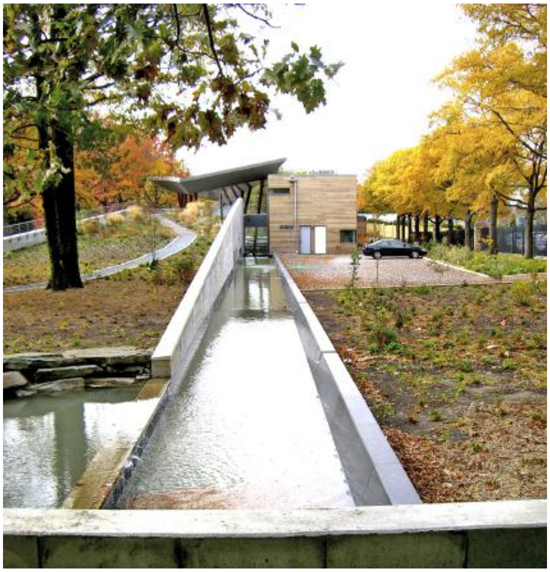

Figure 1.1 Queens Botanical Garden Visitor and Administration Center is an example of integrated rainwater harvesting system design.

> 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.

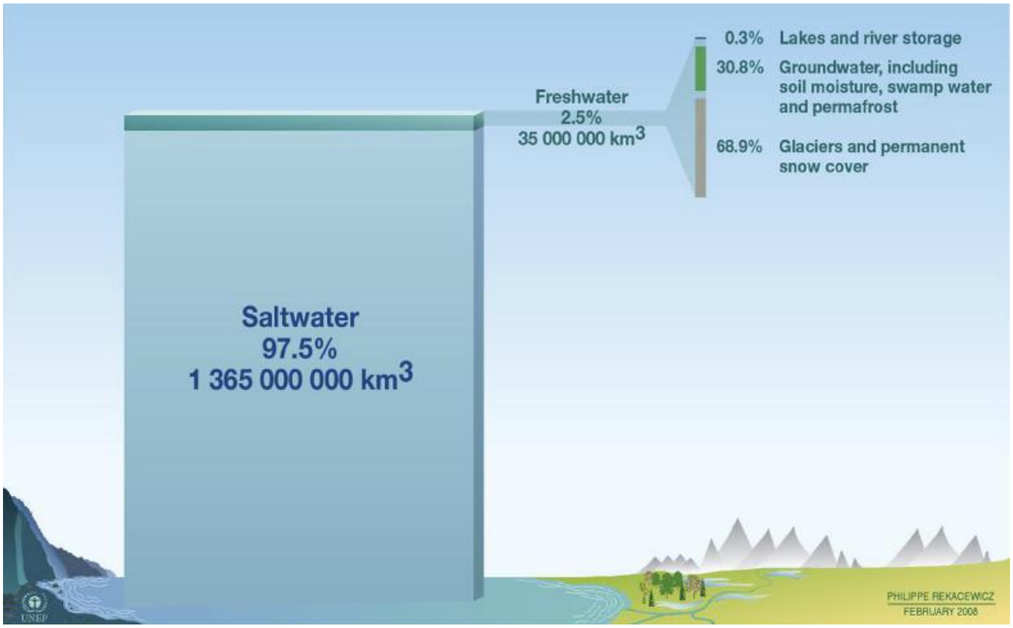

Figure 1.2 EARTH A Graphic Look at the state of the world[5] (*Source: Igor A. Shiklomanov, State Hydrological Institute (SHI, St. Petersburg) and United Nations Educational, Scientific and Cultural Organisation (UNESCO, Paris), 1999. Image courtesy of UNEP.*)

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]

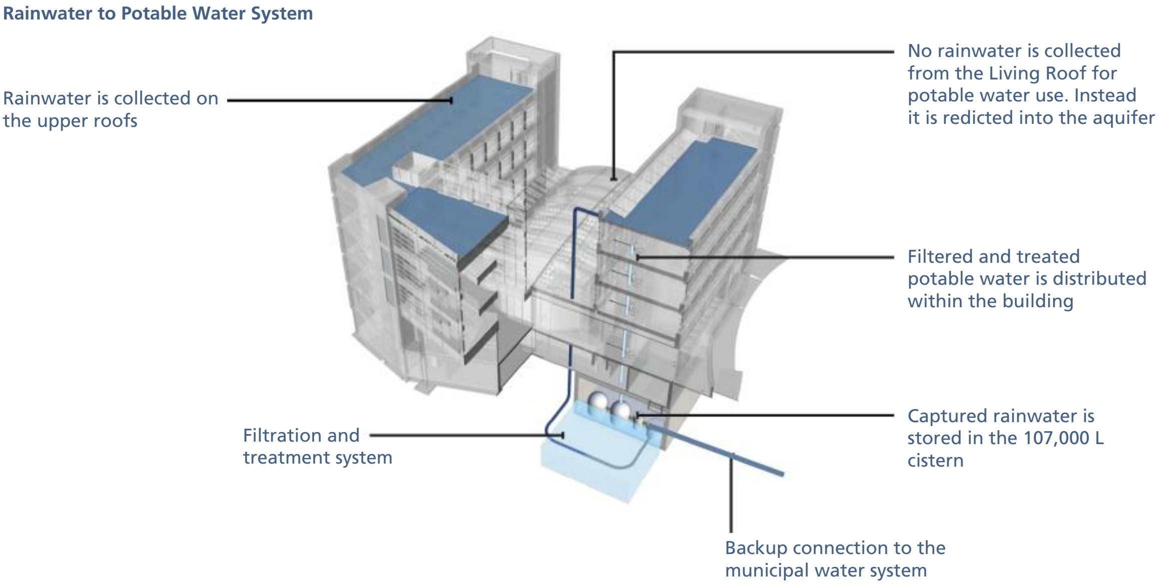

Figure 1.4 Designed by Perkins+Will, the Centre for Interactive Research on Sustainability integrates rainwater collection, graywater reuse, and water treatment for building potable water to meet the Living Building Challenge™. (*Diagram Courtesy of Perkins+Will*)

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.

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.

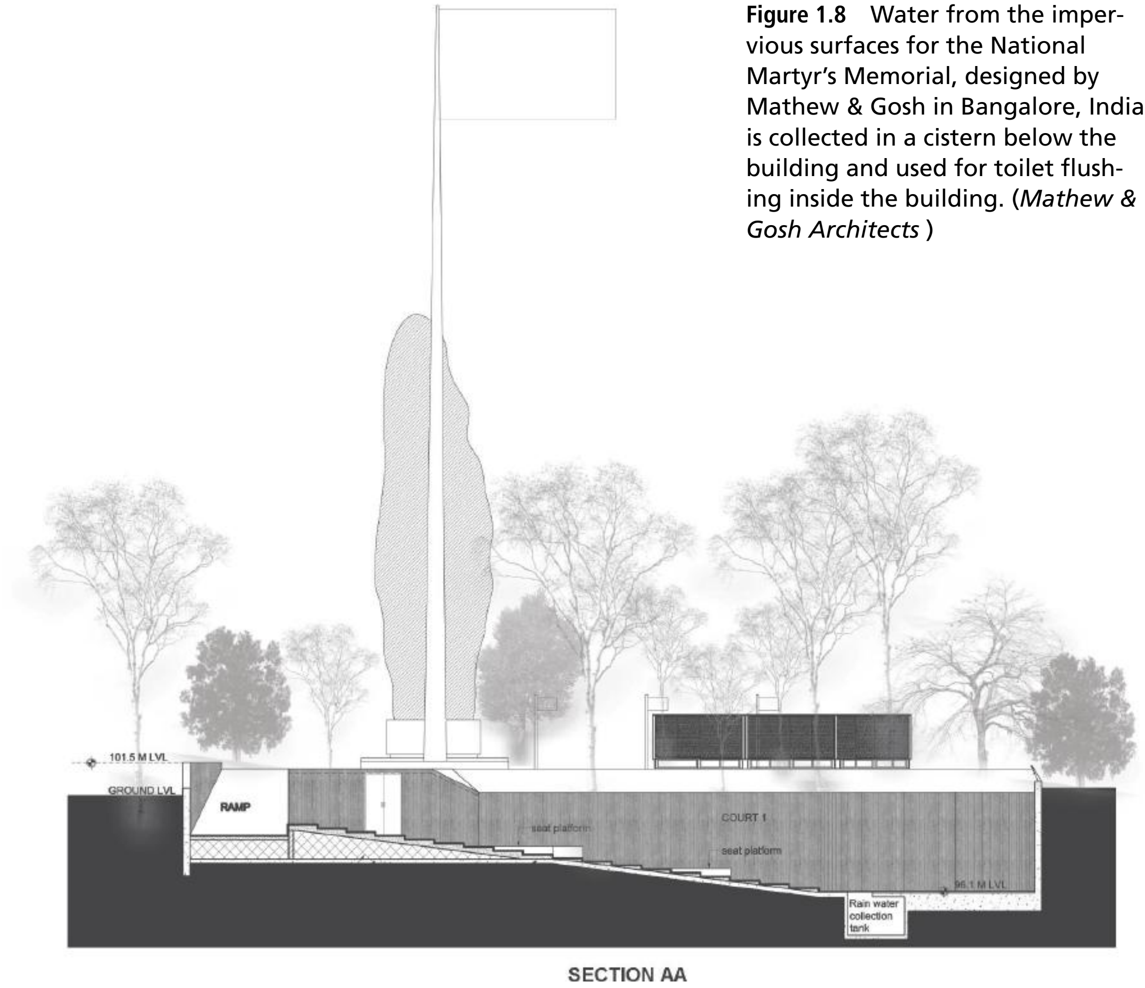

Figure 1.8 Water from the impervious surfaces for the National Martyr's Memorial, designed by Mathew & Gosh in Bangalore, India, is collected in a cistern below the building and used for toilet flushing inside the building. (*Mathew & Gosh Architects*)

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

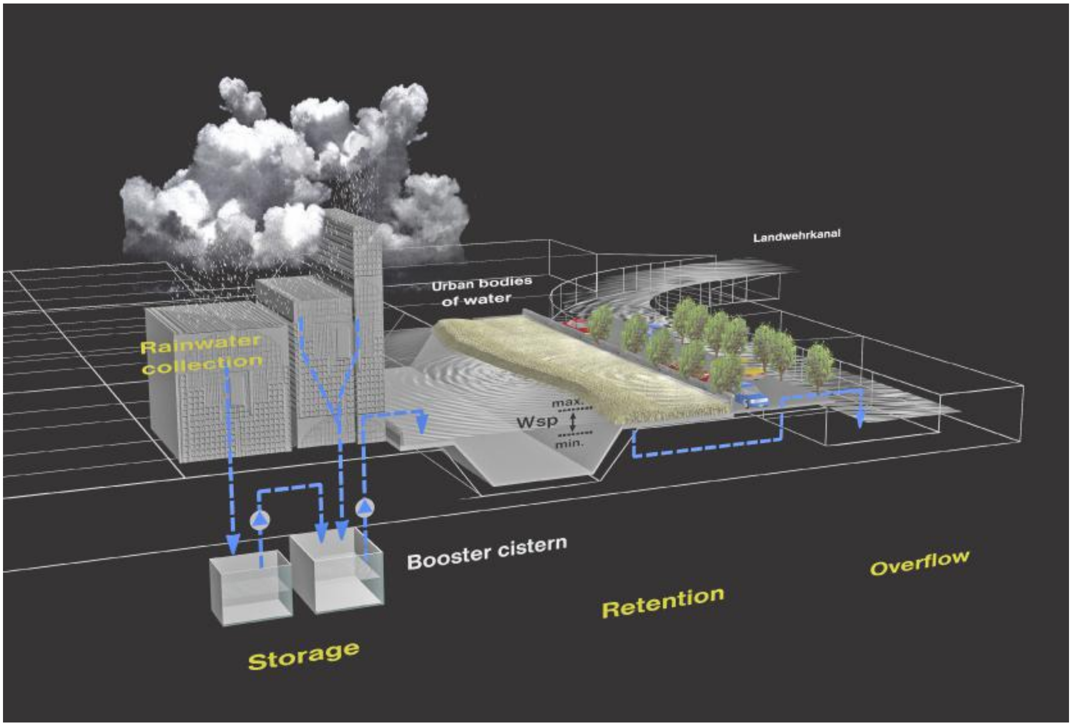

Figure 1.10 At Potsdamer Platz in Berlin, Germany, Atelier Dreiseitl collaborated with numerous architects to design an integrated water system that adds to the vitality and energy of the City as well as providing stormwater. (*Atelier Dreiseitl*)

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.

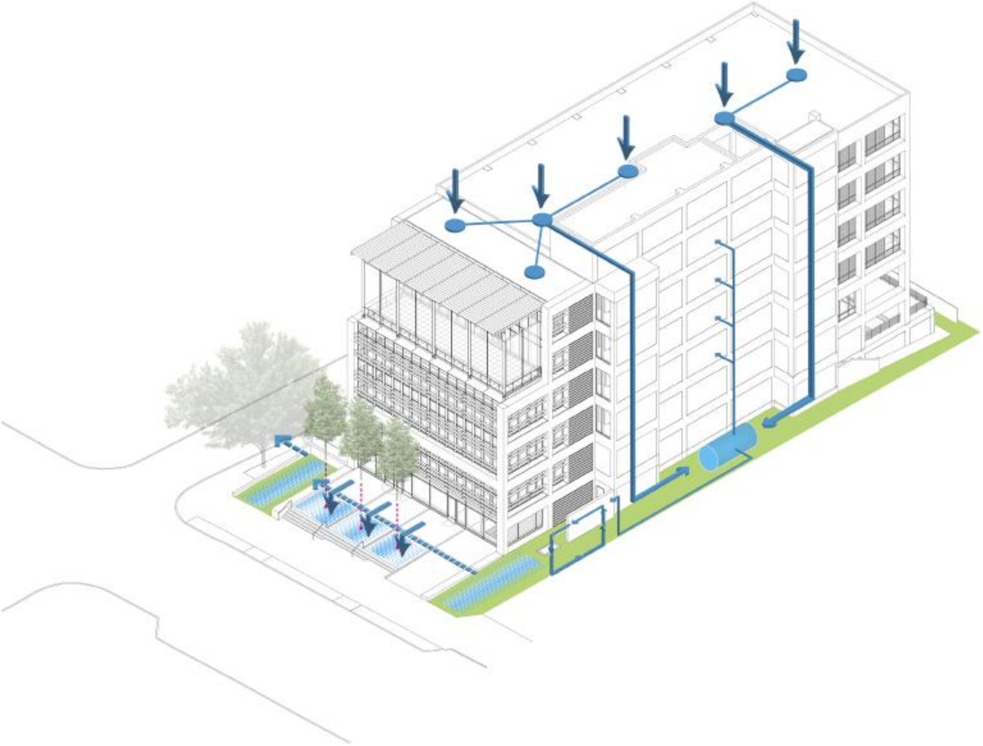

Figure 1.15 Rainwater system diagram for the renovated Atlanta offices of Perkins+Will. (*Diagram: Courtesy: Perkins+Will*)

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.

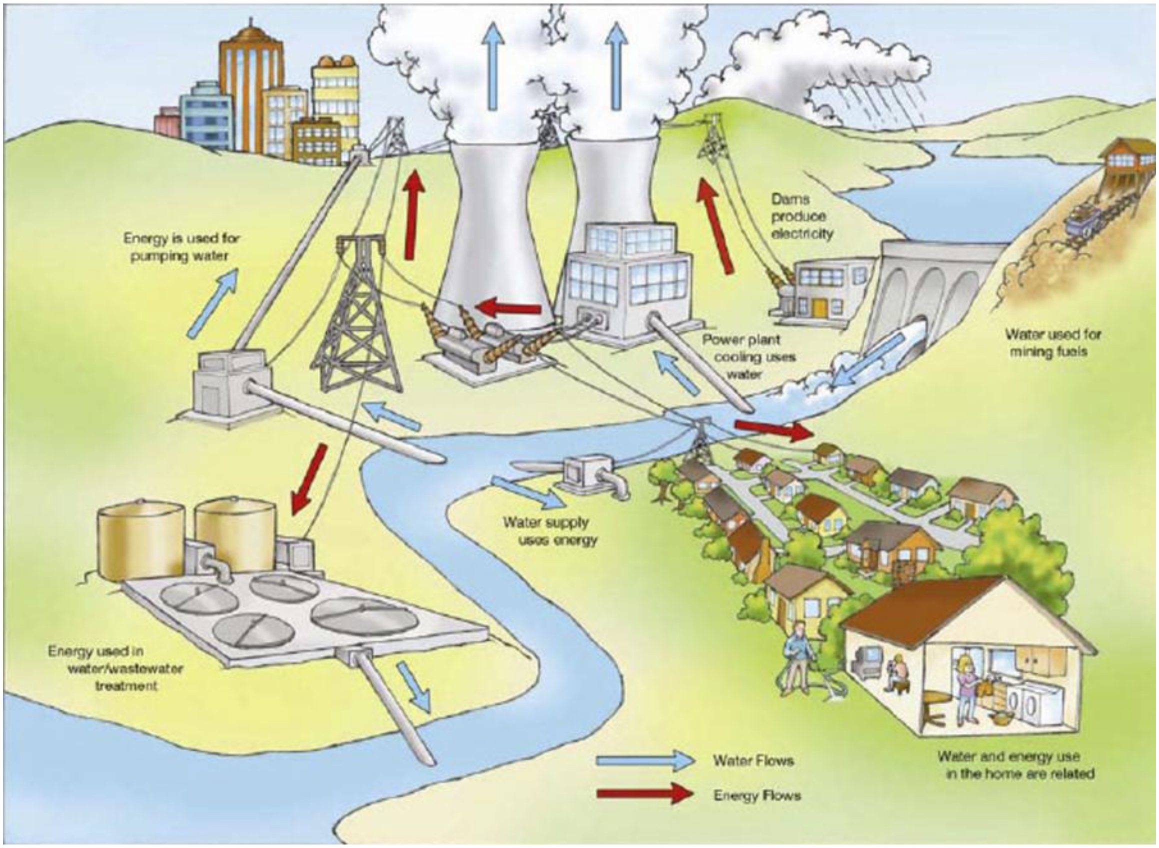

Figure 1.16 Image from "Energy Demands on Water Resources." (*U.S. Department of Energy, 2006*)

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 twofold 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

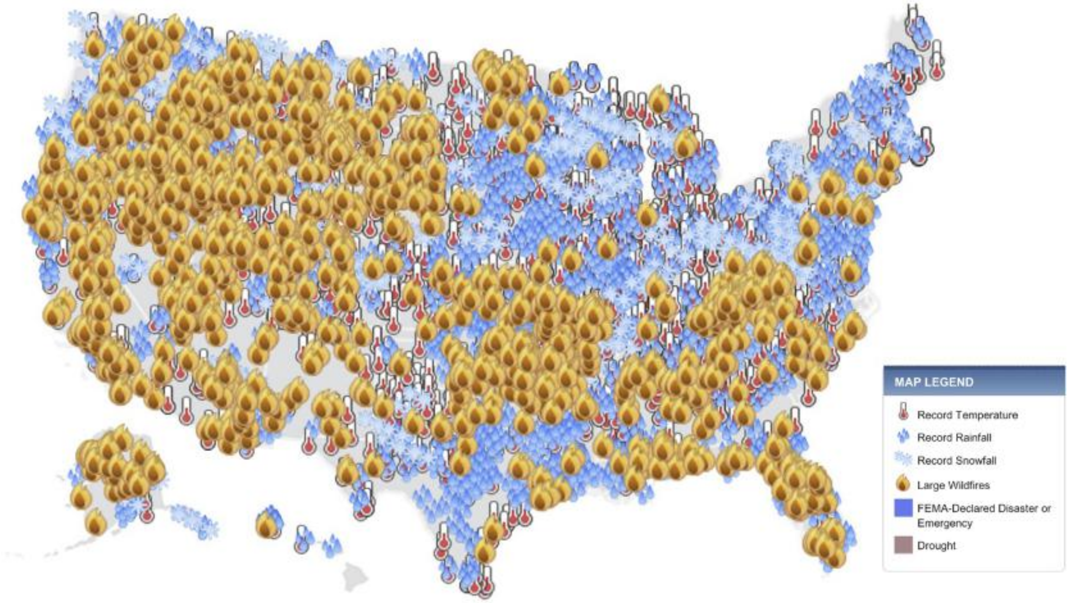

Figure 1.17 Extreme Weather Map showing thousands of weather records broken in the U.S. in 2012. (*Natural Resources Defense Council*[37] *www.nrdc.org/health/extremeweather/*)

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

Cost_{RWH} = cost of rainwater harvesting system ($)
Cost_{MW} = cost of municipal water over time ($)
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 (Cost_{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 Cost_{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 Cost_{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 Cost_{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.

$$\text{Cost}_{\text{RWH}} - \text{Cost}_{\text{MW}} - \text{ED} - \text{PP} - \text{RR} - \text{SI} - \text{HT} - \text{MF} - \text{BA} - \text{MB} = \text{ROI}$$

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.

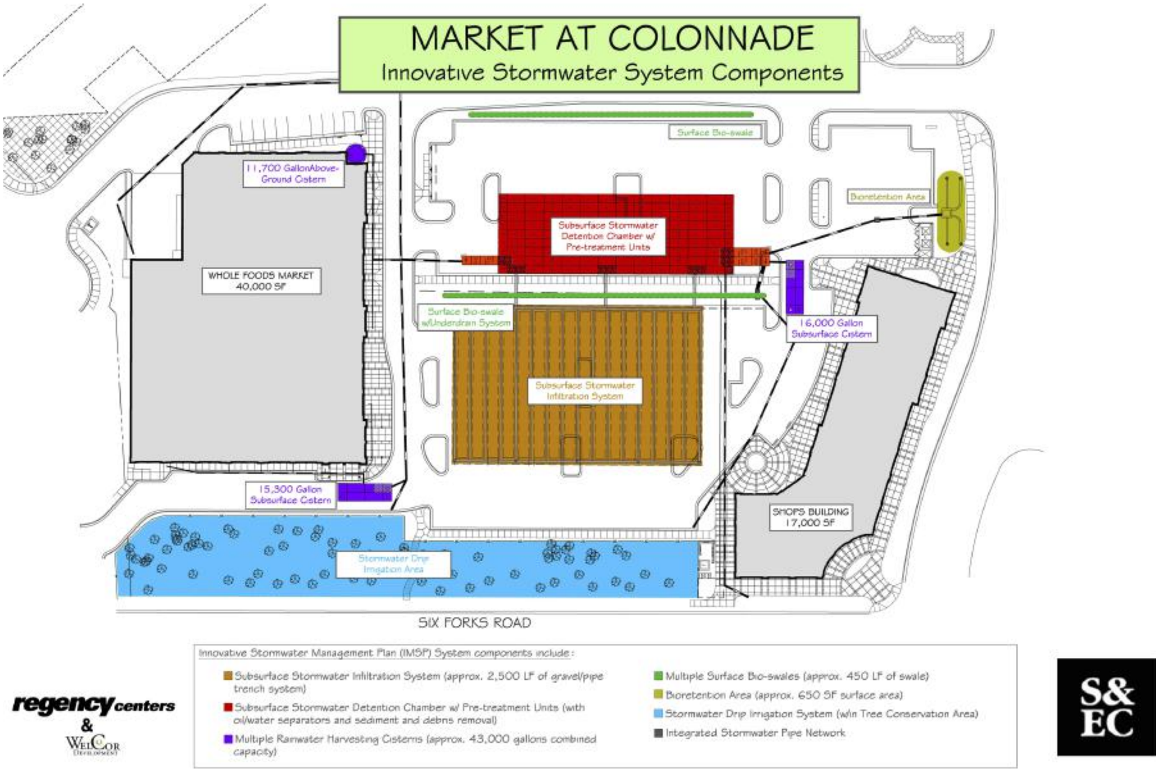

Figure 1.18 Site plan diagram. (*Soil and Environmental Consultants, PA)*

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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CHAPTER 2

System Planning and Policies

Figure 2.1 Stakeholder sessions and green charrettes assure successful rainwater harvesting systems. Atelier Dreiseitl also includes participatory meetings with clients and stakeholders as shown in this project meeting for Queens Botanical Garden. (*Atelier Dreiseitl*)

BENEFITS THAT DRIVE RAINWATER HARVESTING SYSTEMS

Rainwater harvesting systems have traditionally been implemented to meet potable water conservation goals. However, rainwater harvesting systems can be designed to meet many secondary objectives as well, thus increasing their overall benefits. Examples of these secondary objectives include managing stormwater runoff and achieving sustainable building goals.

Harvested rainwater is an alternative source of water that can be used to reduce the consumption of potable water. Rainwater can be used for many nonpotable demands that are currently met with potable water such as irrigation, toilet flushing, cooling tower makeup, and washing clothes. With additional treatment, this water can also be used to meet potable water demands such as drinking, cooking, hand-washing, and bathing, although these uses will probably represent a relatively small portion of the demand for most commercial projects.

Supplementing potable water with harvested rainwater contributes to local, regional, and/or national initiatives to decrease potable water consumption and increase the resiliency of fragile water resources. On a smaller scale, rainwater harvesting systems can reduce the amount of money property owners spend on potable water. Additionally, these systems provide water with a lower mineral content than potable water, which may increase the longevity of building equipment.

Rainwater harvesting systems are unique in their ability to provide an alternate source of water and serve as detention/retention for roof runoff that would otherwise be discharged to the stormwater network. By capturing and storing stormwater runoff for later use, these systems can significantly decrease the volume and rate of stormwater leaving a site and entering the storm sewer network. In areas with separate storm and sanitary sewers (MS4s), this detention/retention can decrease the volume of runoff discharged to receiving waters, thereby improving downstream water quality. In cities and towns that have combined sanitary and storm sewers, decreasing the amount of runoff entering the sewer network during rain events can decrease the magnitude and frequency of combined sewer overflows (CSOs), which discharge raw sewage into receiving waters. Many stormwater regulations are pointing to rainwater harvesting as a viable stormwater management practice, thus allowing property owners to receive credit for their implementation.

In addition to meeting water conservation and stormwater management goals, rainwater harvesting can also fulfill green building and sustainability initiatives. The incorporation of a rainwater harvesting system can create a sustainable, regenerative water infrastructure within a building. Accordingly, many green building rating programs, such as the United States Green Building Council (USGBC)'s LEED® program and the Building Research Establishment Environmental Assessment Method (BREEAM), recognize the value of these systems and award points for their inclusion in building design.

None of these benefits are exclusive to one another and all are approaches that may motivate a property owner to include a rainwater harvesting system into the project. It is critical to clearly describe and detail the reasons for rainwater harvesting at the initial design stages in order to select an appropriate design and successfully integrate the system and building.

PLANNING A SYSTEM

When planning a rainwater harvesting system the following steps should be followed:

1. Interview property owners and stakeholders to determine system objectives, design constraints and considerations, and so forth.
2. Research the regulations and permitting processes required by federal, state, county, and local building codes.

3. Research applicable incentives and green building rating systems.
4. Present various design options to the owner or other stakeholders of a property.
5. Create an integrated plan for water conservation that starts with a water audit and follows through to the specification of water saving fixtures.

By following these steps, the design professional will find that rainwater harvesting can be achieved as part of an integrated sustainable design system regardless of the scale. Owners may often wish to take small incremental steps when considering implementing rainwater harvesting for the first time.

Queens Botanical Gardens: "Where People, Plants and Cultures Meet"

LEED® Platinum 2008

Brooklyn, New York

The Queens Botanical Gardens (QBC) offers a natural respite to visitors and residents of nearby Flushing in Queens, New York, as well as over 300,000 annual visitors. Programs at QBC range from garden tours and working gardens to neighborhood gathering spaces and events. As a physical manifestation to sustainability, the gardens, waterscapes, and award-winning high performance building immerses visitors and staff in a place that respects all water as a basic resource and reflection of health and joyful aesthetics. The design team included all of the stakeholders in the process of this design from the 2001 Master Plan to the completion of the 2008 Visitor Center.

Master Plan

In 2001, a visionary master plan was completed to guide the complete renovation and expansion of the QBG's entire site. The result of an integrated, community-driven process, the master plan identifies programs, features, and garden spaces planned to serve the needs of the neighborhood and the growing number of visitors. The plan provides clear direction and guidelines for each capital project as an expression of the QBG's focus on sustainability and international cultures through water and plants. The first phases prioritized in the plan included the new Visitor & Administration Center and associated water gardens, horticultural/maintenance facilities, and relocated parking. The site and buildings were planned and designed as high performance, integrated spaces and this project has been awarded LEED Platinum Building Certification.

Figure 2.2 Queens Botanical Gardens design plan. (*Atelier Dreiseitl*)

Integrated Team Process

The QBG's Director of Capital Projects was retained initially to help grow the garden facilities commensurately with the original vision. Trained as a landscape architect, she was aware that the only way to achieve high-performance, sustainable results was with a collaborative team of experienced professionals in an integrated design process. A core consultant team was selected for the master plan and initial capital projects. The team consisted of a New York–based architecture firm and two landscape architectural firms (one U.S.-based, one international) that both included ecological engineering and landscape ecology as core disciplines. They helped to interpret the needs of the entire staff, various visitor groups, regulatory officials, and many others to evolve the design in a way that expresses the essence of the water-based master plan vision.

Site Planning

The new building was sited to be subservient to the gardens, to open the view into the gardens, and to reinforce the urban character of the perimeter street. It is located on the site of the former parking lot, between rows of large, mature oaks and conifers, some of the greatest assets of the site. This created an established, finished feeling immediately upon completion.

The project had to address a number of challenging constraints, such as the need to maintain public access and full operations during the entire period of construction. Due to a legacy of being filled, excavated, and filled again several times for a range of activities since the time of settlement, the soil had no original structure remaining and consisted largely of various construction materials and other debris of unknown origin below the surface. This, in combination with limitations on grading due to the extensive root zones of the existing trees, grading, and soil amendments, made the high-priority dual goals of a lush, healthy landscape and that of slowing, cleansing, reusing, and infiltrating all rainwater onsite more difficult.

Water Systems

> "The primary theme of the site design is the visible expression of water—always considered as a resource, and never squandered. As a cultural bridge, the awareness of water is critical and a basic element that supports life in every culture of this world. Therefore, water was consciously taken as a combining theme for both, to reflect the diverse ethnic groups and to celebrate the connection between people and the environment in a dense city." —Atelier Dreiseitl

Water is present in every portion of the renovated gardens, and the water path actually draws one into and through the various garden spaces. Stone, concrete, and steel are artfully crafted to display water in a range of textures and characteristics. This approach is coupled with the integration of a range of high-performance strategies in concert with site and building functions. The water elements make use of harvested rainwater, rather than allowing it to enter the city's combined sewer, thus reducing pollution in Long Island Sound. It is cooled and filtered with bioswales that mimic the function of natural ecosystems in lush, colorful planted gardens with open water surfaces. These features are brought right up to and actually through the building so that one simply cannot avoid the experience of water whether working at or visiting the gardens.

A circular cascading fountain feeds a water channel that one must cross to enter the gardens. It changes in character from irregular to linear as it leads from the garden space to slice through the building to where it emerges into a natural-looking cleansing biotope, replete with grasses and flowering perennials. It is supplied with rainwater harvested from the rain terrace canopy. When it is raining, water cascades from a single point onto a stone dissipater, directing the cooled, aerated water to the water channel in a display, which uses only free, renewable resources—rainwater and gravity. The result creates a dynamic public space on the garden side of the building, which feels comfortable, whether one is alone, in a small group, or in a large gathering. As it is kept healthy with natural systems and without any chemicals, all of the water expressed on the site has a living, vibrant quality to it.

There are even more water and energy conservation measures built into the project, many of which are demonstrations and some the first of their kind in a public city building. Graywater from the Visitor & Administration Center's sinks, dishwashers, and shower is piped to a constructed wetland. The water is filtered and treated naturally through bacterial activity on the roots of carefully selected plants. The treated graywater is returned to the building for use in toilet flushing. Waterless urinals, composting toilets, a photovoltaic array, and a range of green materials have all been integrated into the building, replete with natural light and fresh air.

Pavements and Plantings

A range of surface treatments provides suitable walkways, service drives, and intimate paths. Concrete blocks, stone, and gravel are the primary materials used on the site, all of which are shaped and textured to prioritize people over vehicles. Lasting, durable materials allow water to be infiltrated or directed to bioswales for cleansing and re-use as part of the sustainable strategy. Access to every space is encouraged, even on a portion of the roof. A lightweight green roof system allows for a seamless garden transition from ground level to the roof and is an integral part of the rainwater system.

The approach to living landscape materials is complimentary to the QBG's mission. Planting considerations prioritized use of existing assets and restoration of healthy habitat. Preservation of existing trees was of the highest priority, as the mature Willow Oaks, Pin Oaks, and conifers are irreplaceable in several generations' time. Restoration of soil health and water retention capacity was part of the method used to ensure a living, functioning system. Ornamental vegetation was chosen to support the necessary water functions of the various garden spaces. A wide diversity of species was selected, matching plant needs to water availability and sun/shade characteristics of the space.

Herbaceous grasses and forbs either native or closely related to New York cultivars make up the majority of the plants, and will thrive once established without supplemental irrigation. Termed

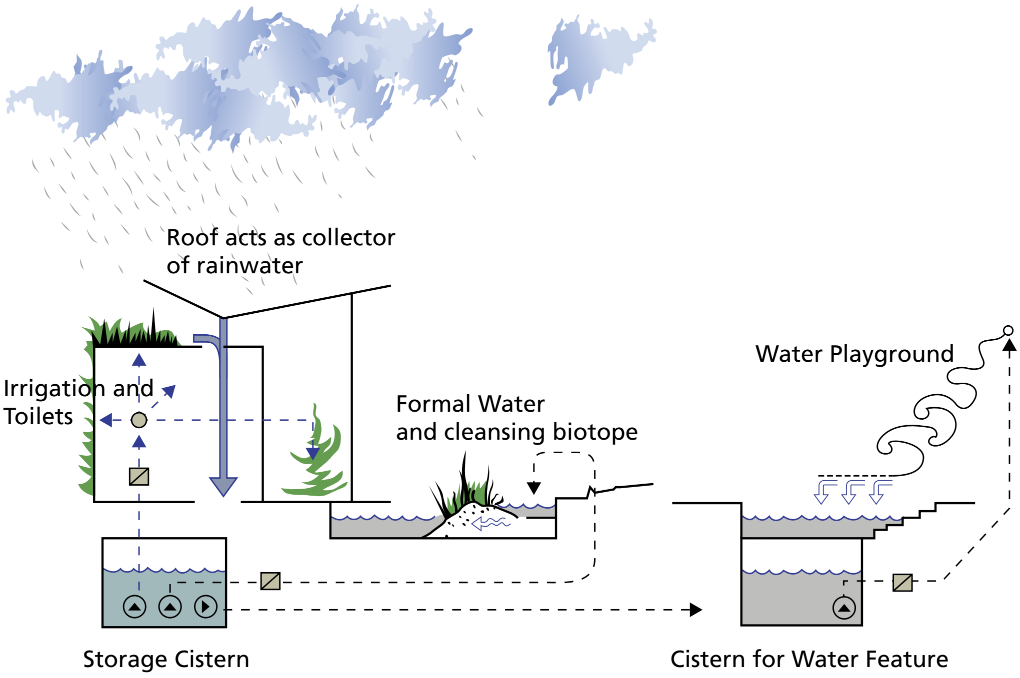

Figure 2.3 Conceptual system diagramming highlights overall water strategies for the entire site. (*Atelier Dreiseitl*)

Plants in Community, the gardens around the building are organized by plant family and feature native plants in a garden setting. Many of the plants are well adapted to the conditions; some are experimental in nature and will be monitored to determine their performance and appropriateness.

Success

As one of the first public green building projects in the city, this project serves as a visible green demonstration and has helped to pave the way for high performance, integrated buildings and sites in New York. The vision and mission of the QBG are about the celebration of cultural connections and a demonstration of environmental stewardship. The QBG has become a place where one can discover the critical links between global conservation, local sustainability, and the importance of traditional cultural practices as they relate to natural resources. In a country where water is becoming increasingly scarce due to its misuse and unsustainable land use practices, the QBG's water landscapes intentionally exhibit a compelling new paradigm and way to think about water, sustainability, and beauty.

Figure 2.4 Children as engaged stakeholders planning waterscapes at Queens Botanical Gardens. (*Atelier Dreiseitl*)

Step 1: Identifying System Goals

The goals for a rainwater collection project are usually based on several components: size and function of the building (commercial, institutional, industrial, or residential), the setting (rural or urban), designated water demands, and applicable regulations, policies, and incentive programs. Each of the following issues is important to the development of robust project goals for a successful rainwater system.

Site Analysis

Traditional site analysis begins with a topographic study of the property. The topography of a site will determine many aspects of system design, such as the contributing drainage area, the placement of collection tanks, and the type, amount, and design of conveyance piping. Site analysis also includes an evaluation of natural elements such as wind, solar aspect, rain, and snow. Renewable energy sources, such as wind and solar, may be used in conjunction with a rainwater collection system to power pumps or other electricity-dependent components. The type, abundance, and distribution of precipitation that occurs at a given site will dictate how much rainwater is available to collect and, consequently, the size of the collection system. Thus, the amount, intensity, and frequency of available precipitation are critical pieces of information that must be known at the onset of planning. The designer will also review the landscape material onsite and the appropriateness to the climate zone of the trees and vegetation on the property. Native plants have evolved to adapt to the rainfall in the region and choosing appropriate plant species conserves water.

Site surveys and soil samples will tell the designer information about site drainage, soil permeability, wetlands, and the availability of water resources. This information is critical in evaluating the ability of a site to infiltrate water discharged from a rainwater harvesting system, including irrigation, constructed wetlands, bio infiltration, etc. Additionally, if stormwater control measures are included in the overall site layout, these factors will likely dictate their placement and performance.

Site orientation, location in the framework of a community, and accessibility (both to the site and on the site) are part of an overall site analysis. For example, if a system uses solar panels, orientation of the building should maximize exposure to the sun. If a community is concerned about protecting a fragile watershed or wetlands, or if the project would be enhanced by the inclusion of water as a public amenity, these considerations will drive overall system planning and design. Furthermore, universal design and accessibility standards require that the designer review paths affected by stormwater and irrigation systems, equipment placement, and signage.

Building Design and Programming

Engaging, listening, and educating the client(s), as well as the design team, are among the most important steps to developing a building program. The design team includes a collection of professionals, architects, engineers, contractors, and the suppliers of systems and components, all of who are necessary to complete any complex building program. Designing a rainwater harvesting system includes the understanding of building use and expected occupancy. Occupancy not only includes building staff, but visitors as well. To develop a successful rainwater system, knowledge of how this particular type of building uses water to maintain mechanical systems as well as how its occupants will use water is required.

Rainwater use inside buildings can include toilet flushing, clothes washing, cooling tower makeup, mechanical equipment, lavatories, showers, and janitorial sinks. Using site-collected water for outdoor purposes such as irrigation is also important, as this can comprise a large percentage of total water use on a site.

Sustainability and Technology

Architects may choose to incorporate many sustainable design initiatives when designing a collection system, depending on the project's overall goals. Some of these initiatives can often be provided at low or no cost to the owner. Team leaders should review applicable energy, water, air quality, and community planning goals to determine how a project might be designed to contribute to one or more of them. Educating clients as to the opportunities for combining green strategies will achieve both economic and social benefits. Technology is rapidly changing, which adds to the design professional's toolkit. New products continue to be developed for designers to use to meet sustainable initiatives, including higher-efficiency water-saving equipment/devices and new rainwater system technology.

Diagramming the path of water through a site is important to help clients understand the complete hydrologic cycle within the site. There are a variety of design approaches and technological solutions that designers may use to facilitate water use, reuse, and treatment

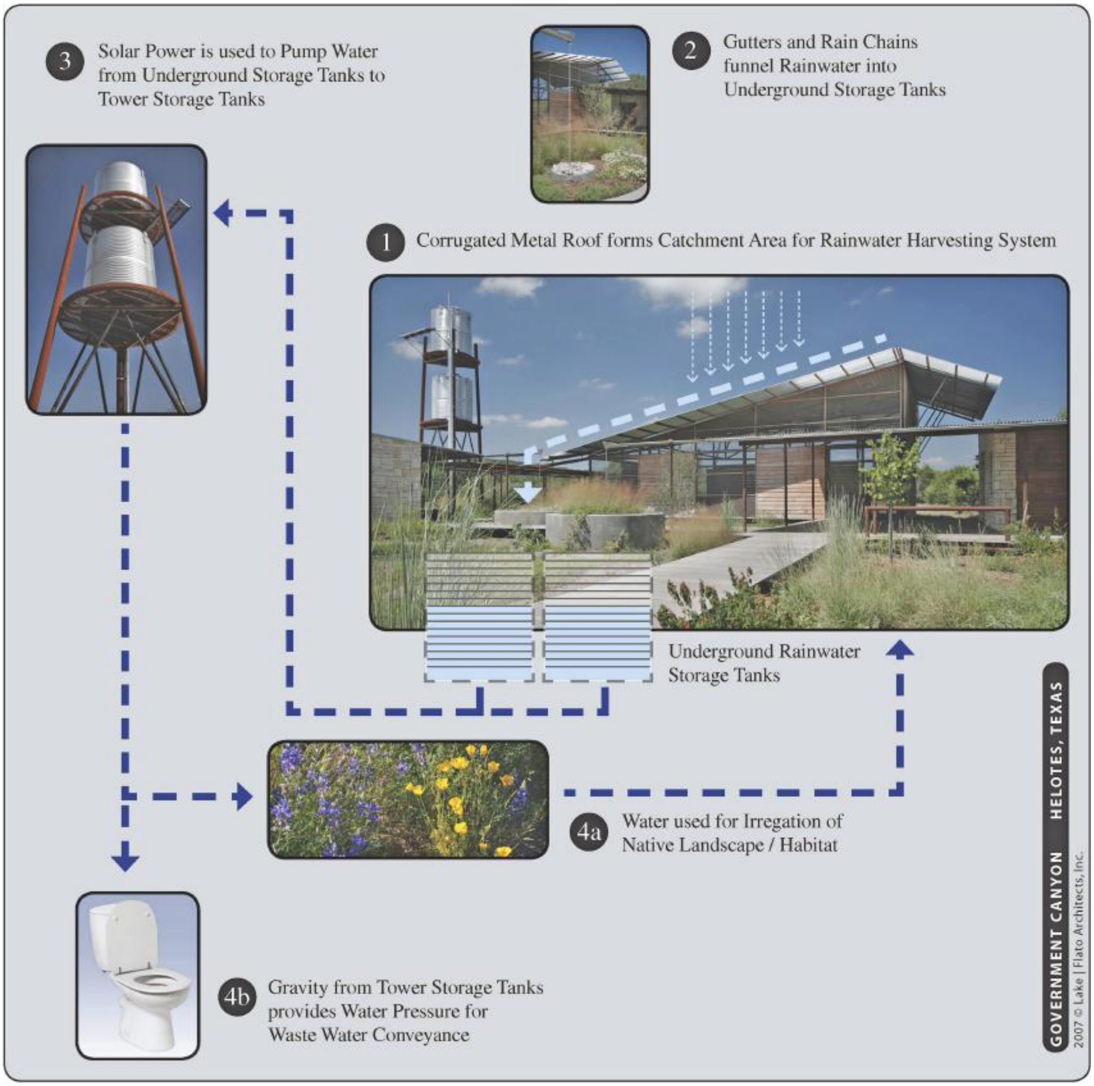

Figure 2.5 Diagrams that show the complete water cycle and integrated strategies through a project site can be used to educate clients and the public. Solar power is integrated with the rainwater system at the Grand Canyon Visitor Center, designed by Lake|Flato Architects. (*Lake|Flato Architects*)

on a site. These range from rain gardens that allow for the infiltration of stormwater to large, permanent storage systems that pump the collected water back into the building, to the use of wetland systems to treat graywater.

A variety of rainwater system types can provide primary and secondary benefits of rainwater harvesting, including cost savings from water conservation and meeting stormwater regulations. Other important benefits include increased aesthetics and environmental stewardship.

Some architecture and engineering firms have developed "quality cost models" that balance economic resources and environmental initiatives with client goals and visions. These analyses may be crucial when the owner is deciding whether or not to include rainwater harvesting as part of the building program. Integrated design maximizes the sustainability of a project and achieves not only these specific project goals, but also contributes to the larger environmental targets of a community. The goals for a project, regardless of size, will build a foundation for decision making and system design.

Step 2: Codes, Standards, and Guidelines

Important Terms and the Big Picture

Although the terms "codes," "standards," and "guidelines" are often used generically and interchangeably by the general public, officials in the code community may use them quite differently.

In many countries around the world, there are national building codes that are developed by governmental and quasi-governmental bodies that regulate building construction. All aspects related to the built environment are covered including electrical work, plumbing, structural design, and many others. These national codes are enforceable across the entire country. They promote uniformity and clarity and allow for a more concise interpretation.

In the United States, however, there is much greater authority given to individual states and local jurisdictions in reference to building codes. Developers of codes and standards from countries outside of the United States often are amazed at the complexity of such a byzantine and redundant system of building rules and regulations from so many different jurisdictions.

Building Code: A set of rules that specify the minimum acceptable level of safety for constructed objects such as buildings and nonbuilding structures. The main purpose of building codes is to protect public health, safety, and general welfare as they relate to the construction and occupancy of buildings and structures. The building code becomes law of a particular jurisdiction when formally enacted by the appropriate governmental or private authority.

Guidelines: Documents designed to outline best practices and give the user of the document knowledge about the subject. Guidelines are generally not enforceable by law.

Regulation: A written legal instrument containing rules enforceable by law.

Standards: Standards are established norms, requirements, and specifications that can be consistently used to ensure the suitability of materials, products, and/or processes for specific purposes. They are documents that can be referenced in codes and as such they can be legally enforced.

Statute: Statutes are laws developed by elected officials. An example of a rainwater statute is the California Assembly Act AB1750: Rainwater Capture Act of 2012.

In the United States, building and plumbing codes are generally developed and published by private entities, whose membership typically includes governmental officials along with members of the private sector. They can also be developed exclusively by governmental agencies. The local and/or state agency may proceed in developing and/or adopting codes at their own rate and cover whatever topics they see fit at the time.

City or local jurisdictions can adopt more stringent rules than those at the state level but not less so. Some states address rainwater collection and blackwater or graywater reuse systems in appendices, local amendments, bulletins, and other planning documents. The development and adoption of these appendices is often driven by the lack of guidance in the model codes.

Code development requires input from manufacturers, engineers, architects (the design community in general), concerned citizens, governmental inspectors, agency officials, and other stakeholders. As model codes are developed, individual states have the opportunity to adopt them at their own rate. Only after adoption by a municipality do these codes become legally enforceable. The local/state agency oversees how the codes will be enforced, a task generally conducted at the local level by the local building department.

The closest thing that exists in the United States to national rainwater harvesting codes is model codes. A model code in and of itself does not have any teeth or enforceability. Only after adoption does it become a legal, enforceable document, and the local/state governing authority can choose whether or not to adopt a given model code.

Plumbing Codes

The International Association of Plumbing and Mechanical Officials (IAPMO) and the International Code Council (ICC) are two of the largest code-writing bodies in the United States. In addition to creating model codes, regular updates, and improvements to existing codes, both of these private entities have developed "green" supplements and overlays with sections directly related to rainwater harvesting. The ICC published the International Green Plumbing Supplement (IGCC) in 2012. IAPMO published the Green Plumbing and Mechanical Code Supplement (GPMCS) in 2010. These supplementary documents detail design and construction criteria for rainwater harvesting systems.[1]

Both organizations have made moves to include aspects of these above-referenced publications into the main body of their respective building codes. Individual states may choose to adopt the green publications by themselves or wait and adopt them when they become part of the main body of the building code.

Since plumbing codes (as a subset of building codes) are reviewed and updated generally every three years, changes can appear to occur rather slowly. This slow pace is deliberate to ensure that the best rulings and regulations are in place—reflecting the public's best interest as well as the latest advances in the building industry.

Complex Interactions Between Regulations and Codes

There are no federal regulations specifically governing the use of rainwater harvesting for potable or nonpotable uses.[2] This is primarily due to the fact that, as mentioned above, individual states have their own laws regarding water rights and permissible source waters and uses. This is why a federal agency such as the EPA has difficulty issuing rulings concerning the use of rainwater as source water. It is easy for such a ruling to conflict with existing state or local plumbing codes relating to water use. For example, if rainwater/stormwater is not recognized as an acceptable source water in a particular state, then there is a conflict.

In addition, the issue of water rights can present problems to the use of rainwater. States in the western part of the United States adhere to water rights laws that restrict the capture and use of rainwater/stormwater due to prior appropriation laws. In states where prior appropriation laws are in effect, a water right may be required in order to collect and use the water. At the time of the writing of this book, Colorado has such a law. Until it is changed, collecting rainwater in any type of container—even a bucket—could be considered breaking the law. This highlights the need for legal updates/clarifications to allow for the use of rainwater harvesting.

There are a growing number of states with published rainwater harvesting guidelines (state or municipal), including Arizona, Hawaii, Georgia, Florida, New Mexico, Oregon, Texas, and Virginia. The information detailed in these guidelines is just that—a guideline promoting best practices and not necessarily enforceable by law.

Some states have guidelines but no regulations; others have regulations but no guidelines. In fact, rainwater harvesting is not regulated in most states and therefore a large gap exists between the use of this environmental strategy and the legal framework permitting its use. Unfortunately, whenever there is a lack of official rules governing the use of rainwater, the code enforcement officials and inspection agencies have little guidance when presented with requests to evaluate a proposal for the installation of a rainwater harvesting system. To these individuals, the design professional's passion for green infrastructure may appear as extra work and increased liability.

While the lack of regulations can hinder the implementation of rainwater harvesting, the presence of peripheral/contradictory rulings can also deter its incorporation into building design. For example, the City of Seattle Municipal Code requires a potable water connection for drinking water in every building.[3] This requirement may deter a developer or property owner from including a rainwater harvesting system, as it will not save them money on potable water connection fees or prevent them from having to plumb a municipal water line. The City of Seattle recently published a report that identifies numerous regulatory obstacles to achieving the guidelines for the Living Building Challenge (an incentive program discussed later in this chapter).[4] Some of the suggestions offered in this report ranged from the removal of institutional barriers to the development of more standards for low-impact development and new property setbacks that would allow cisterns. This document serves as an example of how municipalities may need to reexamine applicable rules and regulations that may be an obstacle to rainwater harvesting.

Along with the need for new rules and regulations concerning rainwater harvesting, there is also a great need to educate the code community (developers and enforcers) as well as the general public. Ultimately, the building code officials are those on the front lines of this new industry. A code official unfamiliar with the technology and the associated codes has the extra burden of deciding whether this seemingly useful concept is safe for the public and worth the perceived and real risks.

The National Conference of State Legislatures maintains a database that includes information related to state rainwater harvesting statutes, programs, and legislation.[5] Appendix A contains a list of some states where rainwater harvesting is treated as a best management practice (BMP) and where there are incentives or legislative initiatives that will support the design and implementation of an integrated rainwater system. In each example, the amount of rainfall and a short description of the type of rainfall are followed by information on policies in that particular state. Useful links to state information are also included in the appendix.

Also important to note is that homeowners' associations (HOAs) often have rules governing property aesthetics and functions within a residential development. Some HOA rules specifically address rainwater harvesting and dictate many aspects of system design.

More research and the proliferation of new projects in the United States and other parts of the world are increasing the acceptance of the use of rainwater and facilitating the inclusion of new information into codes, standards, and guidelines. Increased adoption of these codes will lead to more widespread implementation of rainwater harvesting.

However, the fact remains that until rainwater harvesting has been adopted on the state and local level throughout the United States, those interested in implementing the technology should confirm the legality of doing so. Codes relating to rainwater harvesting have not been adopted by all jurisdictions in all states. Designers should continue to be aware of the green code movement, but inquire at a state and local level for laws that pertain to all uses for rainwater harvesting, particularly for those inside buildings.

Until a more unified system exists, close attention must be paid to all applicable codes pertaining to rainwater harvesting as what is permissible and legal in one jurisdiction may be entirely illegal in another.

Executive Order 131514: Federal Leadership in Environmental, Energy, and Economic Performance

"On October 5, 2009, President Barack Obama signed an executive order setting sustainability goals for federal agencies and focuses on making improvements in their environmental, energy, and economic performance. This document requires federal agencies to improve water efficiency and management by:

1. Reducing potable water consumption intensity 2 percent annually through fiscal year 2020, or 26 percent by the end of fiscal year 2020, relative to a fiscal year 2007 baseline
2. Reducing agency industrial, landscaping, and agricultural water consumption 2 percent annually, or 20 percent by the end of fiscal year 2020, relative to a fiscal year 2010 baseline
3. Identifying, promoting, and implementing water reuse strategies consistent with state law that reduce potable water consumption."[6]

Rainwater harvesting can be used as a tool toward achieving the goals of this executive order.

Regulations and Municipal Revenue Stream

Regulations, or the lack thereof, are not the only deterrents to rainwater harvesting implementation. The sale of potable water is a major source of revenue for many entities. If a rainwater harvesting system reduces the use of municipal water, there is a corresponding decline in associated revenue to the municipality. This reduction is good with respect to water conservation goals; however, some municipalities may balk at any loss of revenue, regardless of its magnitude.

This was an issue of contention when a property owner in a small North Carolina town was interested in installing a rainwater harvesting system at an animal shelter. When the owner applied for a permit, the town denied it, citing a loss in potable water revenue as the deciding factor.

The loss in revenue from reduced municipal water consumption is not the only factor that may deter municipalities from totally embracing rainwater harvesting. Utilities often calculate sewer discharge fees based upon the volume of municipal water consumed. This approach requires the use of only one meter (on the municipal water line). However, when municipal water consumption is reduced (in this case, with site-collected rainwater) the fixture served by the rainwater will discharge unmetered water into the sewerage system, resulting in a loss of revenue for the municipality.

To combat this additional loss in revenue, water and sewer authorities may require designers to include a meter in the rainwater harvesting system that will be used in conjunction with the existing municipal water meter to determine actual sewer contributions and charges. The City of Atlanta in 2010 implemented the first potable water ordinance[7] in the United States. As part of this ordinance, a schedule was constructed in which a fee was calculated to account for the lost sewer revenue associated with the site-collected water supply.

An alternative approach is for utilities to estimate sewer discharges based upon previous use, or charge a flat-rate fee for certain types of buildings (residential, commercial, etc.) that employ rainwater harvesting.

Governance of Rainwater Harvesting in San Francisco, California

Roof-collected rainwater is recognized in the San Francisco Stormwater Design guidelines as a source of water that can be treated for nonpotable applications such as toilet flushing, irrigation, vehicle washing, and so forth. There are two types of rainwater harvesting collection systems promoted for use in San Francisco: small rain barrels (usually found attached to residential downspouts) and the larger cisterns (ranging from 100 gallons to over 100,000 gallons, often used on commercial properties.

The San Francisco Public Utilities Commission (SFPUC), the Department of Public Health (DPH), and the Department of Building Inspection (DBI) have collaborated to encourage the safe use of rainwater for irrigation, toilet flushing, and cooling tower makeup. "In 2008, the SFPUC, DBH, and the DBI signed a Memorandum of Understanding (MOU) for rainwater harvesting systems. This MOU provides an agreement between the three agencies, which concludes that project applicants can safely harvest rainwater."[8]

Rainwater systems are inspected and permitted on a case-by-case basis and the following additional permits are needed for their installation:

1. Plumbing permits are required for all rainwater harvesting systems servicing indoor fixtures, regardless of cistern size.
2. Electrical permits are required for all systems using pumps or other electrical equipment or controls.
3. Building permits are required for cistern footings, foundations, enclosures, roof structures, and rain barrels with downspouts connected to collection systems.
4. Grading and erosion control permits may be required for underground facilities.

Additionally, all systems must comply with the City of San Francisco Department of Public Health, the City of San Francisco Building Code, and the current City of San Francisco Plumbing Code (which consists of the current California Plumbing Code, the most recent Uniform Plumbing Code, and the current City of San Francisco Plumbing Code Amendments).[9] As demonstrated in this example, the permitting process can require multiple agency signoffs and inspections. The design professional will need to review the process for permitting in order to provide time in the schedule for this step.

Stormwater Management Regulations

An important and often underappreciated benefit of rainwater harvesting systems is their ability to help meet federal, state, and local requirements for stormwater management. The Clean Water Act is the main piece of legislation that controls water quality (albeit not water quantity) standards for water use in buildings in the United States. Coupled with the Energy Independence and Security Act of 2007, the quality and quantity of stormwater runoff discharged from a given site is highly regulated throughout the United States.

A Short History of the Clean Water Act

When vacationers experience a peaceful moment alongside a clear stream or take a dip in a lake, they should thank the authors of "The Rivers and Harbors Appropriation Act of 1899." Because of this late-19th-century legislation, waterways are safer and cleaner and provide places for recreation and relaxation. This Act is the oldest major federal environmental law in the United States. It was enacted during a period of great change in the United States at the beginning of what some called the "American Century."

This period was associated with a large growth in industry, technology, and population, along with a wanton disregard for the environment. There was little understanding of the impact of human activities on the local and regional environment. In fact, the law had as much to do with maintaining navigable water safety as it did with protecting the quality of the water. The Act essentially gave authority to the U.S. Army Corps of Engineers to regulate physical obstructions in navigable waters. Effluents in waterways were considered dangerous physical obstructions.

As the United States' population grew over the course of the century, the associated pollutants discharged into local waters grew as well, with little or no concern for the environmental effects. Water pollution was seen primarily as a local or state problem.

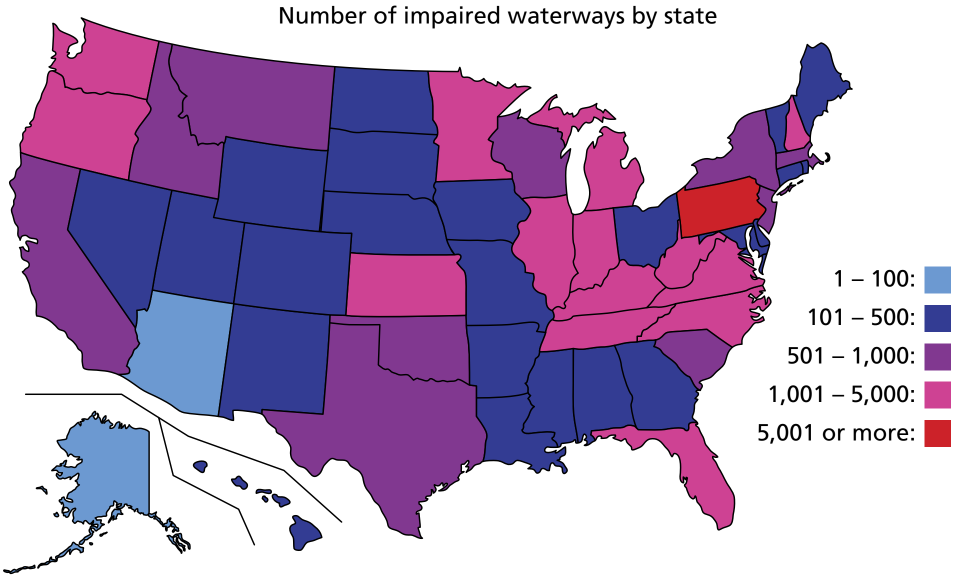

Figure 2.6 Map of states showing number of impaired waterways. (*EPA Water Quality Assessment, National Summary, 2012*)

The federal government had historically been involved only when waterways crossed state boundaries. The relationship of water quality/location in flowing bodies of water was problematic. Differing state rules concerning water pollution limited the federal government's ability to enforce meaningful regulations. Obviously, when a river crosses the state's boundary, it does not mean that the water quality changes for the better or that the effects are any less on the other side of the border. This regulatory environment was a legal limbo that polluters could exploit to avoid adherence to the law.

Over the course of the next half-century, a slow ratcheting of awareness on the part of federal lawmakers ultimately led to the Water Pollution Control Act of 1948. This law directly addressed water pollution that resulted from the rapid growth of chemical and manufacturing plants built to support the war (WWII) effort during the 1940s.[10] Federal grants were provided for the construction of wastewater treatment plants as well as local and state investigation of pollution sources.

In 1956, these measures were continued with the Federal Water Pollution Control Act (FWPCA) and in 1972, amendments to the FWPCA changed the scope to include not only interstate waters, but in-state waters as well. The amended law became known as the Clean Water Act. The Act was introduced by Edmund Muskie and passed both house and senate by March 1972. It was vetoed by Richard Nixon, and then overridden by both house and senate to make it law in October 1972.

Included in the Clean Water Act are requirements that all municipal wastewater must be treated before entering receiving waters. This Act increased federal assistance for municipal treatment plant construction and strengthened and streamlined the enforcement process. The federal role was expanded and the states retained the responsibility for the implementation of the law.

National Pollutant Discharge Elimination System Program

The Clean Water Act authorized the establishment of the National Pollutant Discharge Elimination System (NPDES). This system regulates point sources that use a pipe or a manmade ditch to discharge pollutants in receiving waters. Municipalities, industries, and other facilities must obtain NPDES permits for their discharges. This program is responsible for the improvement of waterways all over the United States.

The primary objective of this legislation was to restore and maintain the chemical, physical, and biological integrity of the nation's waters. It also established a lofty goal of "no pollution" discharges into any water system by 1985 and a short-term goal of establishing water quality that is both swimmable and fishable by 1983. Thirty years past those target dates, this challenge still remains.

NPDES permits are regulated by states. At the federal level, the EPA maintains a list of state permitting agencies. Clustered by waste elimination quantities, these programs control surface water and wastewater point source discharges from public and private sewage collection systems. For example, separate permit regulations are outlined for waste and pretreatment from industrial facilities, concentrated animal feeding operations (CAFO), and landfill runoffs as well as from municipal

The Clean Water Act

The Clean Water Act (CWA) establishes the basic structure for regulating discharges of pollutants into the waters of the United States and regulating quality standards for surface waters. The basis of the CWA was enacted in 1948 and was called the Federal Water Pollution Control Act, but the Act was significantly reorganized and expanded in 1972. "Clean Water Act" became the Act's common name with amendments in 1972.

Under the CWA, EPA has implemented pollution control programs such as setting wastewater standards for industry. The EPA also set water quality standards for all contaminants in surface waters. The CWA made it unlawful to discharge any pollutant from a point source into navigable waters, unless a permit was obtained. EPA's National Pollutant Discharge Elimination System (NPDES) permit program controls discharges. Point sources are discrete conveyances such as pipes or fabricated ditches. Individual homes that are connected to a municipal system, use a septic system, or do not have a surface discharge do not need an NPDES permit; however, industrial, municipal, and other facilities must obtain permits if their discharges go directly to surface waters.[11]

and domestic wastewater facilities. These are the waste load and stormwater discharge allocations by municipalities that apply to most commercial buildings.

Phase I of the U.S. Environmental Protection Agency's Act relied on the NPDES permit coverage to address stormwater runoff from:

- Medium and large separate storm sewer systems, generally serving populations of 100,000 or greater
- Construction activity disturbing 5 acres of land or greater
- Ten categories of industrial activity[12]

Phase II of the Act expanded regulations to include smaller construction sites and to implement programs and best practices to provide even more protection of the nation's water supply. In this case, small construction sites are any sites greater than 1 acre and less than 5 acres of land.

Meeting NPDES Goals in San Francisco, California

Published in 2009, the San Francisco Stormwater Design Guidelines[13] provide a clear example of how meeting NPDES permit requirements can be coupled with meeting green building codes. Engineering, planning, and regulatory frameworks are provided for designing green infrastructure, particularly in urban settings. This document also reviews general stormwater practices in San Francisco and provides examples of how to integrate green BMP's into urban design. It is among the first publications in the United States to describe the relationship between rainwater collection and BMPs that can meet NPDES permit requirements. As described in this guideline, the design goals for sites are:

1. Do no harm: preserve and protect existing waterways, wetlands, and vegetation.
2. Preserve natural drainage patterns and topography and use them to inform design.
3. *Think of stormwater as a resource, not a waste product.*
4. Minimize and disconnect impervious surfaces.
5. Treat stormwater at its source.
6. Use treatment trains to maximize pollutant removal.
7. *Design the flow path of stormwater on a site all the way from first contact to discharge point.*

Although all of these goals are important for rainwater harvesting systems, strategies 3 and 7 speak directly to the integration of rainwater into a building and site system using water as "a resource, not a waste product." The inclusion of rainwater collection for use in buildings as a BMP for meeting stormwater discharge requirements provides another compelling reason for using collected roof water inside commercial buildings. Rainwater harvesting is just one of many low-impact design (LID) principles that are part of an integrated design strategy incorporating municipal infrastructure, architecture, and landscaping with the environment.

Figure 2.7 Landscape architect Rios Clementi Hale Studios collaborated with water system designer Biohabitats to meet stormwater regulations and challenges by using rainwater as part of the design methods for irrigation at Pete V. Domenici U.S. Courthouse in Albuquerque, NM. (*Robert Reck*)

Managing the Quantity of Stormwater Runoff

The Clean Water Act and NPDES program primarily address the water quality aspects of stormwater management; however, managing the quantity of stormwater runoff from a development is equally as important.

The development of new urban land is typically characterized by vegetation clearing and removal. The construction process includes soil grading, soil compaction, and the introduction of large amounts of impervious surfaces and replacement of natural drainage systems with networks of impervious channels and piping.[14]

Increases in impervious surfaces and soil compaction reduce infiltration rates that decrease groundwater recharge, increase the frequency and magnitude of high water volume, and increase water flow variability. Due to the reduction and/or elimination of the natural system of infiltration and decreases in evapotranspiration rates from vegetation, water from new building sites enters surface water bodies as surface runoff, resulting in increased stormflow volumes.

As urbanization increases, peak discharge rates and volumes discharged to surface water bodies increase as well. Construction in urban areas will route surface runoff to streams quickly and efficiently using storm sewers and gutters. Consequently, the watershed's response to precipitation is accelerated. The lag time between precipitation and runoff is decreased, as water is transported to nearby streams within hours instead of days. The magnitude, frequency, and rate of change of stormflow within the watershed are increased and can cause flooding and degradation to surface water systems. Because the water is channeled so quickly to the surface water, the duration of individual stormflow events is decreased.

Increases in flow volumes and peak discharges combined with shorter lag and recession times result in a higher potential for flooding. In comparing urban areas with nonurban areas, the annual flood exposure may be as much as three times larger.[15] Thus, precipitation events that produced no increase in stream flow before urbanization may cause substantial flooding after urbanization.

The Energy Independence and Security Act of 2007 (EISA) addresses stormwater quantity control.[16] EISA requires that the postdevelopment behavior of stormwater runoff for all federal projects exceeding 5,000 square feet match that of predevelopment

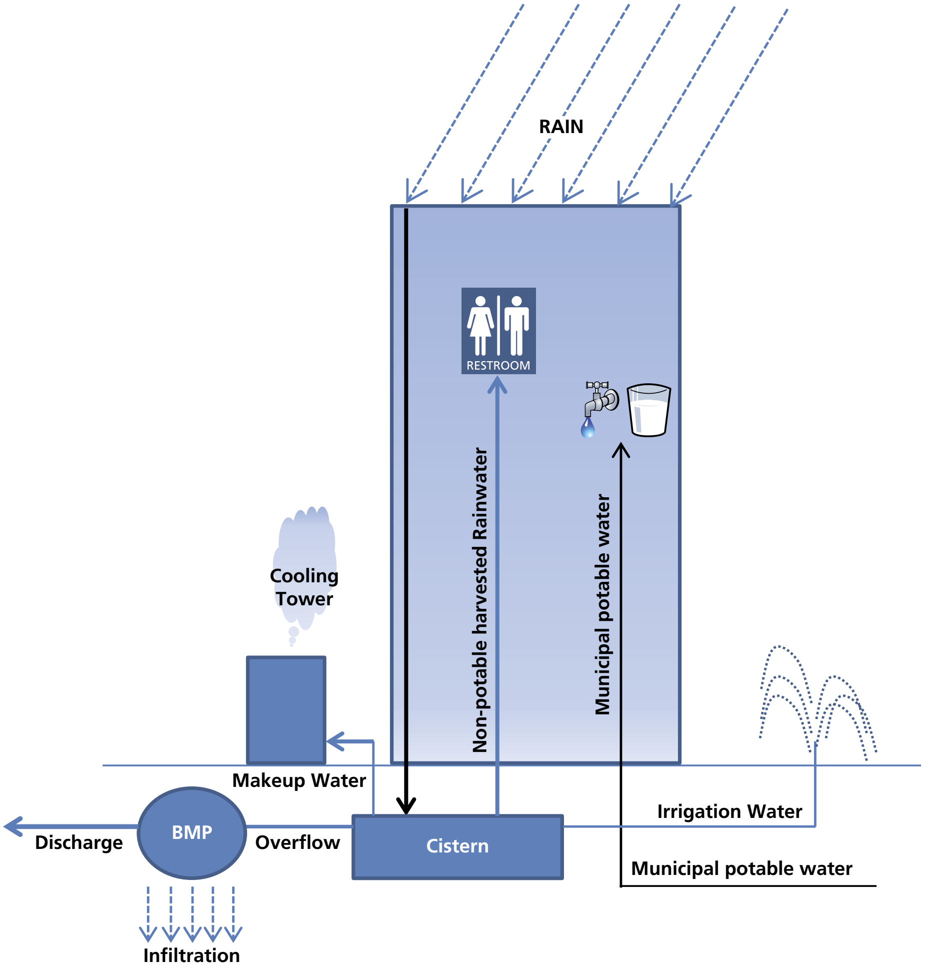

Figure 2.8 Diagram of the top-tier stormwater concepts in Tysons Corner for rainwater harvesting. (*Bruce McGranahan, County of Fairfax Virginia, Land Development Services*)

conditions. Many states and/or municipalities now have similar regulations that require developers to manage the volumes and flow rates of stormwater leaving a site, both during and after construction.

Using Rainwater Harvesting Systems to Meet Stormwater Regulations

In 2008, the National Research Council published a study that included an overview of best management practices (BMPs) that can be used to manage stormwater runoff.[17] EPA defines a stormwater BMP as a "technique, measure or structural control that is used for a given set of conditions to manage the quantity and improve the quality of stormwater runoff in the most cost-effective manner."[18]

Rainwater harvesting systems can provide stormwater management benefits by reducing volumes and decreasing the peak flow for storm events by capturing runoff and storing it for later use. However, the ability of the system to provide these benefits is dependent upon the use of stored water to provide enough room within the tank for the next rain- or snowfall event (precipitation). When the designated uses of a system require frequent, consistent withdrawals of harvested water, the ability of a system to mitigate stormflows increases. In contrast, using the system to meet seasonal or inconsistent demands for water on the site results in the decreased mitigation of stormwater volumes and peak flow rates. These inconsistent demands cause the storage vessel to remain full and overflowing for extended periods of time, thus providing no detention or retention benefits.

For systems that do not have reliable year-round uses, designers can fabricate a method of drawing down or partially draining the system to generate storage space for the next rainfall event. A dual-purpose system can be created to draw down the volume of harvested water by dividing a storage tank into two portions. One portion of the tank will be designated for stormwater detention and the other as retention. The portion of the tank that is designated for retention storage comprises the bottom portion of the storage tank. Water is extracted from this section as needed to meet user demands. The top portion of the storage tank is the designated area for stormwater detention and serves as a temporary holding space for runoff. A passive release opening or orifice that allows the water in the detention portion to slowly drain between rain events separates the two storage volumes.

With this design the detention storage can be emptied prior to the next rain event, allowing the system to reliably capture runoff from a large percentage of rain events while still serving as an alternative source of water for users.[19–21]

Examples of Stormwater Management Programs That Incorporate Rainwater Harvesting

Tysons Corner, Virginia "Urban Stormwater Concepts,"[22] published in April 2012, outlines a comprehensive stormwater planning process in Tysons Corner, Virginia, which includes rainwater collection as a best management practice. Bruce McGranahan, PE, Site Code Research and Development Branch, Code Development and Compliance Division at Tysons, believes that

> "rainwater harvesting is an emerging stormwater management strategy that has great application where rooftops and impervious cover dominate the landscape.

> Rainwater harvesting can be an effective runoff reduction practice in urban areas where the intensity of development precludes using controls that are more conventional. The challenge is to have a reliable year round use for the captured rainfall in order to get stormwater credit. We are seeing the application of rainwater harvesting in the redevelopment of Tysons Corner where the density and stormwater management goals make it an economically feasible option."

Tysons Corner has created a flowchart that a designer can follow based on soils, infiltration rates, and opportunities to maximize rainwater capture for use in a building. Specifically, "stormwater management and water quality controls for redevelopment should be designed to return water into the ground where soils are suitable or reuse it, where allowed, to the extent practicable." At a minimum, a site should be designed to retain the first inch of rainfall through infiltration, evapostranspiration, and/or storage and use. This 1-inch goal may vary depending on the locale.

For example, if the underlying soils support infiltration greater than .52 inch per hour then their recommendation is to maximize opportunities for year-round rainwater harvesting. If a cistern can capture greater than 1 inch of rain on the site from the roof area and show permanent year-round uses that will drain a cistern between storms, then the recommendation is to design the cistern to the volume corresponding to 1 inch of rainwater. If the rainfall captured from the roof is less than 1 inch across the entire site then the cistern should be designed for the actual use.

The Tysons Corner guidelines list the top tier designated uses for harvested rainwater for both interior uses (cooling tower makeup water, toilet flushing, and laundry) and exterior uses (washing [vehicles, building facades, equipment], irrigation, discharge to water features and to subsurface infiltration pits). They also encourage designers to apply for LEED® certification to receive points for reducing stormwater volumes, potable water consumption, and wastewater and potable water demand.

These concepts are based on management principles that encourage the reduction of impervious surfaces and the treatment of pollutants at the source. The recommendations encourage small-scale distribution approaches to rainwater harvesting using multiple strategies and treatment systems. The primary method of pollutant control is to remove them through runoff reduction, thus saving the municipality additional costs for treatment of water for the community. Tysons Corner supplies a checklist for designers who want to follow an integrated path to stormwater management, which can be downloaded from their website.[23]

State of North Carolina The State of North Carolina recently revised their Stormwater BMP Manual to include rainwater harvesting. Under the new regulations, rainwater harvesting is awarded nutrient reduction credit for total suspended solids (TSS), total nitrogen (TN), and total phosphorus (TP), as well as credit for volume and peak flow reduction.[24] Percent reductions of 85, 40, and 10 percent are assigned to rainwater harvesting systems for TSS, TN and TP, respectively. Hydrologic credit is not awarded via

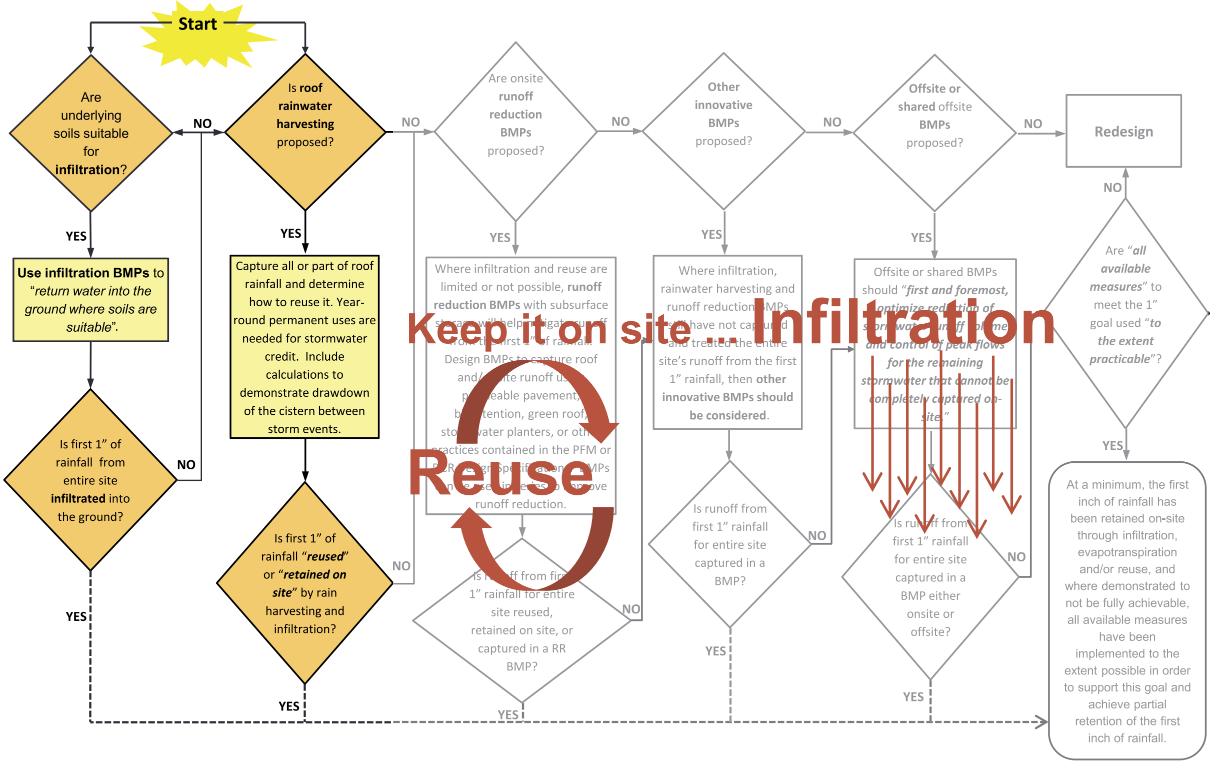

Figure 2.9 Tysons Corner flowchart showing stormwater concepts and the decision tree for the use of rainwater harvesting. (*Bruce McGranahan, County of Fairfax Virginia, Land Development Services*)

percent reductions; rather, the impervious area contributing runoff to a rainwater harvesting system can be deducted from the impervious area used to calculate the size of other BMPs.

Thus, a greater contributing drainage area for rainwater collection systems results in decreased sizes of other stormwater BMPs on the site. This can reduce overall development costs, as well as free up additional buildable area that can boost profits.

To receive hydrologic credit, rooftop runoff must be captured and either used onsite, treated and released, or infiltrated. Specifically, designers must demonstrate, via water balance calculations, that a system accomplishes at least one of the following:

1. The runoff generated by a storm event less than or equal to the design rainfall depth (either 1 or 1.5 inches, depending on location and associated rainfall intensities) must be captured and used or released from the system within five days after the event
2. The system produces overflow of no more than 14 percent of the annual average historic rainfall
3. The runoff generated by a storm event less than or equal to the design rainfall depth must be discharged to a properly designed BMP within 5 days after the event.

As discussed previously, the ability of a system to meet these objectives relies on a dedicated, year-round demand of harvested rainwater. Consequently, the State's regulations require that designers prove a reliable demand on the system to guarantee that stormwater management goals are met. This demand does not have to be an actual water use—it can be a "fabricated" use that allows the drawdown of collected rainwater. Ideally, the water discharged from the passive release device will be discharged to a supplemental stormwater BMP to allow for additional treatment and infiltration.

Step 3: Incentive Programs and Rating Systems

There are a number of incentives and rebates that encourage commercial and residential rainwater harvesting in the United States. These incentives include those that are available for numerous water best management practices combined with other sustainable initiatives. For example, DSIRE[25], the Database of State Incentives for Renewables and Efficiency, does not have a specific area for rainwater or site best practice incentives, but it does list incentives by state for the use of water-efficient fixtures and equipment.

Design professionals should contact the applicable governing jurisdictions to see if there are incentives for rainwater collection (some of which may be found in the information supplied by the National Conference of State Legislatures; see Appendix A). In some cases, these may include the reduction of tapping fees or water rates for the use of rainwater. In other cases, these could include tax exemptions for the equipment or exceptions to the size or type of equipment adding value to the building. Generally, these incentives respond to the local, regional, or state political conditions and the public's awareness of water abundance/shortages.

The implementation and incorporation of financial incentives and rebates has begun to have a huge bearing on the industry as a whole. The key in the development of these kinds of incentives resides in the policy makers' assessment of the efficacy of rainwater harvesting as a whole. HarvestH2O.com[26] maintains a useful online database on rainwater and water conservation incentives that are useful for anyone interested in incentives for their project. Although many of these are focused on incentives for single-family homes, a few programs are beginning to offer incentives to business owners. As a best management practice, rainwater harvesting systems can also be used to apply for stormwater incentives.

Another resource is "Managing Wet Weather With Green Infrastructure,"[27] a municipal handbook produced by the EPA on incentive mechanisms for stormwater initiatives. Initiatives discussed in this document include:

- Stormwater Fee Discounts (based on impervious surface area)
- Development Incentives (examples include zoning upgrades, expedited permitting, and increases in floor area ratios)
- Grants (direct funding or approvals of tax increment financing for stormwater initiatives)
- Rebates and Financing
- Awards and Recognitions (marketing opportunities, public outreach, and even monetary awards. The notoriety associated with these projects is directly tied into a value in the ROI formula.)

The increasing knowledge of rainwater harvesting systems has fostered a movement by educators, professionals, and citizens to search for incentives for rainwater harvesting and advocate for these as part of sustainable city planning.

Rainwater Incentives in Austin and Tucson

Austin, Texas

Austin Water, the City's municipal water supplier, offers a financial incentive to encourage rainwater harvesting for nonpotable uses. Rebates of $.050 per gallon are available to customers or qualified system installers for nonpressurized systems, such as rain barrels and $1.00 per gallon for pressurized systems, such as large cisterns with pumps. Rebates are based on storage capacity and cannot exceed 50 percent of the total cost of the installation.

Austin Water specifies certain system requirements to achieve this rebate, such as the installation of a first-flush diverter, a sturdy base, liners for metal tanks, and backflow preventers for larger systems. Depending on the system, a variety of permits may be required and it is the applicant's responsibility to ensure that the system construction does not violate zoning codes such as setback restrictions or homeowners' association rules.[28]

Tucson, Arizona

With a focus on single-family residential customers, the City of Tucson provides up to $2,000 in rebates to qualified applicants. Customers can apply for rebates for either a passive strategy for water conservation, such as the construction of a rain garden, or apply for rebates for installing a rainwater tank. The rebate is based on the size of the tank. For a 50- to 799-gallon tank the customer can receive $0.25 per gallon and $1.00 per gallon for tanks with a capacity greater than 800 gallons.

Applicants must receive water from Tucson Water and attend an approved workshop.

Additional conditions that pertain to the type, quality, and safety of the system are listed on the Tucson Water website.[29]

Green Rating Systems

In addition to satisfying incentive or rebate requirements, water conservation and rainwater harvesting are usually part of all green building rating systems. The following is a list of some of the primary green building rating systems or programs that award points for rainwater harvesting as part of their certification.

- **United States Green Building Council (USGBC)—Leadership in Energy and the Environmental Design, LEED®**[30]
  LEED® rating systems include certification programs for Schools, Homes, Neighborhoods, Core and Shell, Commercial Interiors, Data Centers, Warehouses and Distribution Centers, Hospitality, Retail, High Rise, Existing and New Buildings. Water Efficiency is one of the main categories in the LEED® system and credits are obtained by maximizing the use of water.

There are several strategies outlined by this program for effective water conservation. Water conservation measures include the specification of low-flow toilet fixtures or equipment that meet WaterSense labels. LEED® credits can also be obtained through the reduction of the use of potable water for irrigation. LEED® recommends that the designer select appropriate plants for the climate, integrate alternative water sources and smart irrigation technologies, and incorporate low-impact development strategies on all projects. Innovative wastewater techniques, such as graywater recycling or the cleansing of wastewater onsite, can also achieve LEED® credits.

The 2014 version of the LEED® guidelines proposes that rainwater management become a "named" credit for LEED® New Construction V4 in the "Water Efficiency" category. The goal of this credit is to "reduce runoff volume and improve water quality by replicating the natural hydrology and water balance of the site."[31]

A new approach for rainwater management is based on replicating the natural hydrologic cycle of the watershed to the 95th percentile of the region's natural process by using low-impact development strategies and green infrastructure. These practices include green roofs, biofiltration, bioretention, green walls, permeable paving, and, of course, rainwater harvesting.

- **BREEAM: Building Research Establishment Environmental Assessment Method**[32]

  www.breeam.org/

  The Building Research organization was founded in 1921 as a governmental housing agency in the United Kingdom and then grew as a private center dedicated to the research of various types of construction. In 1988, this organization initiated the development of an environmental assessment method evaluating the sustainability of buildings throughout the world.

  BREEAM evaluations are used in more than fifty European countries. BREEAM categories include assessments for New Construction, International New Construction, In-Use, Refurbishment, and Communities. A BREEAM assessment benchmarks building performance and impact on the environment. Energy and water use, health and well-being, pollution impacts, transportation, waste, ecology, and management processes are all evaluated in a BREEAM scorecard.

The aim of the BREEAM Wat 01 Category is "to reduce the consumption of municipal water for sanitary use in new buildings from all sources through the use of water efficient components and water recycling systems."

Rainwater systems are required to be installed in compliance with British Standards (BS) BS8515:2009.[33] To date, this standard includes the use of rainwater for toilet flushing, laundry, and irrigation, but not for potable water uses.

- **Enterprise Green Communities[34]**

  www.enterprisecommunity.com/solutions-and-innovation/enterprise-green-communities/criteria

  The Enterprise Foundation collaborates with financial institutions, governments, and community organizations to provide guidance and funding for affordable housing. Their mission is "to create opportunities for low- and moderate income people through affordable housing in diverse, thriving communities."[35] They believe that for housing to be affordable, it also must be sustainable. Every extra dollar spent on utilities is a dollar that can be captured through good design and specification of energy and water saving equipment.

  The Enterprise Green Communities checklist provides guidance on numerous green practices that create vital neighborhoods throughout the United States. Since 1982, they have invested more than $11.5 billion in equity, grants, and loans while strengthening neighborhoods and creating over 410,000 jobs nationwide.

  Protecting community water infrastructure is part of the connective fabric of the Green Enterprise sustainable design criteria. The 2011 Green Communities Criteria checklist requires an initial integrative design meeting for each project. Design professionals are required to submit a green development plan that includes water conservation for both the interior and exterior of a building.

  Site improvements include credits for Efficient Irrigation and Water Reuse (3.5) and the collection and use of rainwater is included as a design strategy. Up to four points can be obtained in Credit 4.3 Water Reuse toward meeting green enterprise criteria by harvesting, treating, and reusing rainwater and/or graywater to meet the project's water needs. (Although technically, rainwater is a primary use of water, not a reuse; it is often included in the reuse portion of many green checklists.)

- **Green Globes[36]**

  www.greenglobes.com/

  The Green Globes rating system was originally derived from BREEAM and developed with input from the Canadian Standards Association, the Canadian Department of National Defense and Public Works, the University of Toronto, and representatives from Arizona State University, the Athena Institute, and BOMA. The Green Globes system is used in both Canada and the United States. Strict third-party reviews and site visits to the projects are included in the certification process of green building performance.

There are three main certifications in the Green Globe rating system, which are New Construction, Existing Construction, and Healthcare Facilities. Water performance, conservation, and treatment is included as a main environmental assessment area for this comprehensive program. Green Globes also includes life cycle analysis (LCA) through links to the Athena EcoCalculator for LCA Analysis for Commercial Assemblies. There are points available for rainwater "reuse" systems designed to manage stormwater and to reduce the amount of municipal water.

- **Living Building Challenge™[37]**

  https://ilbi.org/lbc

  The International Living Future Institute sponsors the Living Building Challenge™. An outgrowth of Canadian sustainable design initiatives, the institute is the parent organization for Cascadia Green Building Council. The Living Building Challenge™ is an international performance standard with rigorous design criteria and goals for designers to provide regenerative designs for the net zero use of water and energy. It is a philosophy, platform for advocacy, and a certification program. The Living Building Challenge™ is comprised of seven main performance areas: Site, Water, Energy, Health, Materials, Equity, and Beauty. "Toward Net Zero Water: Best Management Practices for Decentralized Sourcing and Treatment" is a useful resource published in 2011 by the Cascadia Green Building Council. Buildings that meet the net zero requirements for the Living Building Challenge™ must meet the following standard: "One hundred percent of the project's water needs must be supplied by captured precipitation or other natural closed loop water systems that account for downstream ecosystem impacts, or by recycling used project water. Water must be appropriately purified without the use of chemicals."[38]

  The International Living Futures Institute sponsors research, publishes reports, and certifies projects that include rainwater use. "Regulatory Pathways to Net Zero Water"[39] can be downloaded from the web and provides numerous case studies, examples, diagrams, and research on rainwater systems.

- **National Green Building Standard**

  www.homeinnovation.com/Green

  The National Green Building Standard (NGBS) was published in 2012 by the National Association of Home Builders and outlines a four-level rating system (Bronze, Silver, Gold, and Emerald) that can be used to evaluate the sustainability of a residential development.[40] This standard can be voluntarily adopted by a developer, or can be used by municipalities as a baseline for green building programs. "NGBS/ICC-700 provides 6 points for collecting and using rainwater and 2 points for distributing the water with gravity or a renewable energy source (801.8)."[41]

In addition to the main certification systems listed above, there are numerous other opportunities to benchmark best practices. The EPA, the U.S. Army, state programs such as New Mexico Build Green, MyFlorida, Austin Energy Green Building, and Earth Advantage Commercial are a few of many new programs that are available to the design professional. Green rating systems can provide guidance to professionals as well as marketing and branding advantages to their clients.

VanDusen Botanical Gardens—LEED® Platinum and The Living Building Challenge

Vancouver, Canada

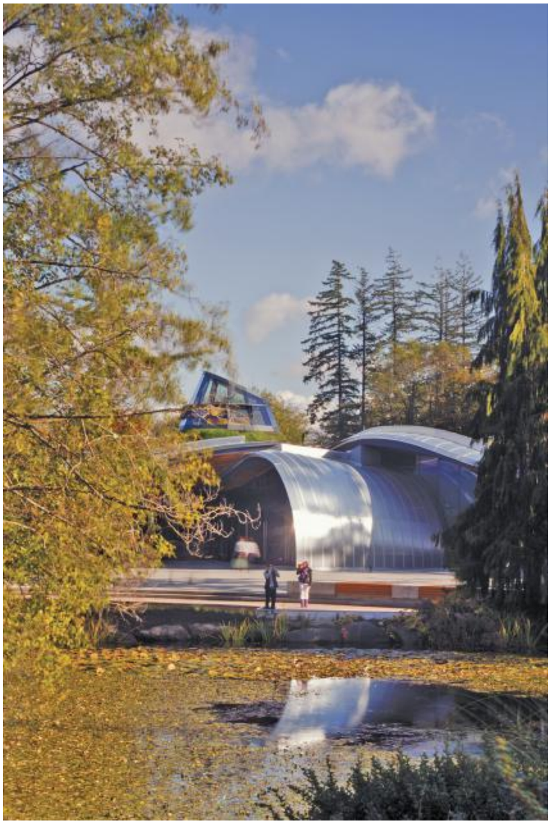

Figure 2.10 Design goals were set at an early stage of planning for the VanDusen Botanical Gardens in Vancouver, Canada. This project was designed by Perkins+Will to be in harmony with nature, and is currently targeting the Living Building Challenge™ and LEED®-Canada NC Platinum. Rainwater is filtered and used for the building's water requirements and various integrated stormwater drainage systems designed to meet local and stringent best management practices for the community. (*Nic Lehoux/Courtesy: Perkins+Will*)

Designed to exceed LEED®-Canada NC v1.0 Platinum, the Visitor Centre is the first building in Canada to register for the Living Building Challenge™—the most stringent measurement of sustainability in the built environment. The Visitor Centre uses onsite, renewable sources—geothermal boreholes, solar photovoltaics, solar hot water tubes—to achieve net zero energy on an annual basis. Rainwater is filtered and used for the building's nonpotable uses. One hundred percent of blackwater is treated by an onsite bioreactor and released into a new feature: a percolation field and garden. A solar chimney, composed of an operable glazed oculus and an aluminum heat sink, which converts the sun's rays to convection energy, provides assistance for natural ventilation. Summer sun shines on darker surfaces to enhance ventilation further. Located in the center of the atrium, and exactly at the center of all the building's various radiating geometry, the solar chimney highlights the role of sustainability by form and function.

Design goals for the integrated stormwater management plan (ISMP) for the project were developed to fulfill both the requirements of the Living Building Challenge™ and LEED®. The ISMP will conform to Metro Vancouver's (MV) Best Management Practice Guide for Stormwater and the current City of Vancouver design specifications and guidelines related to storm drainage systems. To achieve these objectives, various Integrated Stormwater Management Strategies (ISMS) have been incorporated into the design and include:

- Green Roof: Green roofs allow for infiltration through the soil layer and increased evapotranspiration.
- Absorbent Landscaping: Absorbent landscaping provides optimal soil properties for infiltration and percolation to the groundwater table. This allows for recharging of the local groundwater table to maintain the base flow characteristics of our watercourses between precipitation events.
- Gravel Surface: Gravel surface allows stormwater runoff to percolate through the gravel base and subbase layers into the native soil.
- Roof Runoff Collection: A cistern is located under the north roof petal to collect rainwater from the roof for reuse in the building. This use helps decrease impervious area stormwater runoff.
- Bioretention Pond and Swales: Surface stormwater facilities used to temporarily retain stormwater overflow in a shallow depression and gradually allow infiltration into the ground. This allows for increased time of concentration; as a result, runoff peak flows decrease. The pond and swales provide a natural quality treatment.
- Retaining 100 percent of all stormwater on the VanDusen site was not possible in a climate subject to intense rainfall events or on a constrained site with poor soils and with limited infiltration opportunities. It is important to note that even as an undisturbed forested site, this site would not retain 100 percent of all stormwater. However, by adapting a series of site and stormwater design strategies, the project was able to bring the amount of stromwater discharge from the site back to predevelopment levels.
- Rainwater is collected from part of the total roof area. The 6,624-square-foot (582 m^2) roof collects 143,302 gallons of water annually. This rainwater is collected in a 33,000-gallon (125 m^3) cistern and then filtered and used for toilet flushing.

Cistern water levels vary relative to local precipitation and when precipitation cannot meet the needs of the system, makeup water is provided via a municipal water connection.

The rain travels from the SBS (metal) roof to a drain sedimentation tank (DST). The tank assists in the separation of debris and sand from the rainwater. No water is collected from the green roof. After the DST, the water flows to the rainwater cistern (RWC). Because the rainwater system only collects water from the SBS roof and uses a DST, no first-flush diversion is employed. From the RWC, the rainwater is delivered to the flushing fixtures as required. There is an overflow on the RWC that delivers the water to a rock pit (5 m × 10 m × 2 m deep) where the water can infiltrate into the ground. The rock pit also has an overflow to the building sump, which is connecting to the City stormwater sewer system.

VanDusen has achieved 60 percent water use reduction. The water use reduction is calculated in accordance with the LEED® Canada NC v1.0 by comparing a design case to a baseline case. This water use reduction was calculated as equivalent to a total annual volume of 137,700 gallons (517,734 L) of potable water savings. Total rainwater volume collected was 143,302 gallons annually.

The design professionals confronted many challenges while complying with local legislation while applying multiple rating systems (LEED® and the Living Building Challenge™). The Living Building Challenge™ does not allow connections to any municipal services. The Vancouver Building By-Law directly states that a building must have a connection to City services (sanitary, stormwater, and potable water). These demands for connection to municipal services directly contradicted the LBC guidelines and left the team looking for alternative solutions to comply.

In addition, there were lessons learned about the acceptance of different levels of treatment. VanDusen treats the rainwater to Recreation Type 3 Quality, which is a relatively high standard of treatment of rainwater being used to flush water closets. This standard treats the rainwater for both odor and color because there is a strong aversion to slightly discolored water in flushing toilets. Architects at Perkins+Will learned that additional public and client education is important in any rainwater harvesting system installation.

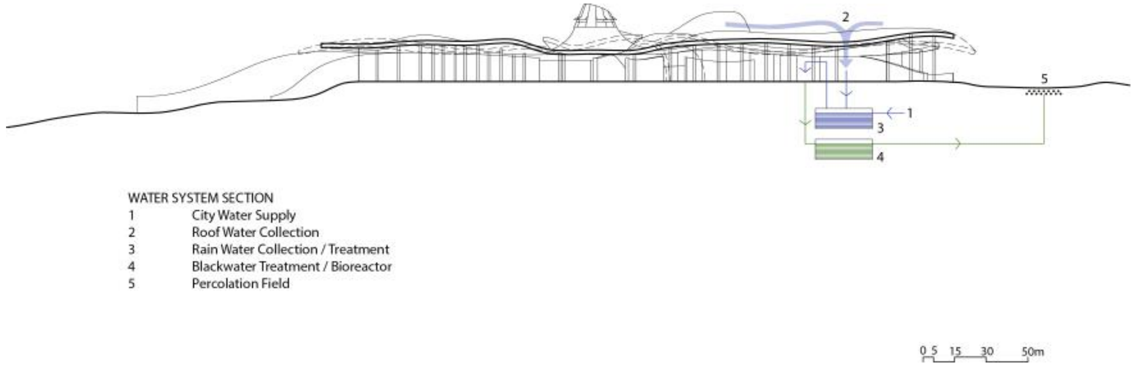

Figure 2.11 Total rainwater volume collected on the roof of the VanDusen Botanical Gardens was 143,302 gallons annually. No rainwater was collected from the green roof on this project. (*Perkins+Will*)

Step 4: Educating and Involving the Stakeholders in the Design Process

One of the major barriers to the development of effective rainwater collection systems is a lack of information and stakeholder involvement. Successful design projects require ongoing communications with all stakeholders and this process may continue beyond project completion. Stakeholders in a project can include:

- Clients
- Architects
- Engineers
- Contractors
- Neighbors, including seniors and children
- Planners
- Utility providers
- Public participants

Many design firms are finding that strong public input as part of the design process increases the likelihood of success with their projects. Many architects begin a project by analyzing its components and developing a "green team" that will begin to engage clients and all stakeholders.

Meetings with the client can be used to educate them as to the type of rainwater systems that are available as well as unique aspects and aesthetics that can be integrated into the design. Architects can present the added value of green rating systems, the economics of system design, and any grants or incentives that might be available. Frequent construction meetings can provide information on the integration of system components, system requirements, and standards preventing "quality engineering" that can negatively impact system functioning or maintenance.

Figure 2.12 Presentations to the team and to the public explain project strategies and provide an opportunity for contributions to the planning process. (*Atelier Dreiseitl*)

Including the public in the education process may involve a series of workshops. Particularly in areas where there are public concerns about flooding, project teams can educate the public as to the value of the new rainwater proposal. Some projects require larger reviews of watershed areas and some propose local or site solutions to water management. Designers may also need to educate the public as well as public officials in projects that include onsite waste processing of graywater through natural filters due to the negative connotation associated with wastewater treatment.

As part of the public process, some firms engage the public in the design of the waterscape, particularly if it includes a play area. Design professionals can both learn as well as educate stakeholders through active involvement in a public design process.

Figure 2.13 Putting it all together means a seamless integration of the environment as part of a building system as seen in this plan by Lake|Flato Architects of the Government Canyon Visitor Center, in San Antonio, Texas. (*Lake|Flato Architects*)

Step 5: Putting It All Together

Government Canyon Visitor Center

San Antonio, Texas

The Government Canyon Visitor Center is situated in a restored field of native grasses and oaks. It forms the gateway to the 8,600-acre Government Canyon State Natural Area. The program for the Natural Area headquarters included an exhibit hall, park store, classrooms, offices, and an outdoor pavilion.

Government Canyon lies along the Balcones Escarpment on the recharge zone of the Edwards Aquifer, the sole source of drinking water for the City of San Antonio. The area is under immense development pressure. The project is in the region's first and only Karst Aquifer preserve, and one of its goals is to protect and restore the natural landscape. The challenge was to create high-use, low-maintenance, and economical structures that reinforce the mission of the Natural Area.

The buildings respect the site's fragile ecosystem and minimize impacts on the aquifer below. They were designed for water conservation, minimizing the disruption of surface water flows, collecting and using rainwater, minimizing stormwater runoff and contaminants, and reducing the use of groundwater. In this way, the buildings become an educational exhibit that demonstrate sustainable water practices.

Figure 2.14 The high-use, low-maintenance, and economical structures at the Government Canyon Visitor Center reinforce the mission of the client. (*Chris Cooper*)

Design goals for this project include:

- Retain stormwater
- Conserve potable water
- Provide water resiliency
- Lower water bills
- Reduce waste
- Protect aquifer recharge (preserve water quality and natural recharge)
- Protect endangered/threatened species and their natural habitats
- Create educational and interpretational opportunities for visitors
- Create atypical building that redefines the standard State Park ranger station/visitor center.
- Design a site that is historically and culturally appropriate based on previous inhabitants

Located in an area of Texas with an average rainfall of 30.74 inches, the 7,800-square-foot roof of this project collects rainwater in five cisterns: two visible, aboveground 3,200-gallon tanks and three belowground 3,800-gallon tanks. They collect enough water to use for irrigation and for toilet flushing for the staff of six and 1,173 visitors per week.

The Lake|Flato team combined a number of sustainable strategies, including effective space planning, right-sizing, thermal envelope design, daylighting, lighting controls, and use of renewable energy. The operational procedures also contributed toward reduced energy consumption for the Government Canyon Visitor Center.

These conservation strategies were accomplished at no additional cost to the owner. These savings were obtained through effective space planning and right-sizing first-cost savings. However, based on actual energy consumption records provided by the utility companies and according to the Target finder model, the project has proven to outperform the average structure of a similar type by more than 80 percent. Based on current local energy costs ($0.0631 per kilowatthour) this translates into a direct energy cost savings of $1,600 annually throughout the lifetime of the facilities.

One major design goal was to create a facility that exhibited a conservation ethic, within the framework of the structures. Every effort was directed toward providing designs that accomplished the client's utilitarian and educational mission with the least material and financial investment possible, optimizing the use of every dollar spent. This, balanced against the need to create both beautiful and appropriate structures, contributed toward a facility that provides lasting value.

The design and the ultimate success of the project is the result of an extensive and long-term collaboration between the owners, design team, and the participating community lead groups. Through a series of design workshops and site visits with cultural and natural resource experts, synergies were built. These synergies allowed for enhanced use and connectivity of the facilities in relation to the natural resources they are created to protect.

Through this contact, the members of the design team came away with a greater understanding of the site, and a greater technical knowledge of material, energy, and water efficient techniques.

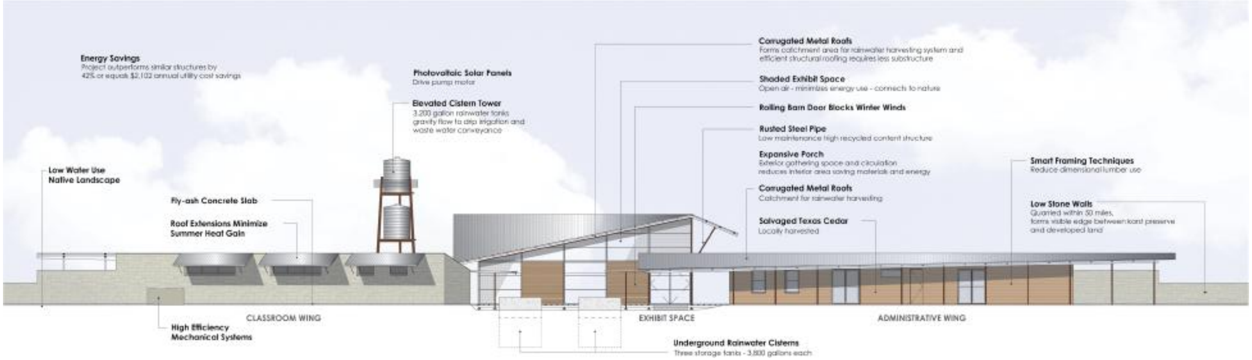

Figure 2.15 Integrated sustainable design strategies were incorporated into the design of the Government Canyon Visitor Center. (*Lake*|*Flato*)

Architects, engineers, scientists, and policy makers are learning more about the advantages and benefits of rainwater systems. A thorough understanding of regulations, stormwater management guidelines, water conservation techniques, and green building rating principles will reveal numerous opportunities to incorporate rainwater harvesting systems in commercial buildings.

By setting clear goals, educating the client, creating a planning team, and understanding the permitting process, the design professional will successfully incorporate a rainwater harvesting system into many of their projects. Meeting strict NPDES guidelines, meeting green building rating system measurements, and providing alternative sources for indoor uses are all reasons for the inclusion of rainwater harvesting systems. The next step for the professional is to learn how to design an integrated rainwater system that supplements the amount of water needed in different building types.

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CHAPTER 3

Water for Thirsty Buildings

RAINWATER: CALCULATING COLLECTION AND USE

Calculating the collection and use for rainwater at a conceptual stage of design is not a difficult process. After setting the project goals, the design professional begins by

1. Creating a water audit
2. Calculating rainwater supply
3. Calculating rainwater demand
4. Sizing a cistern

Other considerations for designing a rainwater harvesting system include the incorporation of other alternative water sources that can be used for onsite water collection and a basic understanding of plumbing design. With this basic knowledge, the design professional can begin the process of creating a successful rainwater harvesting system to meet project goals.

Comparisons of school projects are provided in this chapter as examples of applied rainwater harvesting design calculations. These examples, as well as actual case studies presented in this chapter and in Chapter 7, help to show how to calculate a rainwater harvesting system and to analyze the value of a rainwater collection system in different project locations. Rainwater harvesting collection and water conservation can provide dramatic cost savings for schools and other facilities.

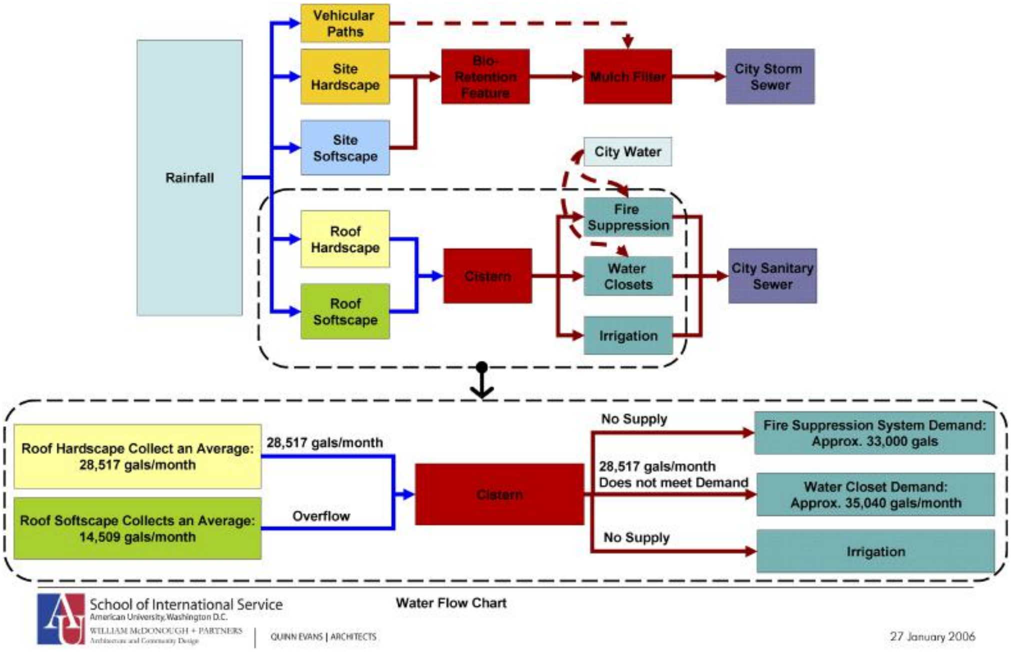

Figure 3.1 Water balance chart and analysis of the rainwater system for American University School of International Service designed by Quinn Evans Architects with William McDonough Partners. (*Courtesy of Quinn Evans Architects*)

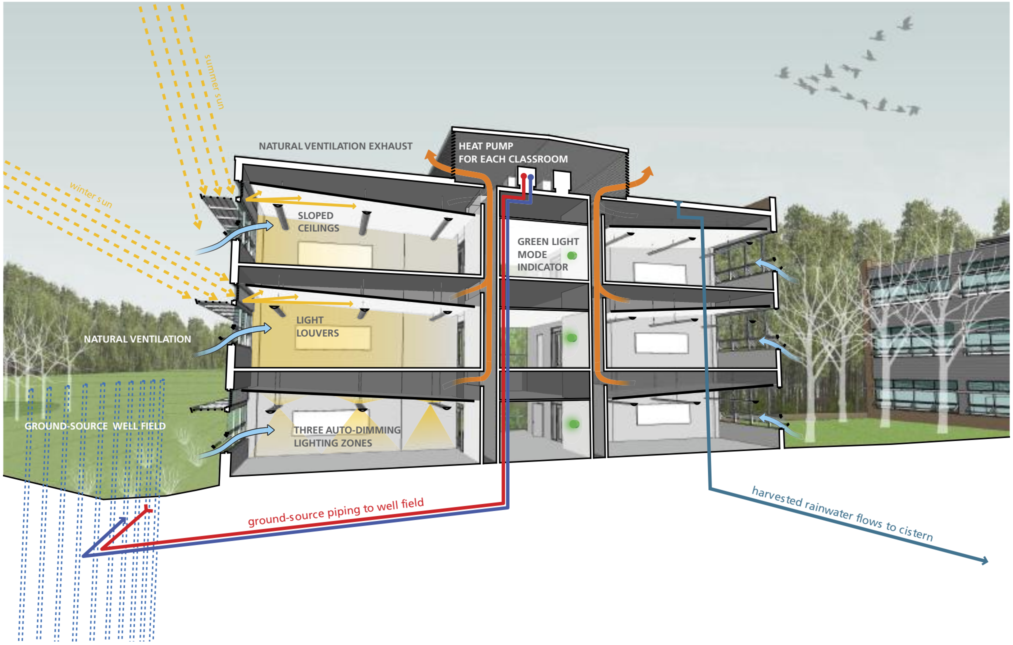

Figure 3.2 Manassas Park Elementary School buildings in Virginia, designed by VMDO, use a monthly average of 570 percent less water than neighboring Cougar Elementary. (*VMDO Architects*)

Manassas Park Elementary Water Savings

Virginia

Water conservation methods and a rainwater harvesting system at Manassas Park Elementary School buildings in Virginia use a monthly average of 570 percent less water than neighboring Cougar Elementary. This school is divided into two buildings: a new 10,500 square foot prekindergarten building that serves seventy students including special-needs individuals, and a 121,200-square-foot upper school that houses up to 875 third-, fourth-, and fifth-grade students. Instructional spaces are tailored for programs in academics, fitness, music, and visual arts.

Rainwater is harvested from every roof surface of both buildings (61,500 square feet total) and diverted into a 79,000-gallon rainwater cistern. Captured water is used for toilet flushing and irrigation, which will conserve an anticipated 1.3 million gallons of water each year. The Virginia Department of Conservation & Recreation awarded this project a $50,000 grant for the project's positive contribution to water quality improvements. Success stories like the one at Manassas Park and other elementary schools are demonstrating the value of rainwater harvesting in buildings.

Water balance is the relationship between the building's access to water and its demand for water. This balance has a variable amount of water at both sides of the equation. On the supply (access) side of the equation, the professional evaluates the following questions:

- Is there an adequate municipal source for water?
- How much rainwater can be collected onsite per year? How much per month?
- How much storage should be provided to accommodate fluctuations in rainfall amounts over time in different climate zones?

On the demand side, the occupancy and function of the building project must be evaluated. The design professional will determine the water demand for a building and the appropriate treatment methods for the end use.

Plans must follow local codes and regulations, and the designer must correctly define water sources in compliance with state or local codes. As of the writing of this book, there are some jurisdictions (state and local) that still refer to rainwater as graywater and vice versa, although technically, according to the International Association of Plumbing and Mechanical Officials IAPMO and the International Code Council ICC, graywater is a distinct water with its own classification. Rainwater is not reused, recycled, reclaimed, or graywater.

Defining Critical Terms

Rain: A liquid form of natural precipitation, which in some cases is modified as it falls through the air.

Rainwater: Rain that has impacted upon a surface and whose composition has been modified by surface flow, diversion, and storage processes onsite.

Graywater: Water that has been used for showering, hand-washing, and clothes washing. Kitchen sink and toilet water are excluded.

Blackwater: Water that contains organic waste such as water from kitchen sinks and toilets.

Stormwater: Precipitation from rain and snowmelt events, which flows offsite over land (both impervious and pervious).

Note: Legal definitions vary from state to state. Due to the variability of these definitions, it is often hard for professionals to communicate exactly what they mean. Depending on the political region, some definitions include references to what is legally allowed.

Step 1: Creating a Water Audit

Whether the designer is using a rainwater harvesting system to meet federal regulations, to receive abatement from a municipality, to lower water bills, or to maximize water conservation, the fundamental first step to any planning project is to educate the client and establish target goals for the rainwater collection system. Beginning with a water audit, the designer lists the equipment and processes that require a water supply, both inside and outside of the building. Like an energy audit, it is important to evaluate the true use of water and the appropriateness of a rainwater system for every building to avoid "greenwashing."

The water audit should separate potable from nonpotable water uses and identify the appropriate filtering and treatment regimen for each type. The goal is to treat the water according to its end use and comply with applicable codes and regulations. For example, water for subsurface irrigation does not require the same level of treatment as the water used for interior toilet flushing. Including unnecessary treatment options is a waste of money and resources.

The New Mexico Office of the State Engineer produced the Water Conservation Guide for Commercial, Institutional, and Industrial Users, which includes an overview of a typical water audit.[1] Beginning with a facilities survey, a water audit documents basic information on the project, including general information such as the number of occupants, the climate and rainfall patterns, code jurisdiction, general fire safety requirements, and a list of water-consuming equipment. The list also includes the size of the building, inventory of plumbing fixtures, list of flow rates for equipment and meter requirements, utility records for the past two years, and anticipated water use. Consultation with the heating, ventilation, and air-conditioning (HVAC) engineer may also reveal potential demands for water, such as cooling tower makeup, as well as estimates for condensate collection that can be part of the overall design strategy.

For an existing building, the inventory is followed by a walk-through survey. This survey should be detailed and completed with a knowledgeable facilities manager or mechanical engineer. Leak detection, the calibration of existing water meters, and a review of the building's maintenance manual and maintenance records are important components of a walk-through survey. Surveys may also include comparisons of the manufacturer's information on water use and the building's actual use. Water quality may also be measured at this time to determine if water used in one source area can be redistributed to another.

Effective water management plans can be partnered with energy saving and water conservation planning. The EPA's WaterSense "WaterSense at Work" planning manual provides guidelines for best management practices for commercial and institutional facilities.[2] By analyzing and minimizing the need for water in equipment and fixtures, the designer will maximize the use of collected rainwater. An integrated rainwater collection system is most effectively implemented when it is part of an overall water conservation design strategy: reduce first, then use the available site-collected water for building projects.

An audit report will include a list of facility diagrams, schedules, water use estimates, and evaluation of the proposed water use with the actual water use in the case of a building retrofit. In addition, a water audit can serve as an educational opportunity for training employees and be used to highlight potential water conservation measures to building occupants and the general public.

Step 2: Calculating Annual Rainwater Supply

The first step in calculating rainwater supply is determining the amount of available water that can be collected. The amount of water is based on the amount of rainfall available, the size of the collection area and the relationship between the two. A greater surface area allows-more rainwater to be potentially collected; however, locations that receive relatively more frequent rainfall will be able to produce more water with less surface area. A widely accepted procedure for calculating available rainwater is described below.

Rainwater Calculation Formula

$$V_{\text{SUPPLY}} = A \times P \times C \times 0.623$$

where

V_{SUPPLY} = volume of available water (gal)
P = annual precipitation (in)
A = collection surface area (ft^2)
C = runoff coefficient (dimensionless)

Note: The value"0.623"is a conversion factor that converts "square feet x inches" into gallons.

This simple volumetric formula generally gives enough accuracy for determining the supply for rainwater harvesting systems. An exception to this rule is for large, complex systems. In those instances, a more complex series of algorithms may be used. The data is entered into spreadsheets or models that calculate supply and demand to aid in sizing the cistern.

Thoughts for the Rainwater Designer

First, **calculate** the supply available from rainwater.

Second, **identify** water demand for a particular project.

Third, **determine** what portion of the demand can be met by the supply within the constraints of storage costs, conveyance costs, and space limitations. Applicable codes and regulations must also be considered.

Example

Before explaining the four parts of this formula, a simple example of the calculation is provided. Consider a building with 10,000 square feet of metal roof, in an area that receives 40 inches of rain annually.

BASIC FORMULA:

$$V_{SUPPLY} = A \times P \times C \times 0.623$$

where

V_{SUPPLY} = volume of available water (gal)
P = annual precipitation (in)
A = collection surface area (ft^2)
C = runoff coefficient (dimensionless)
A =10,000 square feet
P = 40 inches
C = 0.95

$$V_{SUPPLY} = 10{,}000 \times 40 \times 0.95 \times 0.623$$

$$V_{SUPPLY} = 236{,}700 \text{ gallons}$$

Many rainwater discussions begin with the comment that “there isn’t enough rain here.” However, as the next example shows, if the building has a roof and some rain, water can be collected. Even in an area that receives only 8 inches of rain annually, you can still collect some water. The formula with 8 inches of rain will be:

A =10,000 square feet
P = 8 inches
C = 0.95

$$V_{SUPPLY} = 10{,}000 \times 8 \times 0.95 \times 0.623$$

$$V_{SUPPLY} = 48{,}032 \text{ gallons}$$

Regardless of how much rainfall is received, the design professional must choose the appropriate cistern size to match the need for water demand in the building. A study by the National Climate Data Center of eight U.S. cities provides an evaluation of the amount of annual rainfall available per person that can be captured in different climate zones.

A. Collection Surface Area

Shape and Size The formula presented herein uses the overall square footage of the roof’s footprint used to collect rainwater independent of roof slope. Steeper-pitched roofs will shed water at higher velocities and as a result of these higher velocities, some water might overrun the gutters and never make it to the cistern. To have a complete accounting of all water that falls from the roof one needs to use a formula that takes into account roof angles, local rainfall intensities, and roofing material. However, for conceptual design and for the level of accuracy needed in sizing most rainwater systems, the square footage of the roof will adequately serve as the footprint from which to size the collection area.

An early planning of the roof design is critical when the rainwater harvesting system

Table 3.1 Total Rooftop Rainfall for Eight U.S. Cities[3]

City	Estimated 2008 Pop.	Land Area (mi^2)	Acres of Residential Roof	Acres of Non-Res. Roof	Annual Rainfall (in.)	Annual Rooftop Rainfall (Billion Gal.)	Equivalent Number of People Supplied Annually	% of Pop.
Atlanta, GA	519,000	132	4,801	4,462	47.6	11.98	291,772	56.2%
Austin, TX	743,000	252	11,151	4,426	30.2	12.78	311,249	41.9%
Chicago, IL	2,837,000	227	17,288	12,099	39.0	31.10	757,493	26.7%
Denver, CO	588,000	153	7,252	4,260	14.5	4.54	110,548	18.8%
Fort Myers, FL	68,000	22	782	624	54.5	2.08	50,660	74.7%
Kansas City, MO	476,000	314	2,315	3,874	35.1	5.90	143,666	30.2%
Madison, WI	229,000	67	-	2,491	29.5	1.99	48,566	21.2%
Washington, DC	588,000	61	1,318	7,081	39.4	8.99	218,968	37.2%

Source: Rooftop area data provided by case study cities. Rainfall data from NOAA National Climate Data Center. Population Data from Census 2000.
Chart provided by the Natural Resources Defense Council. www.nrdc.org/water/files/rooftoprainwatercapture.pdf

A butterfly roof is ideally suited for rainwater harvesting because all of the water is funneled to one location, thus reducing the piping necessary to transfer the water to the holding vessel. It also allows for efficient placement of aboveground or belowground rainwater storage.

Figure 3.3 A butterfly roof offers an aesthetically pleasing and convenient catchment point for rainwater. To educate students about the environment, a sculpture at Poquoson Elementary School uses rainwater to wash a sundial during wet weather. (©*Prakash Patel/ Poquoson Elementary School—VMDO Architects*)

is integral to the primary program of a building. Modifying a roof design to collect water more efficiently may be part of the initial planning process for an integrated rainwater system. Designers may wish to design the roof slope and divide large roofs into rainwater collection sections to channel rainwater to the appropriate roof gutters. The location of either underground or aboveground storage can be planned in coordination with the roof slopes and assigned water collection areas from the roofs.

B. Rainfall Forecasting the amount of rain in a climate zone can be an inexact science. Although historical data fluctuates with cycles of floods and droughts, the National Oceanic Atmospheric Administration (NOAA) is the source for yearly and monthly rainfall totals. NOAA maintains current records that can be accessed through their website.

NOAA collects information about weather that includes many variables, one of which is precipitation. Water and snow are recorded events that make up total precipitation recorded by observers across the world. There are four major networks in the United States for precipitation data collection. Historically, precipitation data in the United States has been collected at airport recording stations. These observations are provided from over 1,000 stations; records and observations span over 50 years. A second network of over 10,000 volunteer observers, operating as part of a cooperative network under the auspices of NOAA, is the basis for a master database. Among these volunteers is a new organization called CoCoRahs, which is contributing to additional rainfall data across the United States. The third means of precipitation data collection is via radar. NOAA uses the relationship between radar density and drop size to report on "real time" rain events. This data is widely used to report on storm watch events and allows NOAA to make up for gaps in rainfall reporting stations. Finally, there is an older legacy network of hourly rainfall data collected by the use of rain gauges. This network is not as accurate as newer collection programs, but it is useful when comparing historic information.

Figure 3.4 Rainwater waterfall at the NOAA Center for Weather & Climate Protection, College Park, Maryland, USA. (*Alan Karchmer, courtesy of HOK*)

Each state has a climate office supported by NOAA. In addition to providing localized summaries and dissemination on climate information, the recognized state climate offices, or ARSCOs, also are sources of research data about climate impacts.

NOAA—Finding Annual and Monthly Data

Appendix A provides the step-by-step process to find annual and monthly data on the NOAA website. There is a wealth of data on the NOAA site that provides information to the design professional about precipitation and rainfall events. The designer may wish to use annual rainfall data for rough design estimates and monthly data to accurately size a cistern. If there are problems with the NOAA site, contact the customer service representative at the number posted on the site to receive assistance.

Definitions[4]

Weather is defined as the state of the atmosphere at a given time and place, with respect to variables such as temperature, moisture, wind speed and direction, and barometric pressure.

Climate is defined as the expected frequency of specific states of the atmosphere, ocean, and land including variables such as temperature (land, ocean, and atmosphere), salinity (oceans), soil moisture (land), wind speed and direction (atmosphere), current strength and direction (oceans), etc. Climate encompasses the weather over different periods of time and also relates to mutual interactions between the components of the earth system (e.g., atmospheric composition, volcanic eruptions, changes in the earth's orbit around the sun, changes in the energy from the sun itself, etc.).

How to Use Your Rainwater Data

Principle 1. Determine when demand for water occurs during the year. Examples of a system for toilets and urinals:

1. School:
    a. Typical occupancy of August–May would define time of demand.
    b. If school is held year round, demand is from January–December.

2. Office:
    a. Typical 12-month demand
3. Factory:
    a. Typical 12-month demand
    b. If certain processes are seasonal, identify demand during those times.

These examples point out that the demand may vary according to occupancy patterns.

Principle 2. In many areas, the amount of rainfall per month is more useful to the designer than annual data; however, the amount of monthly rainfall varies by climate, by season, and even on a year-to-year basis. Therefore, designers should use thirty-year rainfall averages to design rainwater collection systems.

How many days, weeks, or months of rainfall should be stored onsite? The designer needs to calculate the month-by-month demand of every particular project, not just an average over one year. The expected rainfall needs to be described on an annual, as well as monthly, basis.

Principle 3. If possible, account for any conditions that affect the average figures.

Consideration: Does the "mountain effect" in a locale skew the rainfall data from a large metropolitan area? Is there a rain shadow on one side of a large metropolitan area? The figures obtained from the NOAA information may consider the average for a fairly large area, while the project location may be in an area that typically receives more/less water in a given rain event for the area.

Consideration: Does the "heat sink" effect of a large metropolitan area cause a significant number of rain events to drop the majority of the volume on the windward side of the locale, resulting in less volume on the more distant areas in that same locale?

These examples are a reminder to the designer to gain as much information as possible about project variables.

Community Collaborative Rain, Hail & Snow Network, CoCoRaHS

CoCoRaHS is a nonprofit organization that originated atthe Colorado Climate Center of Colorado State University. This community-based program was started as a result of flooding in Fort Collins and the recognition that precipitation events needed to have more documentation and data collection. This organization solicits volunteers of all ages and background to work together to measure and map precipitation (rain, hail, and snow).This network of volunteers is sponsored by the NOAA, NSF, the National Weather Service, Colorado State University, and others. This organization solicits volunteers of all ages and backgrounds to work together to measure and map precipitation (rain, hail, and snow). By utilizing low-cost measurement tools, stressing training and education, and utilizing an interactive website, their aim is to provide the highest quality data for natural resource education and research applications.

The goals of the CoCoRaHS network are to:

- Provide accurate high-quality precipitation data to observers, decision makers, and other end users on a timely basis.

- Act as an umbrella for one-stop precipitation information nationwide and to increase the density of precipitation data available throughout the country by encouraging volunteer weather observing, as well as by collaborating with existing precipitation networks.
- Increase community awareness about weather by inspiring and encouraging citizens to participate in meteorological science and have fun doing so.[5]

As volunteers join this project and continue to collect data, this tool will become an excellent source for up-to-date information on rainwater collection in a specific locality. As stated on their website, "Rain doesn't fall the same on all." Even within several miles, if not several blocks, precipitation amounts and intensities can vary greatly. Although the design professional will find that fine-tuning rainfall is almost an impossible task, more accurate information for local rainfall data will help with the overall rainwater harvesting design process.

C. Runoff Coefficient A runoff coefficient accounts for the fact that some roof surfaces are more efficient than others at collecting rainwater. Designers who require a more accurate accounting of the resulting rainwater flowing from the roof may want to examine how the texture and material of the roof surface affects the amount of water that can be collected. Rougher surfaces with heavy texture can slow down the water and to a certain degree, absorb some of the water before it makes its way to the gutter. A runoff coefficient accounts for the fact that some roof surfaces are more efficient than others at collecting rainwater. For example, a pitched metal roof is typically the most efficient type of roof for collecting water, delivering 95 percent of the water that falls on it (except for some heavy snowfalls), resulting in a runoff coefficient of 0.95. Conversely, a flat tar-and-gravel roof is typically the least efficient roof type, delivering 80 to 85 percent of the water that falls on it.Thus, a runoff coefficient of 0.8 to 0.85 should be used. Table 3.2 lists the runoff coefficients for common roof materials. Please note that the values in Table 3.2 are estimates. In a very light rain event, the runoff coefficient can equal 0.00, since no rainwater will flow through your catchment system into your cistern.

Table 3.2 Runoff Coefficients for Common Roof Materials[6]

Roofing Material	Runoff Coefficient
Metal	0.95
Asphalt	0.90
Concrete	0.90
Membrane Type EPDM, PVC, etc.	0.95–0.99
Tar and Gravel	0.80–0.85

Step 3: Calculating Demand

According to the EPA, significant water savings can be achieved by a combination of rainwater harvesting and smart, integrated water conservation practices. Aggregately, leaks in water mains and in individual fixtures can comprise significant amounts of water loss. When calculating demand for existing buildings, make sure to identify and repair leaks so that an accurate assessment of the water consumption can be determined.

According to the Department of Energy, "The commercial and institutional sector is the second largest consumer of publicly supplied water in the United States, accounting for 17 percent of the withdrawals from public water supplies. This sector includes a variety of facility types such as hotels, restaurants, office buildings, schools, hospitals, laboratories, and government and military institutions. Each facility type has different water use patterns depending on its function." The following chart (Figure 3.5) shows how water is used in several types of commercial and institutional facilities.[7]

One of the benefits of the collection and use of alternative water resources is making individuals aware of their water use, thus encouraging water conservation and contributing to an overall reduction of municipal water consumption. According to the data listed on Figure 3.5, as much as one-third or more of the municipal water for nonpotable uses in buildings can be conserved by using rainwater for toilet flushing. In schools, it is estimated that domestic restrooms alone account for between 43 and 48 percent of all water demand. In some cases where toilet flushing is the predominant water demand in the building and the surface area/local climate relationship is optimum, a much higher percentage of potable water can be conserved. Many times 100 percent of the toilet flushing, and even potable water consumption (if the code allows) can be achieved with collected rainwater. However, until codes and regulations, as well as treatment technologies, have changed, using rainwater as part of the drinking water system may not be practical in most cases in the United States.

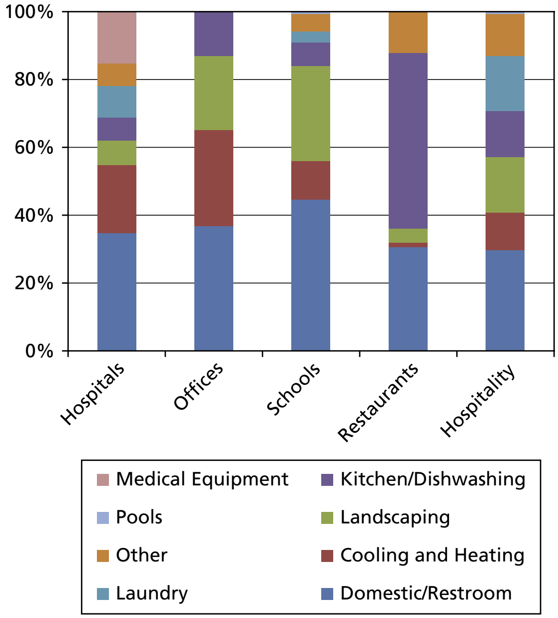

Figure 3.5 End uses of water in various types of commercial and institutional facilities.[8]

The Pacific Institute, located in California, conducts research on environmental protection, economic development, and social equity. In 2000, a study by the Pacific Institute identified water saving in various types of buildings, which has been used by numerous entities as the basis for documenting water use in different building types. The result of research on water savings for office buildings can be found in Table 3.3. Using this information, the designer can begin to extrapolate how to achieve savings not only with water conserving fixtures, but also by developing a plan for providing alternative water sources for nonpotable uses in buildings. Additional studies are needed to determine water use in buildings as plumbing fixtures have become, and continue to be, more efficient.

Also located in California, the East Bay Municipal Utility District (EBMUD) published the 2008 "Watersmart Guidebook"[10] which describes interior and exterior best management practices (BMPs) for water conservation. This guidebook includes the use of rainwater as an alternative, nonpotable water

Table 3.3 Potential Water Savings in Office Buildings[9]

End Use	Water Use (TAF)	Conservation Potential (Percent)			Conservation Potential (TAF)		
		Low	High	Best	Low	High	Best
Landscaping	128.2	38%	53%	50%	48.3	68.0	64.2
Restroom	88.0	49%	49%	49%	43.4	43.4	43.4
Cooling	77.9	9%	41%	26%	7.4	32.3	20.0
Kitchen	10.2	20%	20%	20%	2.0	2.0	2.0
Other	33.9	0%	25%	10%	0.0	8.5	3.4
Total	**338.5**	**30%**	**46%**	**39%**	**101.1**	**154.1**	**133.0**

Details of Commercial Water Use and Potential Savings, By Sector. www.pacinst.org/wp-content/uploads/2013/02/appendix_e3.pdf

supply for buildings and reviews a variety of building types, including offices, schools, hospitals, restaurants, and the like. The guidebook provides an outline of how to create a water management plan for commercial buildings. The EPA provides water usage data for a variety of commercial facilities, in terms of gallons per person, which can be a source for estimates when calculating the potential demand for a rainwater harvesting system.

BUILDING SECTORS, SIZES, AND DEMANDS

Small Office

The most common commercial buildings are offices. This building type includes more than 800,000 buildings, or 17 percent of total commercial buildings in the United States.[11] The following example considers a typical small office building (4,200 square feet) in Ann Arbor, Michigan (a suburb of Detroit). Using rainfall data from NOAA, the design

Looking at the Glass as Being Half Full

Most buildings have a water demand based on the purpose of the building. Activities in the building requiring water include bathrooms, kitchens, manufacturing processes, fire suppression, cooling towers, and so forth. The necessary task is to determine what percentage of that building's demand can be met by site-collected water. The focus of this book is on nonpotable indoor uses in commercial buildings, although some case studies demonstrate net zero water strategies in which rainwater is also used as a potable water source. For practical reasons and to meet limited budget requirements, replacing all of the building's water consumption with roof-collected water is not necessarily the end goal. Alternatively, the design goal is to provide as much of the necessary water supply from rainwater or alternative water sources, thus reducing the demand on the municipal water system.

professional can determine the amount of rainfall available (supply) and compare it to the demand for an office staff of ten members.

1. Supply formula:

$$V_{SUPPLY} = A \times P_m \times C \times 0.623$$

where

V_{SUPPLY} = volume of available water (gal)
P_m = 30-year average monthly precipitation (in)
A = collection surface area (ft^2)
C = runoff coefficient (dimensionless)
A = 4,200 square feet
P_m = 4.88 inches (number of inches of rain in September)
C = 0.95

Calculation:

$$V_{SUPPLY} = 4{,}200 \times 4.88 \times 0.95 \times 0.623$$

$$V_{SUPPLY} = 12{,}130 \text{ gallons/month}$$

In the least rainy month in Ann Arbor, which was less than an inch (.85) of rainfall in May of 2011, this building captured 2,110 gallons.

2. Demand formula for only toilet flushing:

1.6 gallons/flush (efficient toilet) x an estimate of 2.13 flushes/day x 30 days in September x 10 hypothetical staff members = 1,022 gallons/month.

In this example, there is more than enough water for toilet flushing as well as additional water for irrigation for this small office project, even in the driest month.

Table 3.4 Modeled Water Use in Office Buildings[12]

End Use	Unit	Rate	Number	Modeled Water Use (GED)	GED-derived (GED)
Toilet[1]					
Employee use	gpf	3.00	2.60 flushes/day	7.8	
Visitor use	gpf	3.00	0.33 flushes/day	1.0	
Urinals[1]					
Employee use	gpf	1.60	1.25 flushes/day	2.0	
Visitor use	gpf	1.60	0.17 flushes/day	0.3	
Faucets[1]					
Employee use	gpf	0.11	3.85 flushes/day	0.4	
Visitor use	gpf	0.11	0.50 flushes/day	0.1	
Total restroom				11.6	33.0
Cooling	gal/sq ft/day	0.07[2]	350[3] sq.ft/employee	23.3	29.2
Landscaping	gal/sq ft	0.08[4]	547[5] sq. ft/employee	20.7	48.3
Kitchen	gal/meal	10.1[6]	0.33 meals/employee/day	3.3	3.8
Other				12.7	12.7
Total				**72**	**127**

[1] See Appendix D.

Figure 3.6 The rainwater collection system for Fire Station Number 6 in Raleigh, North Carolina, provides water for toilet flushing. (*Celeste Allen Novak, Architect*)

Small buildings with smaller occupancy loads are easily served by rainwater harvesting systems that primarily supply water for toilet flushing. Other building types and similar projects in different climate zones can also benefit from rainwater collection. The design professional should adapt the formula to the appropriate climate, building type, occupancy load, and size of collection area.

Schools in Different Climate Regions

Education buildings are the fifth most prevalent commercial building type in the United States, with approximately 309,000 buildings. This category includes preschools, elementary schools, middle or junior high schools, high schools, vocational schools, and college or university classrooms. They are, on average, the largest commercial buildings, with 25,100 square feet (2,332 m^2) per building, and they account for 13 percent of all commercial floor space.[13]

An official construction report by the *American School & University* magazine reported a continuing trend of increasing school size, in terms of square footage, over the past ten years that continues today. As of 2010, the average elementary school size was 75,000 square feet with an average student population of 600. Middle schools averaged 140,000 square feet with a student population of 936, and high schools averaged 260,000 square feet with 1,600 students.[14]

According to the American Water Works Association, approximately 6 percent of total water use in commercial and institutional facilities takes place in educational facilities, such as schools, universities, museums, and libraries. A 2003 study by the Pacific Institute modeled water use per student using published estimates of restroom visits, irrigated turf areas for playing fields, and building cooling requirements (Table 3.5).

Schools have one of the largest rooftop areas in any neighborhood. Schools were chosen as an example in this book to demonstrate the effect of decentralized rainwater collection in communities. An examination of five middle schools in different climate zones in the United States with hypothetical rainwater collection systems demonstrates the relationships between supply and demand for rainwater collection. The different climate zones greatly affect the potential rainwater supply. In all five examples the collection surface area and the demand stay the

Table 3.5 Model Water Use by Students[15]

End Uses	United Measuring Area or Volume of Use	Area or Volume	Unit Measuring Frequency of Use	Frequency of Use	Total gal/ student/day
Elementary and Middle Schools					
Irrigation[1]	irrigated acres/student	0.004	gal/acre/school day	varies	24.3
Toilet[2]	gpf	3.00	visits/day	2.11	6.3
Urinal[3]	gpf	1.60	visits/day	1.01	1.6
Faucet Use[4]	gpf	0.11	flushes/day	3.12	0.3
Kitchen	gal/meal	9.91[5]	meals/day/student	0.4[6]	4.0
Other[7]					2.0
Total					38.5
High Schools					
Irrigation[1]	irrigated acres/student	0.008	gal/acre/school day	varies	55.6
Toilet[2]	gpf	3.00	visits/day	2.11	6.3
Urinal[3]	gpf	1.60	visits/day	1.01	1.6
Faucet Use[4]	gpf	0.11	flushes/day	3.12	0.3
Kitchen	gal/meal	9.91[5]	meals/day/student	0.4[6]	4.0
Other[7]					4.0
Total					71.8
Other Schools					
Irrigation	irrigated acres/student	0.002	gal/acre/school day	varies	6.9
Toilet[8]	gpf	3.00	visits/day	1.03	3.1
Urinal[9]	gpf	1.60	visits/day	0.39	0.6
Faucet Use	gpf	1.11	min/day	0.96	0.1
Kitchen	gal/meal	9.91	meals/day/student	0.4	4.0
Other[7]					1.0
Total					**15.7**

Table E-26. Modeled Water Use per Student. http://www.pacinst.org/wp-content/uploads/2013/02/appendix_e3.pdf

same. The only variable is the local climate, which determines the available supply in each school. All of these examples are provided in Appendix A. The first example of a school in Atlanta, Georgia, is provided below followed by a case study from an actual Georgia school provided as a comparison.

Please note that the gallons per flush (GPF) for toilet flushes and urinal flushes in the following examples are 1.68 GPF and 1.0 GPF, respectively. These numbers reflect an average GPF for the fixtures. The designer will need to use the actual GPF of specific fixtures in real-life projects.

Hypothetical Example 1: School in Atlanta, Georgia

Annual rainfall varies throughout the United States. The eastern part of the United States receives an abundant amount of rainfall fairly evenly throughout the entire year. For example, Atlanta, Georgia, receives around 48 inches of rain per year. There are other areas within the state that receive less than 48 inches and in some areas dramatically more. Certain cyclical patters are evident throughout the region and some areas of the Appalachians can receive more than 80 inches of rainfall per year. The following hypothetical example demonstrates a rainwater harvesting system used for toilet flushing in Atlanta, Georgia.

An architect working for a school district in Georgia is beginning conceptual design for a new middle school. Recent well-publicized droughts have highlighted the need for a more sustainable approach by the designer for water conservation. The architect has decided to explore rainwater collection as a sustainable design strategy for this project.

DATA COLLECTION

- Total collection area: 109,000 square feet
- Runoff coefficient value (membrane roof): 0.90
- Average number of instructional days during school year: 180 days
- Specific months school is in session: August through May
- Average number of instructional days per month: 20
- Number of students: 650
- Average annual rainfall in Atlanta: 49.71 inches

(Note: Using the figures on the NOAA website, the months school is in session, the months for demand, have fairly even rainfall.)

These figures are derived using the NOAA website. Other local contributing factors may cause variation.

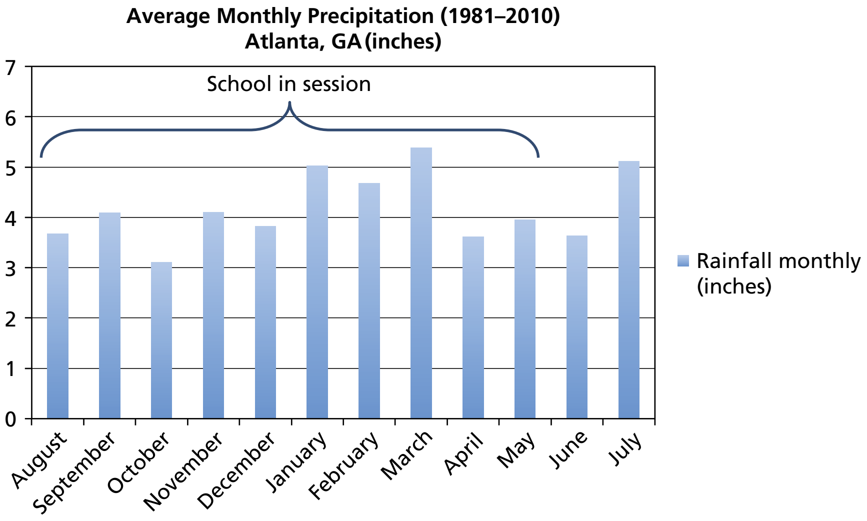

Figure 3.7 Atlanta monthly rainfall.

Table 3.6 Atlanta Rainwater Supply Calculation

Atlanta Avg. Monthly Precipitation (1981–2010)	A Collection Area (square feet)	B Monthly Avg Rainfall (inches)	C Conversion Factor	D Runoff Coefficient	Rainwater Supply (Multiply Columns AXBXCXD)
January	109,000	4.2	.623	.90	256,688.46
February	109,000	4.67	.623	.90	285,413.12
March	109,000	4.81	.623	.90	293,969.40
April	109,000	3.36	.623	.90	205,350.77
May	109,000	3.67	.623	.90	224,296.82
June	109,000	3.95	.623	.90	241,409.39
July	109,000	3.95	.623	.90	241,409.39
August	109,000	5.27	.623	.90	322,082.90
September	109,000	3.9	.623	.90	238,353.57
October	109,000	4.47	.623	.90	273,189.86
November	109,000	3.41	.623	.90	208,406.58
December	109,000	4.1	.623	.90	250,576.83
Annual	109,000	49.71	.623	.90	3,038,091.27

DEMAND

Demand for nonpotable water for flushing toilets and urinals was based on data presented in Table 3.5.

2.11 toilet flushes @ 1.68 gpf = 3.54 gallons

1.1 urinal flushes @ 1.0 gpf = 1.01 gallons

4.55 gallons per student per day

650 students ×4.55 gpd = 2,958 gpd

Monthly demand = 2,958 per day × 20 days = 59,000 gallons per month

SUPPLY

$$V_{\text{SUPPLY}} \times A \times P_m \times C \times 0.623$$

where

V_{SUPPLY} = volume of available water (gal)
P_m = 30-year average monthly precipitation (in)
A = collection surface area (ft^2)
C = runoff coefficient (dimensionless)
A = 109,000 square feet
P_m = 4.2 inches (inches of rain in January)
C = 0.90

Calculation:

$$V_{\text{SUPPLY}} = 109{,}000 \times 4.2 \times 0.90 \times 0.623$$

V_{SUPPLY} = 256,688 gallons per month in January

(See Figure 3.8 for average monthly totals.)

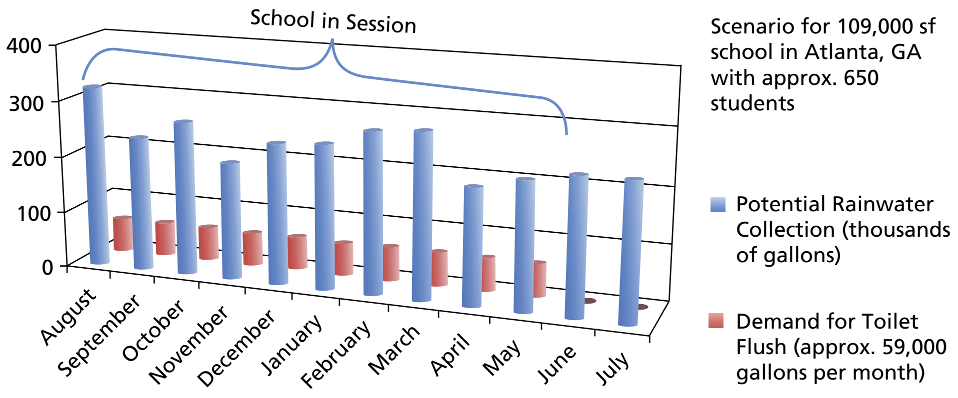

Figure 3.8 Atlanta demand/supply analysis.

Fowler Drive Elementary School

Athens, Georgia

Faculty and administration at Fowler Drive Elementary School in Athens, Georgia, have high expectations and a deep caring for their students.In 2006 and 2007, the school was honored as a Green School. In 2010, Clark County School District decided to add a rainwater harvesting system to the school. The goals of this project were to achieve water resiliency and lower water bills by reducing municipal potable water use.

The system delivers water for toilet flushing in addition to providing an educational tool for students. The rainwater collection tanks are visible from an outdoor classroom that incorporates a demonstration rain garden. The rainwater harvesting control station components are labeled and can be viewed by students through a glass door. Collected rainwater flushes twelve toilets and four urinals with automatic valves.

Similar to the hypothetical Atlanta example, the annual rainfall is 50 inches per year. The roof area used for collection is only 8,000 square feet in comparison to the larger roof used in the previous example. Even so, two 10,000-gallon tanks support the needs of this school, and the system is expected to pay for itself in four years.

Figure 3.9 Rainwater collection tanks are visible from an outdoor classroom that incorporates a demonstration rain garden at Fowler Drive Elementary School. (*Eddie Van Giesen*)

Table 3.7 Comparison of Rainfall Collection at Five Schools

City	Average Annual Rainfall (inches)	Potential Annual Collection of Rainwater fromRoof(gallons)	Annual Water Demand for Toilet Flushing (gallons) in Typical Middle School (average of 10-month school year)	Potential Annual Surplus (gallons)
Atlanta	49.71	3,038,091.27	590,000	2,448,091.27
Ann Arbor	32.81	2,005,225.803	590,000	1,415,225.80
New York	47	2,872,466.10	590,000	2,282,466.1
Phoenix	8.22	502,375.99	590,000	-87,624.01
San Francisco	20.69	1,264,496.25	590,000	674,496.25

Comparing the Results—North, South, East, West, and Southwest School Rainwater Collection Systems

Table 3.7 summarizes and compares the results of the five hypothetical examples which are detailed in Appendix A.

As shown above, in some communities, the public school can become a major water resource for the neighborhood or a small community. By understanding the relationship between supply and demand and the basic formulas for rainwater collection, the next step is to plan for an integrative system for any building type in any community.

Figure 3.10a Installation of 20,000-gallon cistern for the Metro Intermodal Transit Center in Akron, Ohio, designed by GPD Group. (*GPD Group Photo*)

Figure 3.10b Metro Intermodal Transit Center collects rainwater for use in toilet flushing for this 2000 person commuter hub. (*Todd Williams, Shooting Star Photography*)

Step 4: Cistern Sizing

Nicole Holmes, PE, is a registered professional civil engineer and a LEED® Accredited Professional (Building Design + Construction). As a Project Manager at Boston-based Nitsch Engineering, her primary focus is on green infrastructure, stormwater master planning, and innovative stormwater design. She is co-creator of Nitsch Engineering's proprietary rainfall reuse simulation program that simulates scenarios to optimize rainfall capture and reuse systems.

Nicole has extensive experience in sizing systems for commercial buildings. The following is an article she wrote providing information detailing questions to ask before developing a rainwater system plan, along with recommendations as to how to size a cistern.

CISTERN SIZING CONSIDERATIONS

Nicole Holmes, PE, LEED® AP

Project Manager, Nitsch Engineering

Sizing rainwater cisterns is not a complete science. It relies upon predicting the unpredictable—precipitation. In an ideal situation, the rainwater supply would match the end use demand 100% of the time. Unfortunately, this is typically neither practical nor possible. In most cases, the optimal rainwater harvesting tank considers the variety of project-specific considerations, constraints, and concerns and balances the rainfall supply with the end use demand an acceptable amount of the time.

FACTORS TO CONSIDER WHEN SIZING A RAINWATER CISTERN INCLUDE THE FOLLOWING:

Climate Patterns

- Is the project located in an arid, semi-arid, humid, or tropical climate?
- How are rainfall events distributed across the year; is there a distinct drought season?
- How are climate patterns impacted by extreme rainfall events (e.g., hurricanes or monsoons)?

Project Goals

- What are the project goals with respect to water management?
- Is the project seeking LEED Certification or more aggressively striving to achieve net zero water?
- What contribution to the overall water demand will be harvested rainwater?

Project Budget

- What is the project budget for the rainwater harvesting system?
- What are the expectations for return on the initial investment for the rainwater system?

End Use

- Will the harvested rainwater support a seasonal (such as irrigation) or year-round use (such as toilet flushing)?
- What is the average estimated daily, weekly, monthly, annual demand for the end use(s)?

Stormwater Management Goals

- Will the rainwater harvesting system be used to meet all or a portion of the project's stormwater requirements or goals?
- Are there any groundwater recharge requirements or water rights issues to consider?

Catchment Area

- What is the size and characteristics of the collection area?

Availability of Makeup/Bypass Water

- Will it be possible and/or acceptable to periodically supplement the end use demands with potable water?
- Are there any additional inputs for makeup/bypass water?

The simplest way to size a rainwater cistern is based upon the end use demand. For example, if the average weekly non-potable water demand will be 1,000 gallons per week, a cistern size of 4,000 gallons or 8,000 gallons may be selected to supply one or two months of rainwater, respectively. However, the problem with this methodology is that it does not take into consideration the supply-side of the system. How do the rainfall patterns and the size of the catchment area relate to these cistern sizes?

More accurate sizing methodologies factor in both the supply and demand ends of the rainwater harvesting system.

The following sizing methodologies can be used to size rainwater cisterns.

- Dry Season Demand vs. Supply
- Simple Water Budget
- Computer-Based Simulation Methods

For larger systems, engineers use more complex graphical and statistical methods not discussed in this book.

DRY SEASON DEMAND VS. SUPPLY

This methodology is generally well suited for arid climates, which have a distinct dry season. In this case, the water demand during the dry season is estimated and the cistern is sized to store enough water to sustain the dry season. The dry season demand volume should also be compared to the potential rainfall capture associated with the rainy season to confirm that the cistern has the potential for being full at the start of the dry season. If not, the cistern may be considered to be reduced in size for cost savings.

SIMPLE WATER BUDGET

This methodology can provide any project with a simple, general evaluation of the rainwater harvesting potential for a project.This methodology considers the inputs (supply) and outputs (demand) on a monthly basis based on average (or median) monthly precipitation and user-estimated monthly water demands.This methodology does not account for the day to day inputs and outputs of a rainwater harvesting system since the analysis summarizes the entire month's supply and subtracts the entire month's demand at the end of each month.

This simple water budget methodology is much like balancing a check book. First, the average (or median) monthly precipitation depth is used to calculate the monthly rainwater capture volume based on the area and collection efficiency of the catchment area. Then, the estimated monthly demand is subtracted from this value to determine the end-of-month storage. For the second month, the end-of-month storage from the previous month is added to the second month's rainwater capture volume and the monthly demand subtracted to estimate the second month's end-of-month storage, and on and on. The end-of-month storage determined at the 12th month can be used to estimate the appropriate tank size.

Note: An assumption can be made at the start of the analysis as to whether the tank is partially full (say 1,000 gallons) at the start of the analysis. Also, the analysis should be re-run if the selected cistern volume is less than any of the end-of-month storage volumes, since the maximum volume that can be carried to the next month would be the cistern volume itself.

COMPUTER-BASED SIMULATION METHODS

The most accurate method for sizing rainwater cisterns is using computer-based simulation models. Computer-based models typically perform a simulation of the estimated daily demand using historic daily precipitation records over a range of years. Depending on the complexity of the software, it may test a range of cistern sizes or the user may need to test various cistern sizes individually.

A continuous simulation can be used to determine the most efficient cistern sizes, especially in humid climates where precipitation occurs frequently. Most software programs are proprietary, but some are available online and are provided by various vendors or academics. Keep in mind that the budget will determine the depth of calculations.

ALTERNATIVE WATER SOURCES

Other Wastewater and Recirculated Water

There are other water sources that design professionals are using in buildings, including recirculating water from various sources. Some examples include:

- Directing blackwater to small-scale treatment areas where it can be cleaned sufficiently for onsite irrigation purposes

> "You will base the amount of time you will spend calculating the tank size based on the size of your project, i.e., if you are working with domestic single house dwellings, or middle size commercial or a large scale commercial. In terms of sizing cisterns, there is a fine line between the time and money that you can spend in designing the tank."
>
> (From interview with Lutz Johnen)

Table 3.8 EPA WaterSense: Water Quality Considerations for Onsite Alternative Water Sources[16]

	Level of Water Quality Concern					
Possible Sources	**Sediment**	**Total Dissolved Solids (TDS)**	**Hardness**	**Organic Biological Oxygen Demand (BOD)**	**Pathogens (A)**	**Other Considerations**
Rainwater	Low/Medium	Low	Low	Low	Low	None
Stormwater	High	Depends	Low	Medium	Medium	Pesticides and fertilizers
Air Handling Condensate	Low	Low	Low	Low	Medium	May contain copper when coil cleaned
Cooling Tower Blowdown	Medium	High	High	Medium	Medium	Cooling tower treatment chemicals
Reverse Osmosis and Nanofiltration Reject Water	Low	High	High	Low	Low	High salt content
Gray Water	High	Medium	Medium	High	High	Detergents and bleach
Foundation Drain Water	Low	Depends	Depends	Medium	Medium	Similar to stormwater

Note: The use of single-pass cooling water is also a possible source of clean onsite water, but facility managers should first consider eliminating single-pass cooling because of its major water-wasting potential. For that season, it is not included in the list.
*Key:
Low: Low level of concern
Medium: Medium level of concern, may need additional treatment depending on end use
High: High concentrations possible and additional treatment likely
Depends: Dependent upon local conditions

- Directing graywater to treatment systems where it can be used for indoor toilet flushing and outdoor irrigation
- Collecting condensate from mechanical equipment and directing it for reuse as makeup water

Dr. Diana Glawe's broad experience across industry, nonprofit, academic, and governmental sectors directs her vision toward a balance of research, education, and policy in addressing challenges facing society. Her study of condensate collection in buildings has led to her recent publication of the *San Antonio Condensate Collection and Use Manual for Commercial Buildings.* According to her research at Trinity University, the best application for condensate from large air handling units (AHUs) is for cooling-tower makeup water.Alternatively, condensate can be used in other applications similar to rainwater.

CONDENSATE COLLECTION

Diana Glawe, PhD, PE, LEED® AP

Associate Professor, Engineering Science

Trinity University

Condensate as a byproduct of air-conditioning systems is another source of water to use in buildings. The moisture in humid air forms condensate as it flows over cool evaporative coils located inside the air-handling unit (AHU) that conditions the air. This condensate drips into a pan below the coils and is carried away through a drainage pipe connected to the drip pan. Gravity or a condensate pump can direct this water to a storage tank or a location for immediate use as make-up water for mechanical equipment, fountains or nonpotable use in buildings.

The quality of condensate is similar to distilled water. It is mineral free with a Total Dissolve Solids (TDS) level that is near zero. Because of its lack of mineral content, condensate tends to react with materials it contacts along its flow path. Therefore, it is common to find trace amounts of metals from mechanical equipment and transport pipes in the condensate. Condensate may corrode metals over time, if untreated.

Since condensate is cold and contains near zero mineral content, condensate is particularly beneficial for use as make-up water in cooling towers. This application of condensate simply requires routing the condensate to the cooling tower via pipes and gravity or a condensate pump. There is no need to treat the condensate beyond the treatment already integral to the cooling tower operations. In addition, the low mineral content of the condensate acts to dilute the total dissolved solids (TDS) that build up in the cooling tower as a result of the inherent evaporative cooling process.

Diluting the TDS reduces the required frequency of the blow-down cycle, by which water with high TDS is discharged and replaced with water with lower TDS, usually municipal water.

Figure 3.11 Center for the Sciences and Innovation at Trinity University, San Antonio, Texas, designed by EYP Architecture & Engineering and RVK Architects. The reclaimed water system using condensate collection earned 6 points in the Water Efficiency category toward LEED® Gold. (*Robert Benson Photography*)

The amount of condensate produced from an air-conditioning system will not exceed the amount of make-up water required by the cooling tower. For most commercial buildings the condensate only provides about 5–15% of the total make-up water needed by the cooling tower.[17] Therefore, a storage tank is not needed when condensate is routed to a cooling tower. Using condensate as cooling tower make-up water is practical and offers a quick return on investment.

Alternatively, condensate can be used for other applications similar to rainwater. In fact, condensate is commonly added to rainwater storage tanks to supplement the water supply between rain events. Condensate can likewise be combined with other alternative water sources for applications ranging from irrigation to water features.

For example, Trinity University in San Antonio, Texas, collects an estimated four hundred thousand gallons of condensate and combines it with an estimated two million gallons of reverse osmosis wastewater to flush toilets in their new Center for the Sciences and

Innovation. This reclaimed water system earned 6 points in the Water Efficiency category towards Leadership in Energy and Environmental Design (LEED®) Gold Certification for the building. Dennis Ahlburg, the President of Trinity University, states,"Obtaining LEED® Certification for Trinity University campus buildings demonstrates the university's commitment to sustainability.Collecting and using condensate and reverse osmosis wastewater in the Center for the Sciences and Innovation supports our continued effort to conserve water resources on campus."

Figure 3.12 shows the potential amount of condensate produced per cubic foot per minute (cfm) of outside air flowing through an AHU located in San Antonio. The data in this figure was generated using typical meteorological year data[18] for temperature and humidity in San Antonio, Texas.[19] The potential amount of condensate from outside air passing through the AHU will be less in dryer and cooler climates.

The monthly condensate distribution in Figure 3.12 shows the maximum condensate to occur during the summer between May and September. Since airflow through the AHU and/or operating capacity (depending on type of system) can be difficult to determine, condensate prediction models commonly rely on correlations between airflow and tons cooling capacity and/or square footage of conditioned space.

Rule of thumb values published in literature indicate condensate in hot and humid climates during the summer to range anywhere between 2.4–8 gallons per day per ton cooling capacity or 12–14.4 gallons per day per 1,000 square feet of conditioned space, depending on which building parameter and rule of thumb is chosen for the estimate.[20] A more general rule of thumb, not specific to summer in hot and humid climates, is provided by Alliance for Water Efficiency as 3–10 gallons per day per 1,000 square feet of conditioned space.[21]

An example of a measured condensate volume for a large commercial building in San Antonio is provided here for comparison with the rule of thumb values.

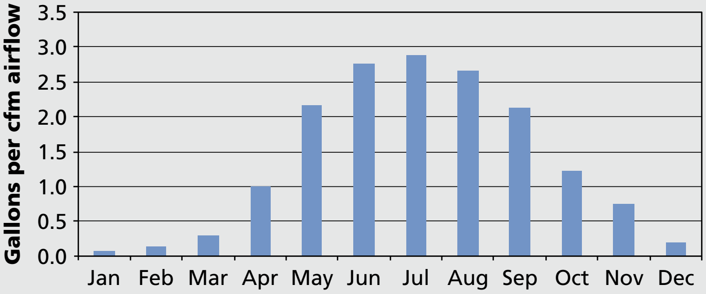

Figure 3.12 Gallons condensate continuous outside airflow through the AHU, per month. (*San Antonio Condensate Collection and Use Manual for Commercial Buildings*)

LABORATORY EXAMPLE

San Antonio, Texas

A 267,000-square-foot laboratory-type building in San Antonio with a 2,400-ton cooling capacity AHU that draws in 100 percent outside air produced 385,548 gallons of condensate in July 2011. This equates to a nominal condensate volume of 5.4 gallons per day per ton cooling capacity, which falls within the aforementioned rule of thumb range of 2.4 to 8 gallons per day per ton for hot and humid climates during the summer. The remaining months produced less volume, following a distribution similar to that shown in Figure 3.12, and add up to 2,693,403 gallons for the entire year 2011. This is a 20 percent decrease in annual condensate as compared to condensate measured the previous year (2010), which demonstrates the fact that condensate generated year-to-year varies with climate conditions and building operating conditions and use. For high-ventilation buildings, like laboratories and hospitals, which require large cooling capacity per square foot, the rule of thumb values based on square footage tend to underestimate the amount of condensate produced.

Online condensate calculators are available on the web, but should be used with caution.[22] These calculators often only calculate condensate for one condition. However, meteorological and building conditions change constantly. It may be tempting to use average monthly values in the calculator to calculate monthly condensate; however, this approach incurs errors because average values of requisite parameters, such as outside temperature and humidity, are not coincident in time.

Time-dependent dehumidification load models for ventilation air, like the one used to generate Figure 3.12, can be extended to include the dehumidification loads due to infiltration air (e.g., air entering through doors, windows, and leakage), occupants (e.g., perspiration and respiration), activities, building features (e.g., natatorium), and building operation.Although ventilation air is the primary dehumidification load in most buildings,[23] other sources of moisture can be significant for some building types. These more complex models are used by heating, ventilation, and air-conditioning (HVAC) professionals to properly size air-conditioning systems.

The components in a condensate collection and reuse system (e.g., valves, storage tanks, treatment systems, delivery systems) are similar to those found in other reclaimed water systems, except for the air-seal associated with an AHU. A functioning air-seal located where the condensate exits the commercial AHU acts to sustain positive flow of condensate down the drain line. A malfunctioning air-seal will cause the condensate to backup into the AHU. The most common type of air-seal is a p-trap. Improved designs include p-traps with additions or pneumatic air-seals. In any case, inspection and proper maintenance of the air-seal ensures proper condensate flow.

Although condensate contains nearly zero mineral content and only trace elements picked up along the flow path, airborne pathogens such as Legionella can be a concern, especially if the water stagnates in a storage tank before use. As with all alternative water sources, treatment and water quality monitoring may be necessary to ensure water quality is fit for the intended purpose.[24] In addition, monitoring the quantity of condensate produced is recommended to determine the actual water savings and to alert personnel of condensate collection system malfunctions. For more information on condensate use see the *San Antonio Condensate Collection and Use Manual for Commercial Buildings* published by San Antonio Water System (SAWS).

Engineers are beginning to discover how to harness these new sources of water for use in buildings. Condensate from air-conditioning units can provide a significant source of high quality water. The amount of water that can be collected from a given indoor environment varies greatly, depending on climate, heating, ventilation, and air-conditioning (HVAC) equipment, building size and operations.

The Alliance for Water Efficiency is a stakeholder, non-profit organization dedicated to the efficient and sustainable use of water. They provide comprehensive information about water-efficient products, practices, and programs. AWA recommends that designers and engineers consider the use of condensate for uses that are similar to rainwater.[25]

PLUMBING DESIGN AND THE MYTH OF UNLIMITED WATER SUPPLY

Throughout the developed world, water has historically been considered a virtually unlimited resource. Advancements in the procurement and transport of water include inter-basin transfers, large impoundments, and aquaducts that rely on large-scale pumps, which require an electric grid that can supply the necessary electricity. These initiatives have allowed vast areas of the United States to develop where they otherwise would not have done so. It has only been recently that serious attention has been focused on how these water supplies can be made sustainable for future generations. Populations have increased while the available water supplied to the affected areas has remained the same.

In a society that equates magnitude with greatness, conventional wisdom dictates building large-scale projects such as huge dams and deeper wells. Economies of scale view onsite-generated water as both impractical and having a relatively insignificant impact on the overall water supply picture.

Site-collected water and decentralized water systems using rainwater harvesting can greatly impact a community's ever-growing need for more water. Once the decision is made to construct a building (particularly a commercial building), the mechanical engineer is charged with designing the building to meet the anticipated demands for water based on historic usage patterns and flow rates.

The question has never been how much water is needed to achieve a specific purpose in buildings in terms of quantity, but how water can be made available for all possible building services. Traditionally, it is assumed that there will be an unlimited supply of water from the municipality.

Plumbing design in the United States is based on the premise that there is only one supply pipe to the building and that it will be sending the same quality water to all of the end uses, as this is the simplest and safest way

WHAT RAINS IN LAS VEGAS STAYS IN LAS VEGAS?

The City of Las Vegas receives a finite amount of water from Lake Mead, approximately 300,000 acre-feet of water annually. One acre-foot of water is a volume of water that will cover an area of 1acre to the depth of 1 foot (43,560 cubic feet) and it is equivalent to 326,000 gallons of water. This amount, 300,000 acre feet of water, is the amount upon which the City must count in order to survive and dazzle the millions of tourists that flock hourly to spectacular water features such as the famous fountains at the Bellagio hotel. In a part of the country that receives regularly between 2 and 4 inches of rain annually, the irony could not be more apparent. Still, the City has to live within this water supply framework. There simply is no more water to obtain.

To counteract the City's water usage, Las Vegas has developed a sustainable water conservation plan. The City itself acts as a gigantic rainwater harvesting system in that water collected from rooftops and all sorts of collection surfaces is funneled back to Lake Mead. The City of Las Vegas receives credit for this water that is returned to the lake.

Nonetheless, over the past thirty years the water levels at Lake Mead are slowly receding, like a person drawing more money out of the bank than he is depositing. This reality in "Sin City" is most likely the future for the rest of the country. This is not to say that the United States will turn into a desert, but rather that water supplies will increasingly govern the way cities grow and develop. Plumbing engineers will continue to calculate pipe sizes the same way they always have, only they will be more focused on the conservation side of the design.

of assuring the safety of the water to the users. In other words, all interior plumbed water lines are treated as though all water would be used for drinking.

With the rapid rise of cities, the design question has not been how much water does a building need in terms of volume, but how to design the piping to carry all the water the building needs whenever it needs it. Normally, the local municipal water authority determines the adequate supply of municipal water for an individual project. The plumbing engineer's job is then to adequately size the piping system to serve the fixtures.

Current practice and traditional plumbing code regulations are based on 20th-century design premises, and are not necessarily focused on the conservation needs of the 21st century. Engineers follow certain formulas, derived from accepted conventions, when estimating pipe sizes to accommodate adequate volumes and flows. Different fixtures have different flow requirements.In order to determine the required size of pipe, an arbitrary unit is used for pipe sizing, which takes into account the likelihood that all the fixtures will not be used at the same time. This is called fixture unit. To size a building's water demand, the engineer inputs the quantity and type of fixtures (for example, toilets, faucets, sprinkler heads, hose bibs, and so forth) and refers to charts in the plumbing code to assign and add up the fixture units. In plumbing, a fixture unit is equal to one cubic foot of water drained in

USING RAINWATER HARVESTING SYSTEMS TO DECREASE BUILDING COSTS

Designers who work with sustainable goals in mind will consider both the environmental and economic benefits to the immediate infrastructure of a building as well as to the community at large. For example, by reducing the water demand load of a building, a municipal water authority saves money for water treatment and can delay upgrades for the cost of an ever-growing municipal potable-water supply system. On the other hand, the water purveyor has decreased revenues as a result of the conservation. This dilemma points to the fact that we, as a society, still do not have a firm grasp on the true cost of water.

Although revenues to the municipal water provider may be decreased by lesser demands, the municipal system will realize savings due to lesser treatment costs associated with smaller volumes and increasing efficiency of the existing infrastructure.

From an individual building owner standpoint, because the demand for water from the utility is smaller, the cost of larger supply stub and piping into a building can also be reduced. The reduction in demand by a building can reduce the one-time municipal tapping fee in addition to reducing monthly water bills. If demand is significantly reduced so that a smaller diameter supply pipe from the municipality meets the water needs for the building, the subsequent savings will be realized in not only smaller taps, but smaller water meters, smaller backflow devices, and the like. This is one of the greatest benefits that decentralized site-based rainwater systems can provide.

a 1–1/4-inch pipe over one minute. A fixture unit is not a flow rate unit, but rather a design factor. Fixture unit values can be determined using charts from the International Plumbing Code, the Uniform Plumbing Code, or similar codes of local jurisdictions.

Next, all of the total fixtures in the building are added up and the total numbers of units are translated into gallons per minute (gpm). Using this method, engineers determine a maximum flow rate for the building. The relationship between gallons per minute and fixture unit is not constant, but varies with the number of fixture units. For example, 1,000 fixture unit is equivalent to 220 gpm, but 2,000 fixture unit is not double that, but is only 1.5 times as much, or 330 gpm. Charts and tables that account for conservation strategies are in both the Uniform Plumbing Code and the International Plumbing Code and other similar codes. These guidelines can be chosen based on the design intent of the project and may or may not include aggressive water conservation planning.

Additional charts are used to calculate the allowable velocity of water flowing through the pipe. The speed of water flow in a plumbing supply system is regulated and documented in plumbing charts. Water will move faster through a smaller pipe than a larger pipe in a given amount of time. Increasing the diameter of the pipe will result in the same volume of water moving slower. Faster moving water has the ability to erode the inner walls of pipes more quickly than slower moving water. Therefore, the plumbing code also takes into consideration both the quantity of water as well as the flow rates through the system.

In conclusion, the water supply into a building is sized to meet the gallons per minute and pressure requirements, all within the allowable flow velocities. When designing for rainwater collection, the issue is not how much potable water can be supplied to a building on an unlimited basis, ***but how much water is required to achieve the requirements of the building's water usage.*** The design issue is to provide both potable and nonpotable water for different end uses in a building.

During recent droughts, building occupants in major U.S. cities were within days of finding out that even municipal water supply has limits. As the cost of water increases and the quantity of surface water decreases due to drought and excess consumption, the necessary adjustments for water demand will require new calculations. Many studies are beginning to focus on the conservation of water based on increased equipment efficiency. These studies are contributing to new plumbing designs.

THOUGHTFUL PLANNING BRINGS SUCCESS

In conclusion, the planning for a rainwater system demands careful considerations of a building's location and water demands. There is no one-size-fits-all approach; each project will have a unique solution. The next step in the design process is to review some of the equipment choices that will produce a successful rainwater system.

Burton Elementary and Middle School, Grand Rapids, Michigan

Water System Design: Rainwater management solution
Architect: Progressive AE
Engineers:Owen-Ames-Kimball Co.
Date: August 1, 2008

Project Description:

Burton Elementary School is one of nine schools in Grand Rapids to be renovated to LEED® standards. Burton School is a historical building located in the inner city area of the Grand Rapids school district housing kindergarteners through eighth-graders. It was built in 1925 and some additions were made in the 1960s.

Figure 3.13 Burton Elementary and Middle School in Grand Rapids, Michigan was designed to collect rainwater to flush toilets and water closets as part of a sustainable renovation to this historic building. (*Brian Kelly*)

The 188,000-square-foot building renovation included 43 regular education classrooms and 12 special education classrooms. Also included was a fully equipped two-story media center, a historically renovated auditorium with seating for 550, and an integral community health clinic and recreation facilities.

Design Goals

This system uses 12 water closets and assumes each water closet flushes 49 times a day. The tank size for this system was driven by the available site area in which to locate the tank while still having a system large enough where the students would be able to observe the operation. The system was sized and designed with teaching as the influencing criteria.

Occupancy:

Usage: Toilet flushing (number of units): 12 units

Climate:

Annual Rainfall: 38 inches

Statistics:

Roof Area:11,000 square feet

Roof Material: White PVC

Cistern Volume: 10, 000-gallon FRP tank

Number of Cisterns: 2 small cisterns with filters and a larger underground cistern

Separate Plumbing: Yes

Progressive AE

Permitting/Code Approvals:

Standard Codes for Michigan

Rebates/Incentives:

No rebates but the building received a LEED® point for harvesting rainwater.

Detailed description of this project including the system design can be found at: www.journalofgreenbuilding.com/doi/abs/10.3992/jgb.4.4.19

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CHAPTER 4

System Elements

Figure 4.1 Storage is celebrated and integrated into the aesthetics of the courtyard in a rainwater fountain. (*Viviane Van Giesen*)

INTEGRATED APPROACH

Eugene P. Odum, considered the “father of modern ecology,” offers a way to understand any type of system: “If you want to understand a large-scale system,” he said, “you have to start with the function of the organisms in the system. Function before structure.”[1] In line with this approach, a rainwater harvesting system is an integrated group of elements that work together to provide collected rainwater ready for utilization. It is important to understand these fundamental elements, their functions, and the various components that comprise each of them. With this understanding comes an awareness of the interdependency necessary to integrate the elements into a successful system.

Any systems approach involves various elements working together to achieve end results. In this book's discussion, a particular labeling of elements has been chosen to describe a rainwater harvesting system. Some overlap in function may occur between the described elements. Other publications and approaches may use different labeling, as nomenclature and terminology within the rainwater harvesting industry may vary.

The simplified graphic of a rainwater harvesting system shown in Figure 4.2 identifies the relationships of its elements. The fundamental elements of a rainwater harvesting system include:

1. Collection/Catchment Surface: The surface is typically the roof of a building. If other surfaces are used, a higher degree of filtration/treatment may be required.

Fundamental Elements of a Rainwater Harvesting System Integrated System Components

Fundamental Elements of RWHS

1. Collection/Catchment Surface
2. Conveyance
3. Prefiltration/Debris Exclusion
4. Storage: Tanks or cisterns in various locations
5. Distribution

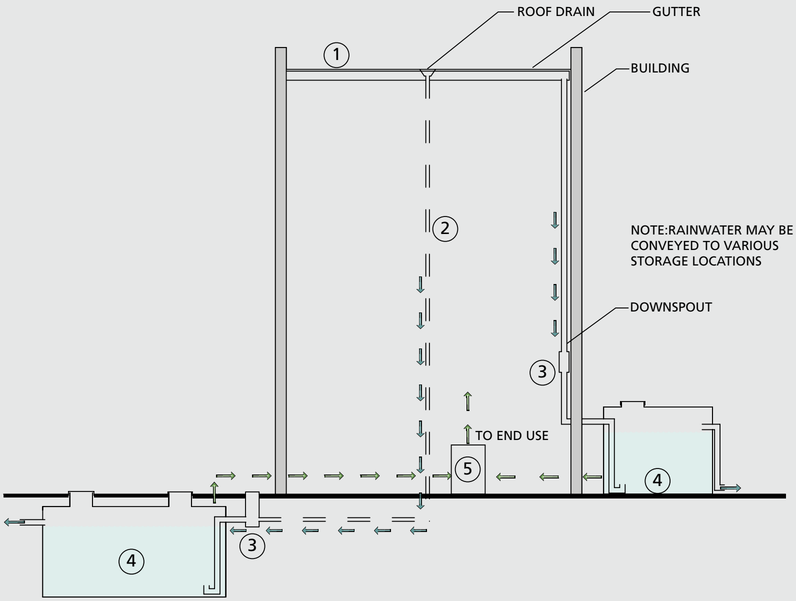


Figure 4.2 Fundamental elements of an integrated rainwater harvesting system. (*Fred Smotherman*)

Figure 4.3 An integrated system provides water for toilet flushing and cooling towers at the University of Georgia Visual Arts Building. (*Viviane Van Giesen*)

2. Conveyance: Roof runoff is typically conveyed to a rainwater collection system via gutters with downspouts or roof area drains with leaders. Other miscellaneous piping may be included in the conveyance system as needed.
3. Prefiltration/Debris Exclusion: Filtration devices are used to remove particulate contaminants en-route to storage. In some systems, a first-flush method may be used to completely bypass an initial amount of roof runoff so that it cannot enter storage.
4. Storage: Tanks or cisterns are used to store harvested rainwater. They may be placed in various locations:
    a. Aboveground, outside a building
    b. Aboveground, inside a building
    c. Belowground, outside a building
    d. Belowground, inside a building (i.e., a basement)
5. Distribution: Using harvested rainwater to fulfill designated uses normally requires pressurizing, filtering, treating, controlling flow to end use, monitoring storage tank levels, and/or controlling the need for switching to backup/bypass/makeup water.

Variations of these elements and their inclusion in a system will become clearer in later discussions of each element and its components.

Opportunities for an Integrated Approach

Undoubtedly, the most efficient approach to designing and building a rainwater harvesting system is to complete the installation at the time of initial construction of the building; however, a rainwater collection system may not be part of every new construction project. Whether rainwater harvesting is integral to the building program or not, the architect/engineer/designer has the *opportunity to make decisions* *that can enhance harvesting opportunities in the future.* Decisions such as choosing the location and design of mechanical room(s), providing sleeves through walls and under/around exterior site improvements, and/or providing dedicated interior piping may be included in new construction/renovation projects to facilitate the implementation of new and future systems. Additional opportunities include:

1. Providing dedicated power supply for a future rainwater control station
2. Providing foundations and accessibility for future installation of tanks (interior or exterior)
3. Designing gutters/roof drains/downspouts/leaders to be adaptable for future conveyance to storage tanks
4. Plan the site layout to accommodate a future rainwater harvesting system (for example, install conduit, sleeves, and foundation(s) for tanks and plan exterior plantings and other amenities accordingly)

Knowing that the elements of a rainwater harvesting system are interrelated is only part of an integrated approach. The relationship between these elements and the planning process must also be understood, as the elements are also related to architectural, site, structural, mechanical, electrical, and plumbing aspects of a project.

1. COLLECTION/CATCHMENT SURFACE (ROOF OR OTHER)

The roof of the building is the primary collection surface considered in this book. The roof of a building essentially serves to protect the building and its occupants from climatic factors. With rainwater harvesting systems, the designer can collect and utilize one of those factors (rain) as a valuable resource. Among the many obvious purposes that a roof can serve, the focus of this discussion includes these two important aspects:

1. To protect people and materials from the weather and climate,
2. To serve as a surface to collect rainwater.

Goals exclusive of rainwater harvesting may drive roofing choices, but familiarity with roofing materials will reveal benefits/constraints that will guide overall system strategies and material choices downstream of the roof. As a general rule, the designer must assess the roofing materials (new and existing) and weigh their effects on other aspects of the rainwater harvesting system. The best surface to use for rainwater collection is glass, because water slides over it very efficiently. Glass roofs are found on greenhouses and other specially controlled environments such as botanical gardens and shopping malls.

Prisma Gostenhof

Nuremburg, Germany

Prisma in Nuremberg, Germany, is a mixed-use facility with 61 residential units, 32 offices, 9 stores, a coffeehouse, and a kindergarten. It was built with urban ecology in mind.

Natural air-conditioning and innovative rainwater management set in an artfully designed environment encourage a conscious use of natural resources. Rooftop water is collected on a glass roof, cleansed, and sent in two separate cycles through the building. The first cycle irrigates

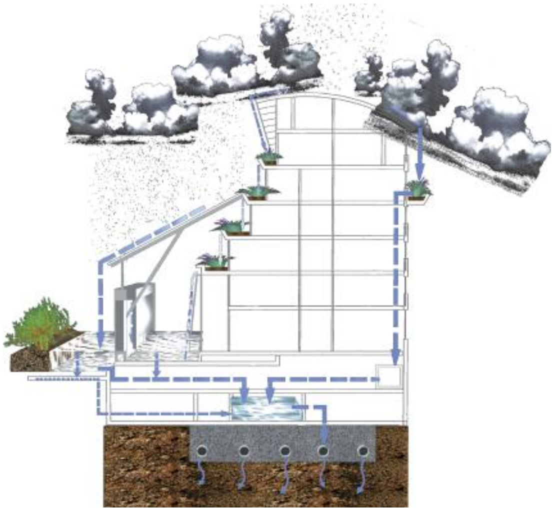


Figure 4.4 Rooftop water is collected on a glass roof and used for irrigation and in a waterscape of creeks and ponds. (*Atelier Dreiseitl*)

the plants in the 50-foot-high (15 m) greenhouse and creates an interesting waterscape of creeks and ponds. Another water cycle pumps water in between 16-foot-tall (5 m), colorful glass walls. In this process, air is pulled inside through open crevices and exits purified and cooled together with the waterfall into the glasshouse.

Figure 4.5 Prisma waterscape in atrium of building. (*Atelier Dreiseitl*)

Typical roofing surfaces include the following:

- Metal (Steel: Galvanized, Painted, Stainless, Terne-Coated, Aluminum, and Copper)
- Membrane: Including modified bitumen, EPDM, PVC, polyester (some with insulation and aggregate ballast)
- Asphalt/fiberglass shingles (typically fine aggregate surface)
- Wood shingles
- Roll roofing (may have fine aggregate surface)
- Builtup roofing
- Slate
- Tiles: Clay and Concrete
- Glass/plastic/fiberglass panels
- Green roof: Typically membrane-covered with growing media and plant

Occupied roofs (outdoor living spaces, typical in dense urban areas)

When terms such as “asphalt shingles,” “clay tile,” and “painted steel” are used to describe a roofing type, the roofing surface is also comprised of supplementary materials that are important to consider. Underlayments,

Figure 4.6 A butterfly roof in Denton, Texas, offers aesthetics and a convenient catchment point for rainwater. (*Eddie Van Giesen*)

flashings, and fasteners are a few of the parts of a roofing system that can also come in contact with rainwater. Erosion and degradation of the roofing material itself, mineral grit from asphalt shingles, flaking of clay tile, and the oxidation of paint can also be washed off the roof and be present in rainwater.

In addition to the materials comprising a roofing system, many roofs host a number of add-ons that are in contact with rainwater as well. These include heating, ventilating, and air-conditioning (HVAC) units, exhaust fans, gas lines, electrical conduit antennae, utility screens, and enclosures. All of these materials can affect the quality of the rainwater that runs off the roof. Studies have noted possible contaminants that might be expected in rainfall collected on various roofing materials in different locales. Specifications for different materials, local weather, and pollution levels also play a role in the reactions these

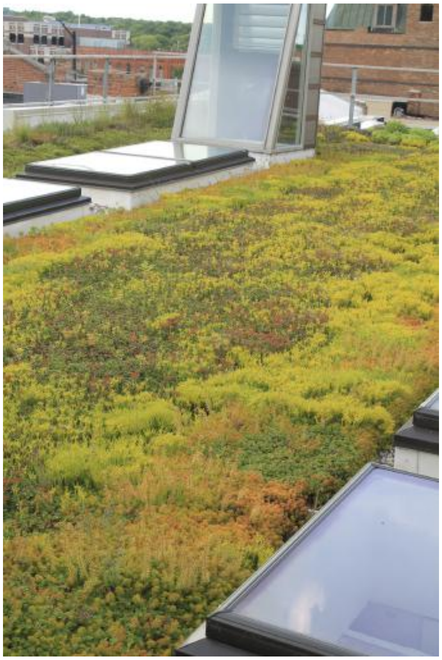


Figure 4.7 Example of a green roof installed by Ann Arbor Architects Collaborative that included rainwater collection for roof irrigation in Michigan. (*Celeste Allen Novak, Architect*)

materials have with rainwater. Proximity to certain activities such as agricultural, construction, and highways also influence rainwater quality.

Various factors in the building program influence roofing material choices, including the client's preferred aesthetics, budget, code requirements, energy efficiency goals, and so forth. Existing construction design may also be the determining factor influencing roofing choices.

Rainwater Harvesting—A Comprehensive Review of Literature, contains a compilation of case studies from different locales and climates available from the North Carolina Water Resources Research Institute. The authors have summarized effects of roofing materials on rooftop runoff quality in a number of charts in Appendix B. This review discusses that even with the presence of some contamination, rainwater harvesting can still be successful and safe for most nonpotable uses advocated in this book.

These case studies must be viewed in context. They are in different locations with nonuniform materials, in both urban and nonurban locales. Maintenance protocols are not necessarily consistent, and some of the systems are analyzed in relation to potable water production. The information may seem overwhelming, considering the number of factors affecting the quality of rainwater. The fact is that many large municipalities source their water from lakes and rivers that may be as much or more contaminated than the rainwater in the case studies. These water sources are treated successfully to a high-quality for potable use by municipalities.

Remember, the focus of this book is primarily on indoor nonpotable uses. In most instances, the effects that the roof surface will have on the constitution of the stored water and its impacts on the user are minimal in the nonpotable context.

By mentioning the contaminants/pollutants in rainwater, some fundamental facts are established:

- The quality of rainwater is affected by local climate, atmospheric conditions that the rain passes through, and the surfaces that it passes over.
- Roofing materials on existing and new buildings vary widely. Variations in manufacturers' specifications in different countries also add to the mix.
- Contaminants/pollutants can be found and may be picked up by rainwater flowing over roof surfaces. With certain levels of filtration and treatment, this water can be safely used for nonpotable indoor uses such as flushing toilets/urinals and cooling tower makeup (thousands of systems are in service worldwide). With a higher level of treatment, the collected rainwater can also be used for potable uses (though this is not the focus of this book). This removal of contaminants from the water reinforces the importance of a rainwater harvesting system as an effective BMP in stormwater management.

The professional's choice for roofing for a project should consider **all of the design goals** (including rainwater harvesting systems). Two roof types requiring more careful consideration (if rainwater is collected from their surfaces) are copper and green roofs. Copper is found in roof flashing, gutters, downspouts, and piping that are parts of a rainwater collection system. As a general rule, runoff containing copper can be a source of stains and can react with other metals and alloys found along the plumbing routes. Green roof soils/media may leach tannins and other dissolved solids that can be costly to remove. Irrigation is perhaps the best use for water that is collected from these two roof types, taking care that the water is not sprayed on building surfaces.

Construction debris, soil from foot traffic, and anything else that would be unwanted in the tank should be removed from the roof prior to the commissioning and startup of a rainwater collection system. It is important to note that after construction, roofs are largely ignored until there is a leak. Proper education on the part of the maintenance staff, as well as the inclusion of an owner's maintenance manual and training is key in the long-term success of a rainwater harvesting system.

The presence of birds, rodents, and insects should be limited as much as possible from a roof surface. Widespread bird roosting can be prevented or reduced by the use of decoy snakes or birds, as well as the installation of various spiked wire products to interfere with roosting. Traps and decoys can be used for rodents. Anticipation of pests, diligent inspection, and appropriate actions can reduce fecal contamination, as well as minimize the presence of dead birds and rodents in rainfall runoff.

Determining the portion of the roof that will be used for rainwater collection is related to:

1. The volume of rainwater the system is expected to provide
2. The location of the storage tank and the preferred method and route of conveyance
3. Costs associated with items 1 and 2
4. Aesthetic consideration (hidden or highlighted conveyance and storage)
5. Opportunities or restrictions for overflow protection due to site elevations or other constraints

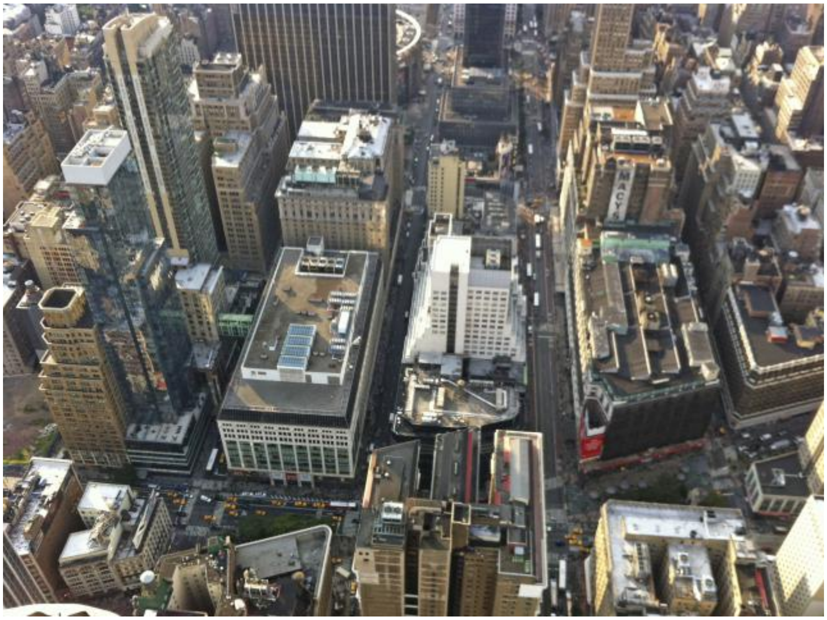


Figure 4.8 Urban roofs provide many opportunities for rainwater collection. (*Eddie Van Giesen*)

Figure 4.9 Typical design of a multilevel gravel roof. Over time, debris will accumulate on this roof. The degree to which this type of roofing material will affect water quality in the tank is determined by intensity of local rainfall and how well the roof is maintained. (*Eddie Van Giesen*)

These elements and their components are *interrelated* to other elements. This relationship must become integrated into the planning process as other elements of a system are considered.

2. CONVEYANCE (GUTTERS AND DOWNSPOUTS)

Rainwater is typically conveyed from the collection surface (roof) to a storage tank or cistern in two ways:

1. A sloped roof typically drains to gutters and downspouts at the outer edges(s) of the building envelope. Scuppers, oversized gutters, and other methods are employed for overflow protection.
2. A flat or semiflat roof may use roof area drains that connect to leaders (downspouts). These leaders penetrate the roof, and flow either overhead to the exterior or down and then under the floor to the building's exterior. Siphonic and gravity-drained pipes then convey the water down to the storage vessel. Scuppers or unobstructed roof edges are typically used for overflow protection.

Siphonic roof drains are carefully engineered systems that use a siphonic action to convey water instead of gravity. The siphonic action of a drainpipe running full of water is used to create suction that pulls the water into the storage tank. The advantages of this type of roof drainage for flat or semiflat roofs are:

1. Horizontal runs within the building envelope can be run with smaller-diameter pipes.
2. These runs can be almost level until they are tied into the vertical leaders of the roof drain system.

Figure 4.10 Water is conveyed from a butterfly roof to storage at the Young At Art Museum. (*Eddie Van Giesen*)

Pipe runs can be run in shallower ceiling spaces and along more flexible routes not as dependent on slope. These drainage systems are advantageous for interior space planning purposes, and they may be a viable option if conveying rainwater to a desirable location that is not possible using conventional gravity-only drainage.

Note: Overflow protection in storage tanks *is not a substitute for proper roof overflow protection.* Accepted methodologies must be incorporated in roof planning apart from storage overflow strategies.

Dry Conveyance versus Wet Conveyance

Rainwater is best conveyed through a dry conveyance arrangement, which drains water out of the pipe after runoff ceases. The piping from the collection surface to the storage tank is dry between rain events, thereby lessening the presence of stagnant water and the potential for freezing.

Rainwater conveyed through wet conveyance is piped from collection to storage and may be partially or completely flooded between rain events. In such a system, the entrance to water storage is higher than the lowest point of the conveyance route. As a general rule, this method is sometimes employed due to site constraints, but it is not recommended.

Both wet and dry conveyance may have components with lower sections with potential for freeze damage in colder months. Thus, a provision for the drainage of retained water, or some other method of freeze protection, must

Figure 4.11 Insulated leaders from a flat roof convey water inside the building envelope to a rainwater tank. (*Eddie Van Giesen*)

be included in the maintenance protocols for both types of conveyance.

Sizing and Numbers

Depending on the project, either the architect, the designing engineer, or the roofing contractor will be responsible for the proper sizing of the gutters and downspouts. Methods of sizing gutters, downspouts, area drains, and insulated leaders are typically derived from four primary sources:

1. International Plumbing Code, by The International Code Council (ICC)
2. Uniform Plumbing Code, by The International Association of Plumbing and Mechanical Officials (IAPMO)
3. Architectural Sheet Metal Manual, by Sheet Metal and Air Conditioning Contractors' National Association (SMACNA)
4. Architectural Graphic Standards, by The American Institute of Architects (AIA)

When considering the four methodologies mentioned above, the design professional should choose the one that is most compliant with the local codes, the circumstances and details for a particular roof, design loads for ponding potential, and the type of rain events expected to occur.

RCI is an international association of professional consultants, architects, and engineers who specialize in the specification and design of roofing, waterproofing, and exterior wall systems. They published an online article regarding different methodologies for sizing gutters. The authors found that different methodologies produce different results. The variation is due to the assumption that all roof flows are evenly distributed among roof downspouts. There also can be a wide discrepancy in the rainfall intensity data, which may be obtained from different sources.[2] Despite the method employed, all piping used in a conveyance system should be sized to *meet or exceed* local code requirements while giving due diligence to best practices for a particular roof type and configuration.

In many commercial applications where gutters are attached directly to the roof material, the gutter is hung exactly level. This can be noticed on many commercial roofs, especially on larger retail buildings. Sloping a gutter prevents standing water, which can lead to mosquito breeding, excess weight on drainage piping, leaching of piping materials into the runoff water, or freezing of retained water.

Aesthetics/Functions/Budget

Conveyance Aesthetics

Conveyance through gutters, downspouts, roof drains, internal leaders, and other piping devices can be approached in two ways. One is to *harmonize* with other aspects of the building and site. Internal drains may be hidden in ceilings, exposed and painted to blend in with other exposed utilities (ducts, conduit, and the like). External conveyance elements may be part of the “rhythm” of the facade. One typical approach is for downspouts to follow the pattern of exterior pilasters, controlled joints, and other patterns that are of the external view of the building.

Another approach is to *contrast* with the building’s exterior for an aesthetic/educational effect. Internal leaders in a building with exposed utilities (HVAC, wiring conduit, plumbing, roof drains) might be painted to identify the travel route of rainwater that is to be used to meet some of the building’s water needs. External downspouts can also provide a visual statement for the building as well as an opportunity to highlight a sustainable feature, as shown in the Fowler Drive Elementary School project.

Figure 4.12 Interior downspout attached to conservatory structure recedes into the planting bed on its way to storage. (*Eddie Van Giesen*)

Figure 4.13 The gutters and downspouts used on this building repeat as part of balanced modules in the facade of Blue Ridge Electric Membership Cooperative, Young Harris, Georgia. With over 100 downspouts, they serve as a strong visual element in the facade of the building. (*Eddie Van Giesen*)

Figure 4.14 Exaggerated conveyance provides educational opportunities in a rain garden/rainwater harvesting system for the Fowler Drive Elementary School, Athens, Georgia. (*Viviane Van Giesen*)

Conveyance Functions

Elements of conveyance include the following:

1. Proper size: Meeting SMACNA and other applicable standards and/or regulations
2. Watertightness: Protecting the building and its occupants from leaks and including proper overflow strategies
3. Materials: Selecting those appropriate for aesthetic goals, climate, local air quality, acceptable water quality, and compatible with adjacent materials
4. Connectivity: Aesthetics and ease of physical transition to other components such as filtration devices, pumps, storage, and additional piping.

Conveyance Budget

In discussing financial aspects of a system, the initial focus is on materials of acceptable quality that convey the rainwater at a reasonable cost. It is important to note that identifying rainwater harvesting as a part of the building program *early* in the design process can be one of the most budget-conscious decisions made.

In many cases, both for new and existing buildings, routing strategies can guide decisions that result in substantial savings. Conveyance routes, both interior and exterior, can be shortened in length, combined in trenches with compatible utilities, or included in ceiling utility groups. Opportunities to hide or highlight the route may also result in savings. Again, early planning is the key to maximizing the budget.

3. PRESTORAGE FILTRATION AND DEBRIS EXCLUSION

Sometimes known as inlet filtration, prestorage filtration is the element responsible for removing a number of contaminants from rainwater prior to storage. The importance of reducing debris (organic or otherwise) in rainwater cannot be overstated. Some in the industry consider this element to be the most important one in the system.

Typical contaminants that cause problems include the following:

- Leaf litter, branches, other plant debris
- Bird, rodent, and insect droppings
- Bird, rodent, and insect carcasses
- Trash
- Dirt and pollen
- Pollution particulates
- Degrading roof materials

By reducing contaminant loads with good prefiltration, a higher level of water quality can be achieved in the storage tank. Maintenance costs for tanks, equipment, and other components can also be kept to a minimum.

Prestorage Filter Types and Applications

There are many prestorage filtration devices available on the market that have different locations in the system, different scale-driven applications, and different levels of efficacy. It is vitally important for the rainwater harvesting professional to research and become familiar with the models, brands, and especially performance of these components. Developing relationships with industry experts—other designers, contractors, and manufacturers—will assist in the successful implementation of this element. The primary types of devices include *downspout filters, basket-type filters, centrifugal-type filters*, and *cascading-type filters.*

Figure 4.15 Large capacity downspout filter with built-in overflow. This filter is installed vertically and must be accessible for ease of cleaning as water cascades over the screen. (*Eddie Van Giesen*)

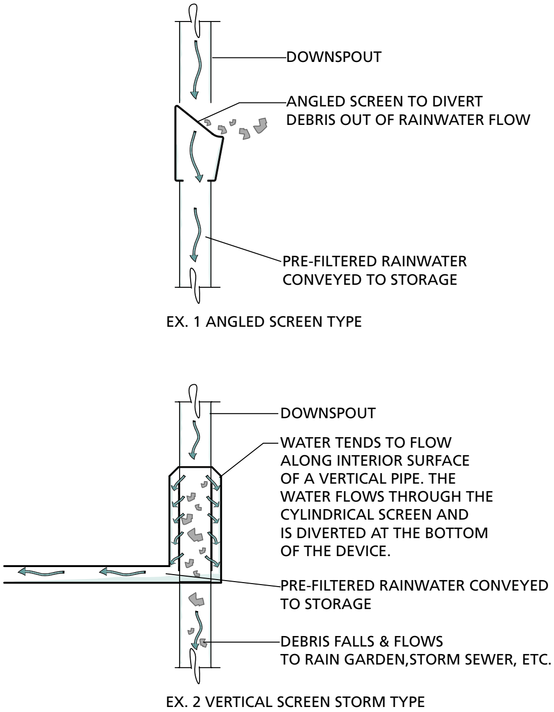


Figure 4.17 Two types of Downspout Filters: Downspout filters include angle screen and vertical screen types. (*Fred Smotherman*)

Figure 4.16 This filter has an angled screen, which excludes debris. (*Eddie Van Giesen*)

Downspout Filters

Downspout filters are typically located in the earlier stages of conveyance and in line with the downspout. This filter typically will be placed vertically in the downspout, interrupting its flow and creating an air gap between the bottom edge of the downspout and the debris-excluding screen. Sufficient space should be left between the downspout and the screen for maintenance of this device.

The height of this filter's installation is based on being above potential contamination by animals and ease of maintenance. These filters are primarily designed for smaller downspout sizes and must be located at each downspout. For these two reasons, they are typically associated with residential and small-scale commercial applications. The screens must be inspected regularly since debris may remain after a light rain and clog the openings as it dries out. Many filters are designed to be installed on an angle to allow debris to automatically slough off and not make it to the system.

If multiple downspouts are going to be routing rainwater into the storage, a downspout filter is needed for each downspout, or multiple downspouts can be combined into one pipe. When combining downspout pipes, it is imperative to ensure that the pipe receiving multiple downspouts is large enough to convey the flow of all contributing pipes. In other words, the single pipe should have a cross-sectional area equal to or greater than the cumulative cross-sectional area of all contributing downspouts. If the rainwater is routed to an underground tank, "manifolding" or combining the downspouts at grade or underground and sending this water into a larger at-grade filter may be a better choice than individual downspout filters. Again, understanding the basics will guide the component integration.

Vertical-screen downspout filters operate on the principle that water flowing from the downspout does not pour out of the middle of the pipe, but rather clings and flows along the sides of the pipe. Some manufacturers take advantage of this by constructing a filter

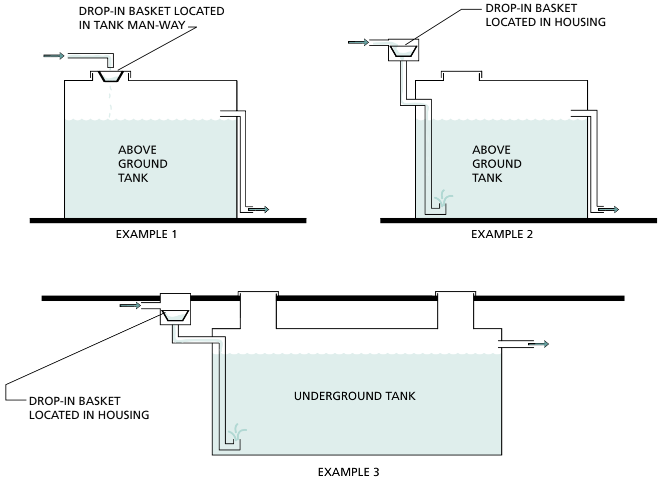


Figure 4.18 Basket-type filters may be used in several locations. (*Fred Smotherman*)

that allows the water running along the edge to pass through a screen while excluding the debris. The debris then falls downward to its normal storm path.

Basket Filter

A basket-type filter generally sits in the access way of the storage tank and prevents larger debris, animals, and vectors from entering the tank.

Advantages

- Inexpensive
- Easy to install and easy to clean (simply remove and tap or shake it out)
- Simple design
- Can eliminate the need for a calming inlet when used at the access way to a tank. The "rain shower" pattern of the water flowing through the filter, in contrast to a strong flow dropping from a pipe, will not create significant turbulence at the sediment level.

Disadvantages

- If not properly maintained, an accumulation of debris can slowly decompose into small enough particles that eventually make their way through the screen and into the tank (tea-bag effect).
- Unlike many downspout filter designs, this filter does not facilitate a self-cleaning mechanism. Consequently, it can clog easily, causing inlet water to overflow the basket and never reach into the tank.

Take care in choosing the right filter medium for a given application to avoid direct exposure to the sun whenever possible. If the screen is plastic, direct exposure to sunlight will degrade the screen. A stainless steel mesh provides a better screen material.

A subcategory of a basket-type filter is one that is housed in a molded enclosure, which prevents the introduction of sunlight. If there is not a gap between the downspout and the basket filter, the filter enclosure should include a built-in overflow. This overflow prevents the inlet water from being forced back up the inlet

Figure 4.19 Typical commercial roof with HVAC commercial rooftop units. Contaminant loads exiting commercial roofs are highly variable, depending on locale and rooftop inspection and maintenance. (*Eddie Van Giesen*)

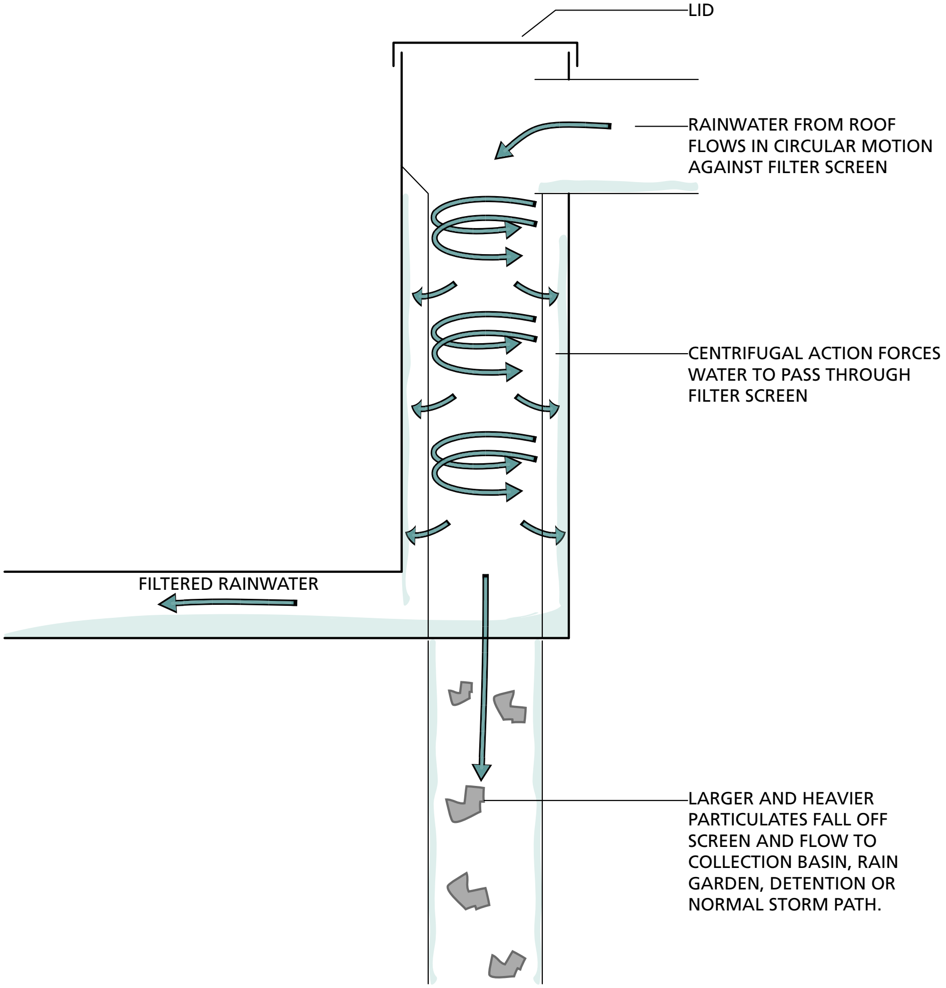


Figure 4.20 Centrifugal Filter. (*Fred Smotherman*)

pipe or overflowing from the top of the filter itself. These filters are sized to handle a certain flow, which will correspond to the roof area in a given climate zone. Care should be taken that this design flow is not exceeded.

It is important to note that in certain applications, especially in residential ones, basket filters can be used effectively when closely monitored and regularly cleaned.

Centrifugal Filters

This filter's operation is based on the principal of water being forced through a screen by centrifugal force. The debris and trash are directed downward and allowed to pass to the normal storm path. For a higher-quality water, professionals may want to select a filter with a typical micron size between approximately 280 and 380 microns.

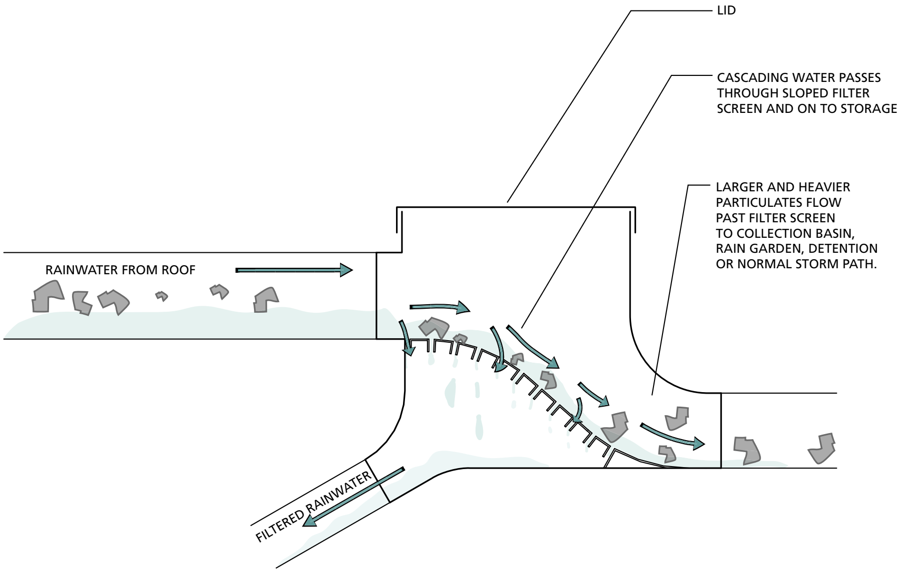


Figure 4.21 Cascading type filter. (*Fred Smotherman*)

Screens should be inspected regularly, but this filter type is much less susceptible to clogging than basket-type filters. Centrifugal filters can be installed aboveground or underground. For belowground applications, pedestrian-rated lids or vehicle-rated lids can be provided to handle various loads.

These filters are available in a wide range of sizes and the resulting water quality is very high. In larger systems, a single appropriately sized unit can accommodate combined conveyance flows in greater diameter pipes.

One disadvantage with this type of filter is that at certain low flows there is not enough centrifugal action to force the water through the filter screen. Capturing condensate water, for example, may be problematic with this filter. A separate line may be needed to bypass the filter altogether to allow for this water source. *Again, integrate components for each particular project.*

Cascading Debris Excluders

These devices allow gravity to pull cascading water through an inclined screen. Particulates are washed past the screen, while rainwater passes though the screen and on to storage. Cascading filters are available in a wide range of sizes to accommodate various flow capabilities.

Typically, these filters are largely self-cleaning. Some of the more sophisticated devices have the option of adding water injection nozzles that can be set up to spray water over the screen to keep it clean between rain events. This is especially important in areas of the country that experience long periods between rain events, such as California. The surfaces can become caked with dry organic matter and sediment and, without regular cleaning, they will not allow water to pass through the screen.

Prestorage Filtration Devices

Various large-scale debris/contaminant filters are available that are essentially precast concrete manholes with filters and debris separators. They are used primarily for filtering inlet water for stormwater management purposes. The design of this filter sequesters light particulates that float as well as heavy particulates that settle, and filters other dissolved and suspended contaminants.

These filters have been successfully adapted for the filtration of rainwater prior to storage. Their high-volume designs make them especially valuable as retrofit installations. The units must be cleaned with an industrial vacuum regularly to remove floating and settled debris. Filter inserts (when applicable) must be changed as needed.

These types of prestorage filters not only keep the debris from entering the tank but also keep the pollutants from going downstream by trapping them in the vault for later removal.

Filter Sizes

When properly maintained, these filters produce very high-quality water. All filters are designed to receive a certain flow rate based on rainwater produced by a roof area in a particular climate zone for certain rainfall intensity. The designer must select the appropriate filter type and calculate conveyance pipe sizes for the proper intensities and flow rates based on the locale.

How Components Help Merge the Goals of Rainwater and Stormwater

A rainwater harvesting system works to collect an onsite supply of water and keep debris and contaminants out of that water supply (storage tank). Typically, little thought has been given to the destination of separated debris and contaminants.

In contrast, a stormwater management system normally works to keep debris and contaminants out of downstream waters (quality improvement) and to mitigate the flow (quantity and velocity) of water leaving a site through various best management practices, such as infiltration, retention, detention, or reuse. *The primary goal in this case is not to use the water, but only to manage its' quality and quantity.*

Rainwater harvesting systems are increasingly being used as methods of managing urban stormwater runoff. Bill Hunt, Professor and Extension Specialist at North Carolina State University and a prominent researcher in Urban Stormwater Management, notes that stormwater mitigation can be achieved by rainwater systems in the following ways:

- Designated uses of harvested rainwater are chosen—or created—to facilitate frequent, consistent use of harvesting rainwater, which allows the system to capture a greater volume of stormwater, thereby facilitating volume and peak flow reductions.
- The release of harvested rainwater is performed in anticipation of rain events in order to maximize the capture of stormwater, thus mitigating stormflows.
- Larger roof debris are collected through prestorage filtration and disposed of, as opposed to contributing to stormflows.
- In the storage tank, some of the smaller and dissolved contaminants are sequestered and treated by biological and chemical activity that occurs at the bottom of the tank, which improves the quality of water used/released from the system.

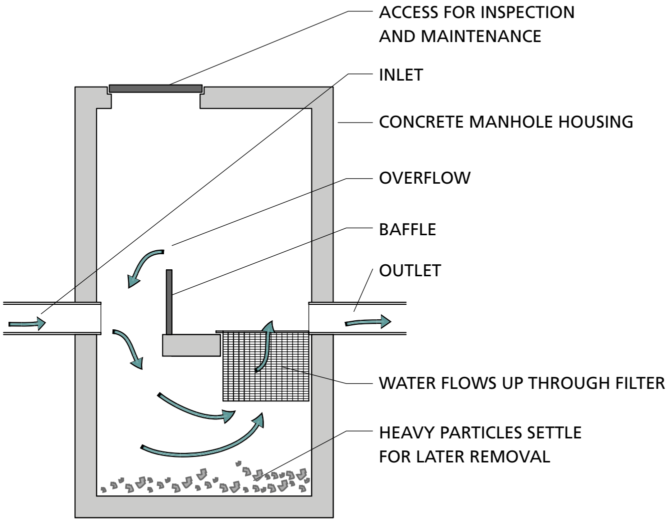


Figure 4.22 Representative stormwater debris remover with potential use in Rainwater Harvesting. (*Fred Smotherman*)

- Filters and treatment processes used during the distribution process remove even more of these contaminants before end use.
- In the municipal sewer treatment plant, the water that is used in the building (toilets, sinks, and the like) is sent to the sanitary sewer system, and it is treated at the wastewater plant before it is released to receiving waters.

Many products and techniques used for stormwater management can and are currently being adapted for rainwater collection. Reviewing current products and periodicals in the stormwater industry will provide cross-application understanding both in products and design goals. Most products used in conveyance of rainwater are not unique to the rainwater industry—many are typical materials and devices that are part of the general plumbing and drainage industries.

4. STORAGE

For general use in this text, the terms "storage (unit)," "tank," and "cistern" may be used interchangeably. While the tank is the largest component of storage, there are numerous supporting components that are fundamental to the functioning of this element. The components of a storage system include the following:

1. Tank
2. Rainwater Inlet from Conveyance
    - May enter the tank from top, side, or bottom via riser
3. Calming Inlet
    - Minimizes disturbance of sediment at bottom of tank by reducing agitation from the incoming water
    - Incoming water provides aeration

4. Intake (Extractor)
    - Provides extraction of water from a location below top surface. Generally, higher water quality is found below the top surface and above the very bottom of the tank. A floating screen inlet reduces vortexing and the introduction of air into the pumping system.
    - An alternative is to provide a fixed intake with a screen (to reduce vortexing) placed a minimum of 6–8 inches above the bottom of the tank.
5. Water to Distribution
    - Rainwater from storage flow to distribution
    - Submersible pumps typically used in belowground tanks
    - Flooded-suction pumps preferred in aboveground tanks
6. Water Level Indicator
    - Device to monitor water level in tank and communicate with components in distribution
    - Types include floating or electronic based
7. Overflow
    - Excess water flows out of tank to grade, stormwater sewer, stormwater control devices, or other appropriate path per local requirements/system goals
8. Vent
    - Provides ventilation for stored water and pressure relief from incoming water
9. Tank Access
    - Should be secured to prevent unauthorized access
    - Access from belowground tanks should be minimum 4 inches above surrounding grade

Figure 4.23 Corrugated tank with access opening is attached to the top section of the tank. (*Eddie Van Giesen*)

It is important to become familiar with strategies for storage and new products that are on the market. Investigate built projects by talking to owners, designers, manufacturers, and other experienced rainwater harvesting system experts and follow case studies in professional trade publications.

In nearly all instances, the storage tank will at some point overflow. The overflow must be at least equal to the inlet in terms of pipe size. Failing to plan for this important part of a storage tank will result in the water backing up into the conveyance pipe or out of the top of the tank.

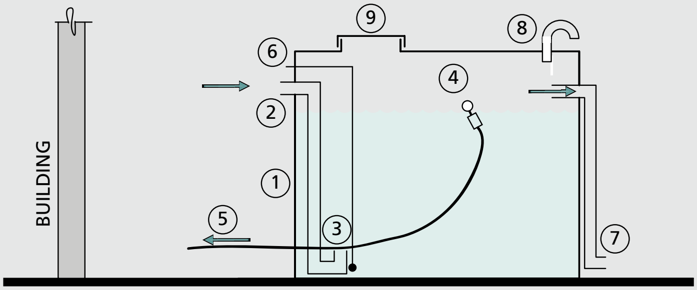
When the tank is placed in an indoor location such as in a mechanical room, provisions must be made to allow for the overflow water. In addition, when the tank is placed in an outdoor location the designer must account not only for the overflow pipe but also for the increased amount of water that will be flowing out of the pipe. Water which previously was distributed to downspouts is now concentrated into one outlet.

The designer should think about all the factors affecting the function, aesthetics, and costs (initial and long-term) of all the elements in a rainwater harvesting system. Finding the

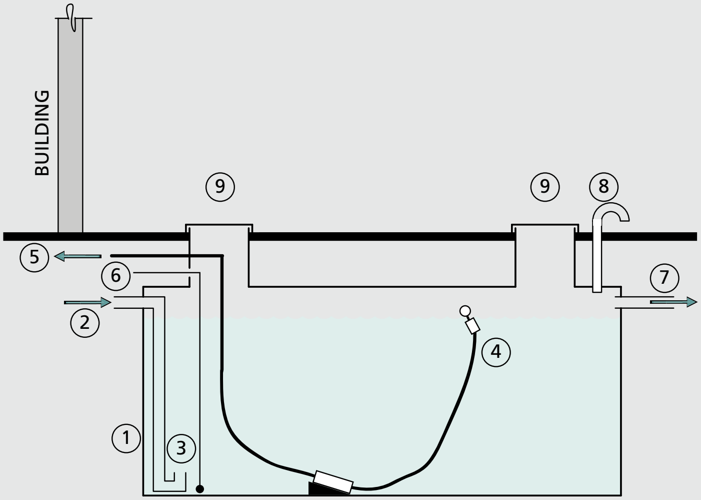
TYPICAL COMPONENTS OF STORAGE: COLLECTED AND PREFILTERED RAINWATER IS CONVEYED TO STORAGE, WHERE IT IS AVAILABLE FOR DISTRIBUTION ON DEMAND.

Key for Typical Storage Components

1. Tank (representative)
2. Rainwater Inlet from Conveyance
3. Calming Inlet
4. Floating Intake (Extractor)
5. Water to Distribution
6. Water Level Indicator
7. Overflow
8. Vent
9. Tank Access



ABOVE–GROUND



BELOW–GROUND

Figure 4.24 Typical components of storage. Collected and pre-filtered rainwater is conveyed to storage, where it is available for distribution on demand. (*Fred Smotherman*)

Figure 4.25 Aboveground tanks at Posty Cards Manufacturing Plant in Kansas City, Missouri (*Aaron Daugherty Photography*)

best storage tank and supporting components for a particular application is key to a successful system.

Aboveground Tanks

Typical Materials for Aboveground Tanks

Tank shapes and sizes may vary even within a material category (horizontal, vertical, short and wide, tall and narrow, and so forth). The following is a list of typical materials for aboveground storage tanks.

Plastic tanks (Polypropylene, Polyethylene)

Fiberglass and Fiberglass reinforced plastic (FRP)

Metal (Stainless steel with gaskets, Coasted steel, Galvanized and Aluminized steel (with flexible liner)

Concrete (Cast-in-place, Precast one-piece, Precast modular, Ferro-concrete tanks (concrete sprayed on frame)

Flexible Bladder (Synthetic fabric construction)

THE IMPORTANCE OF OPACITY AND COLOR IN STORAGE TANK SELECTION

Black or dark-colored polyethylene tanks can absorb heat from the sun and cause the water temperature to rise. This increase in temperature increases the biological activity in the tank and the activity can contribute to lower-quality water. Painting the exterior of the tank with a lighter color can block some of the sun's rays and help maintain lower water temperatures. Reflective steel tanks will typically reflect sunlight and consequently contribute to maintaining lower water temperatures. Therefore, tanks that are lighter in color are preferable to darker ones. Regardless of the tank material, the tank should always be opaque enough to prevent sunlight from entering the tank and causing algae growth. It does not take very much light to stimulate the growth of algae.

Summary of Recommendations for Aboveground Storage Tanks

Designers should follow manufacturer-recommended guidelines and designs for foundations of storage tanks. They should prevent light from entering the tank using opaque materials, gaskets, and/or caulking as needed as light promotes algae growth. When possible, position tanks away from direct sunlight to promote cooler water temperatures. Additionally, some components may be more susceptible to UV degradation from sunlight, rain, and temperature. Plan the location of the storage tank on the site appropriately.

Belowground Tanks

Typical Materials for Belowground Tanks

The following is a list of typical materials for belowground storage tanks.

Plastic tanks (Polypropylene, Polyethylene)

Modular cube-type frames.

Fiberglass and Reinforced plastic (RFP)

Metal (Coated steel, Galvanized and Aluminized steel)

Concrete (Cast-in-place, Precast one-piece, Precast modular)

Modular "cube" frames similar to plastic counterparts

Recommendations for Belowground Storage

Potential conflicts for interactions between subsurface utilities and conveyance piping must be assessed early in the design process to prevent costly consequences. Follow all manufacturers' recommendations regarding installation, foundation design, water table issues, buoyancy anchoring, and backfilling. Consider and address the implications to activities and structures that might be above an underground tank's location. Protect the storage and conveyance piping from contamination and runoff during construction and implement a rigorous maintenance plan upon completion of installation.

Figure 4.26 Care must be taken during construction to prevent introduction of mud and debris into tank. Note that this inlet pipe is temporarily covered during construction. (*Eddie Van Giesen*)

Factors to Consider

Storage will vary in size and can be aboveground, belowground, outside, or inside the building envelope. Materials differ in appearance and application. Numerous factors from the building program and site influence the most appropriate size, type, materials, and location of a tank or cistern.

Factors Affecting Size of Tank

There are many factors that can affect the size of a tank. These include:

- Water supply: The water demand the system is expected to supply
- Aesthetics
- Smaller tanks connected in series may be preferred to reduce the scale of the tanks in relation to other architectural features
- Large tanks may intentionally exceed the necessary capacity so that the tanks become a landmark for advertising
- Other uses: If rainwater harvesting is part of a stormwater management strategy or BMP, the size of tank is determined by water demand *and* stormwater management needs.

Factors Affecting Type of Tank

The factors that can affect the type of tank include:

- Cost: Belowground tanks typically have higher costs, but site conditions may dictate this choice. Tanks as part of a building's structure may be the only option on small sites. There are "sweet spots" in pricing (cost per gallon of storage) in all types of tanks. Compare prices of different types of tanks to discover economies of scale.
- Connections: Required connectivity to various conveyances and distribution routes may be more readily achieved using certain types of tanks.
- Aesthetics: The "look" of a certain type of tank may be desired in a given location (i.e., industrial look of corrugated steel). In contrast, the desired aesthetics for a project may involve hiding tanks with screens consistent with the building's architecture.
- Location: Physical ability to construct or install a type of tank may guide the choice. The site may present constraints to using a tank that requires confined space entry.

Figure 4.27 Wood cladding transforms a utilitarian plastic tank into an attractive fountain feature. (*Vivian Van Giesen*)

- Function: Whether a tank is providing water for a building's end uses or is serving as a BMP for stormwater management may determine the type of tank used.

Factors Affecting Materials of Tank

The factors that can affect the materials of a tank include:

- Cost: Tank price, shipping, and installation
- Aesthetics: Hidden or highlighted; subtle appearance or use in "conservation education, use in marketing and advertising
- Site conditions: Access for installation and/or assembly, elevation (grade constraints), special air or soil type considerations
- Weight constraints: Shipping and ability to install in the available space

Factors Affecting Location of Tanks

The factors that can affect the location of a tank are:

- The portion of roof (collection area) that will be providing rainwater supply
- The space requirements for the size of tank needed; availability of exterior space
- Elevation (grade) and its effect on conveyance strategies to the tank location
- The relationship of end-use location to storage location
- Temperature considerations (i.e., cold weather use; freezing considerations)
- Aesthetics: Hide or highlight the tank; make an environment statement or advertise or conceal?
- Site constraints, including conflicts with utilities, future expansion plans, and so forth

These factors should demonstrate that early planning is essential for the design and implementation of a successful rainwater collection system.

5. DISTRIBUTION

Distribution is the element responsible for delivering water with the appropriate quality and pressure. All the components in distribution must be chosen carefully for compatibility and application. Distribution is affected by factors such as location of the tank, location of the control station, and the water supply expected from the rainwater system.

Typical components of *Distribution* include:

1. **Pressurization:** A pump provides pressurization on the downstream side of storage. For belowground tanks a submersible pump in the tank is the preferred type of pump. With careful planning, a suction-lift pump may be used in some applications. When choosing aboveground tanks, a flooded-suction pump located outside of the tank is recommended. The design of the system must prevent air from entering the piping, thus damaging the impellers.
2. **Filtration:** The main post-storage filter types used in rainwater harvesting systems are fine-mesh screen filters, bag filters, cartridge filters, and membrane filters. The purpose is to remove particles in the water including silts, clays, organic particles, microorganisms, and various compounds that may have formed in storage.
    - Removing these contaminants is important due their possible negative effects

TYPICAL COMPONENTS OF DISTRIBUTION

Key for Typical Components of Distribution:

1. Pressurization
2. Filtration
3. Disinfection
4. Controller
5. Automatic Protected Bypass
6. Makeup Supply

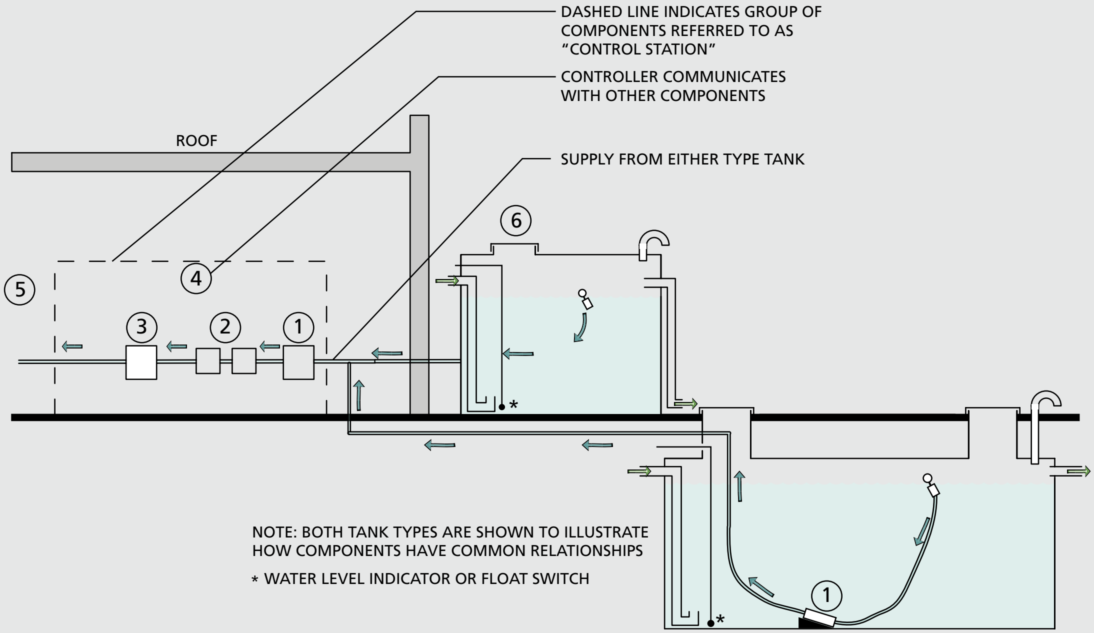


Figure 4.28 Typical components of Distribution. Distribution includes components that link the pre-filtered water from storage to pressure, filtration, disinfection and to end use. (*Fred Smotherman*)

on human health and/or equipment and materials in the system. It is also *very* important to remove the particulates so they do not cast shadows on microorganisms that are targeted in UV disinfection, as full exposure to UV light is necessary to disinfect the stored water.

- Filters must be chosen that are appropriate for removing unwanted contaminants. The micron rating (smallest particle size filter) must be considered, as well as the location and arrangement of filters for ease of maintenance and replacement. Consideration of pre-storage filtration practices will lessen expenses and maintenance problems in both the storage tank and post-storage filtration. At least two filters of decreasing micron size are recommended to be placed in series before disinfection.

3. **Disinfection:** Further improvement of water quality is provided through disinfection techniques. Disinfection is primarily achieved by the following methods:
    - Exposure to UV light: Water flows in a sealed chamber containing UV light bulbs. The UV light disinfects the water by applying a certain light intensity over a period of time.
    - Exposure to chlorine: Chlorine is introduced to the water and kills microorganisms. The water maintains a residual amount of the chemical that helps to maintain water quality in the distribution system.
    - Exposure to ozone: Ozone is injected into the water for disinfection.
4. **Controller:** Multiple relationships between various components on the pressure side of storage must be managed in an operating rainwater system. Simpler systems may employ a control station that only has on/off pressure switches, motor starters, and float switches. Larger systems usually have more complex equipment and higher performance expectations. To manage more information, these systems require setups that are more sophisticated.

    A program controller monitors and manages various functions such as:

    - Water level in tank (supply)
    - Demand from end use
    - Backup/makeup supply
    - Pressure differentials on filters that might indicate maintenance is needed
    - Other maintenance data points
    - Data received from smaller controllers in other components that will influence decisions by the main controller
    - Weather data input related to stormwater management
    - Various usage data
    - Real-time data to be displayed for educational purposes

Careful planning will identify data points required for operations and observations within the system.

In this project a preassemble control station contains the distribution components. A cabinet provides protection from tampering and it is aesthetically pleasing.

A preassembled control station contains the distribution components. The "control station" components are normally recommended preassembled by the rainwater system provider and mounted in a cabinet. Another approach is to combine pump, filter(s), disinfection unit, and controller in a convenient grouping and mount on a frame or skid. Most of the components on the post-storage side of the system are under pressure, and therefore their interactions are more complex than the gravity-fed interactions on the upstream side of storage.

The importance of the control station is that as a *discrete entity*, it is not a random

Figure 4.29a Control station closed. (*Eddie Van Giesen*)

Figure 4.29b Control station open. (*Eddie Van Giesen*)

arrangement of parts. The components are not only chosen so that their functions are in line with the system goals; they are sized and configured in a harmonious arrangement that preserves the integrity of the water path in terms of (a) required pressure, and (b) required communications between components.

The advantages of a skid-mounted control station include:

- Allows for factory testing
- Improves shipping and installation
- Provides a single warranty
- Saves space in mechanical room
- Is convenient for maintenance

5. **Automatic Protected Bypass:** For all systems that use rainwater for critical uses in the building, an automatic bypass strategy must be employed. In the event of low cistern water levels or mechanical failure, a means of allowing water to flow from the backup source (usually the municipal cold water supply) to the end use is mandatory. This should happen seamlessly so that there is no interruption to the end use.

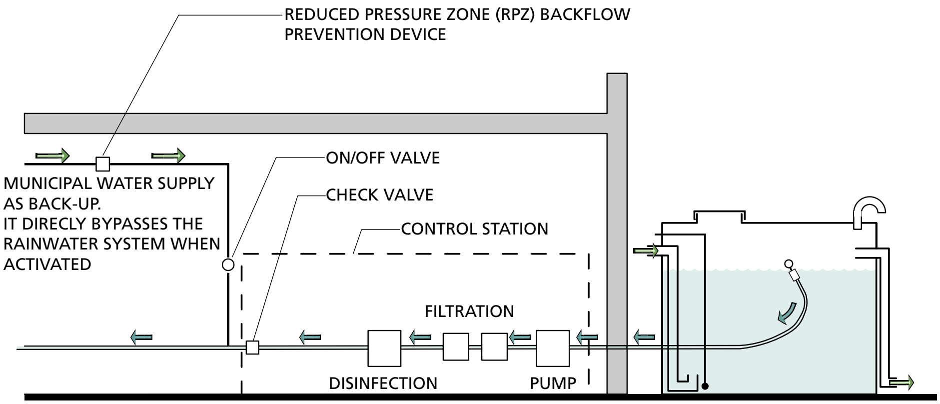


Figure 4.30 Automated Protected Direct Bypass to end use after disinfection. This configuration directly bypasses the entire rainwater harvesting system with protected municipal water. The inherent pressure and water quality of the municipal water is fully utilized. (*Fred Smotherman*)

There are a number of methods that can be used to accomplish this goal. *Solenoid valves*, *three-way valves*, and *nonelectrically controlled pressure valves* are examples of how this is accomplished. In essence, the alternate water feed must be controlled by some intelligence concerning the water levels in the main tank or work on the principal of pressure.

One of the other benefits of having a direct bypass is that it takes advantage of the embedded energy in the municipal water supply as opposed to requiring the municipal water to be released back to atmosphere and then more energy must be consumed in order to repressurize the water again. This is very energy-intensive and can be avoided when the bypass water is directly connected to the outgoing water supply downstream of an approved backflow prevention device. Additionally, these types of bypass systems reduce the need for duplicate booster pumps for redundancy, which can provide significant cost savings for the owner. Most plumbing codes allow for this type of protected connection but ultimately the authority having jurisdiction will have the final say.

In the event that the automatic measures fail to operate as planned and the owner desires the system to operate regardless, a manual bypass must be designed so that, with the turn of a valve or two, flow can be restored to the end use. Keep in mind that this manual setup only bypasses the control portion of the mechanism and not around the backflow preventer. *The backflow preventer must never be circumvented,* as it is the device that protects the municipal water supply from the intrusion of nonpotable water.

6. **Makeup Supply:** Although this may sound redundant, the term “makeup supply” implies the refilling of a tank or vessel. There are basically two ways of supplying makeup water to the rainwater system.

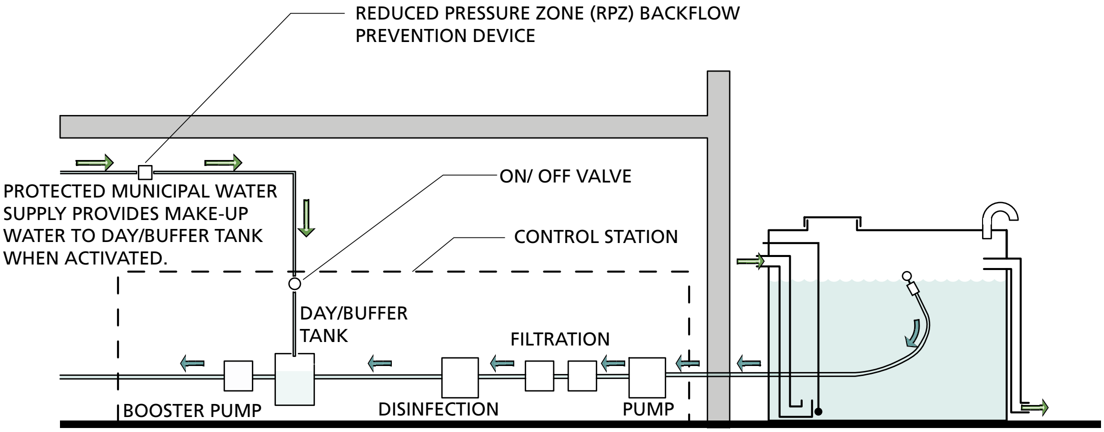


Figure 4.31 Make-up supply to main tank with air-gap protection. In this configuration, make-up water flows from municipal supply to main tank. Air gap provides backflow protection to municipal supply. The inherent energy (pressure) and water quality of the municipal water are lost due to the mixing with untreated rainwater in a non-pressurized tank. (*Fred Smotherman*)

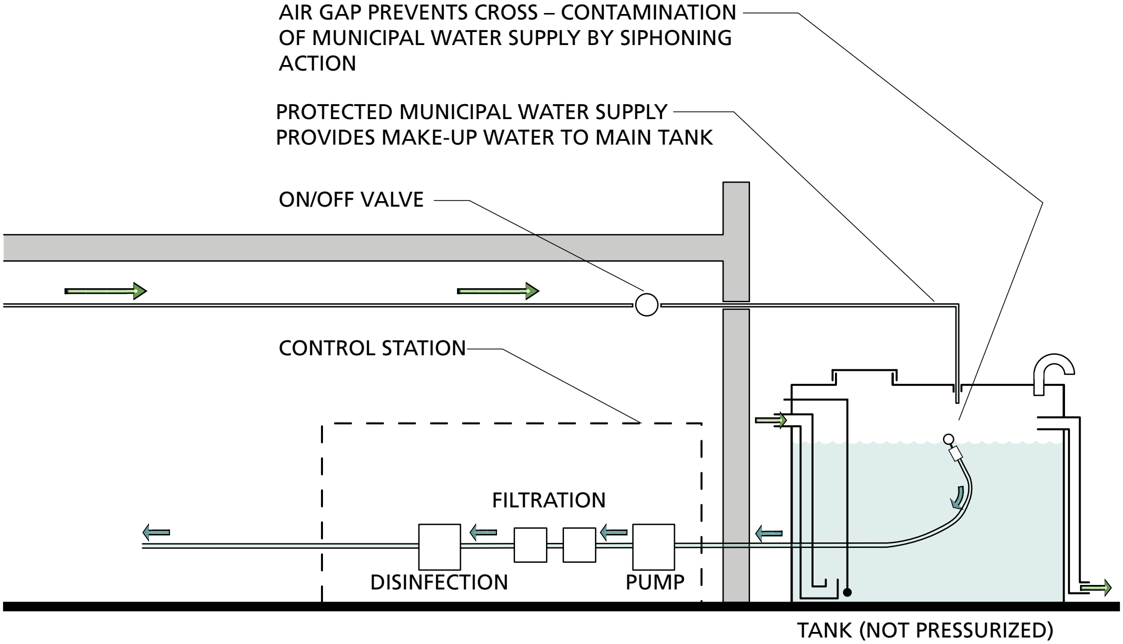


Figure 4.32 Make-up supply to day/ buffer tank with air-gap protection. Municipal supply provides make-up water to day/buffer tank with air-gap protection. Quality of make-up water is not compromised since day/buffer tank stores water treated suitable for end use. A booster pump is required since the inherent pressure of the municipal water is lost flowing through the air gap. (*Fred Smotherman*)

Either the municipally supplied makeup water is directed to the main storage tank or it is directed to a buffer tank. Generally, supplying municipal water to the main storage tank is a strategy used on smaller residential systems. Trickle top–type fill valves can top up the system when water levels are low. This type of system is commonly found in Australia and New Zealand.

The other method is to supply the municipal water to the buffer/day tank. A buffer/day tank is a tank smaller than the main storage tank, which holds a particular quantity of water. It can also serve as a vessel for receiving makeup municipal supply for the system.

In either instance, the makeup water (potable) supply is protected via an air gap. An air gap keeps the water in the tank from siphoning back into the potable water supply in a potential backflow situation. This is because the overflow on the tank or buffer tank is below the pipe supplying the makeup water to the system. In some jurisdictions, this method of protecting the municipal water supply is the only approved method.

Keep in mind that systems employing a makeup water supply in the described manner are at the mercy of booster pumps. When these booster pumps fail, the system is out of commission until the pumps are repaired. This is why so many engineers design redundancy (duplicate or triplicate pumps) into systems that use makeup supply strategies.

INTEGRATION, THOUGHTFUL PLANNING, AND CONTINUING EDUCATION ARE THE KEYS TO SUCCESS

Integrating a rainwater system into the overall building and site design is more effectively accomplished when included in the initial design and construction phase. A rainwater system requires multidisciplinary thinking. Designing and implementing a system will involve many disciplines including civil, architectural, structural, mechanical, plumbing, electrical, controls/building automation, as well as others.

A rainwater harvesting system is composed of integrated elements that work together to deliver water of a particular quality to the end use. It is vital to understand each element, the various components that comprise each element, and their functions. To summarize, these fundamental elements are:

- **Collection/catchment surface**: The roof is the primary collection surface. Various surface shapes and materials affect the quantity and quality of rainwater that can be collected. Various environmental factors affect the quality as well, and dictate filtration strategies downstream.
- **Conveyance**: The rainwater is collected and moved from the roof surface to storage. Gutters, downspouts, and various piping strategies are the primary ways that the rainwater is conveyed to storage.
- **Prefiltration/debris exclusion:** During conveyance, the rainwater is prefiltered to remove contaminants prior to storage. The type of prefiltration is selected to ensure maximum efficacy in the removal of targeted contaminants and debris.
- **Storage:** On most projects the storage vessel will be the costliest part of a rainwater system. The rainwater supply and demand will impact the size, type, and location of the tank. Depending on the project, the designer may disguise or celebrate the rainwater tank.
- **Distribution:** The rainwater is pressurized, filtered, and treated/ and/or disinfected to meet requirements for the end use.

Professionals in various disciplines who are actively involved in rainwater harvesting organized the not-for-profit American Rainwater Catchment Systems Association (ARCSA) in 1994. This organization has taken the lead in communicating to rainwater professionals and others by providing educational programs and working with allied organizations to advance rainwater harvesting standards. It is an ongoing source of information on the development of the latest components for rainwater collection.

System design and components will vary with each type of project. The relatively new field of rainwater harvesting will need professionals who continue their education and knowledge of new policy, procedures, and technology. There are many opportunities for the use of rainwater in an integrated rainwater harvesting system, particularly when the design professional understands the process of water treatment and maintenance.

The principles contained in this chapter provide an outline that is applicable for rainwater systems of any scale. The designer will gain invaluable knowledge by studying existing systems, staying abreast of rainwater product offerings, and consulting with rainwater harvesting system experts.

ARCSA

Provided by Heather Kinkade, FASLA, LEED® AP BD+C

Executive Director of The American Rainwater Catchment Systems Association

The not-for-profit American Rainwater Catchment Systems Association (ARCSA) has taken the lead in the U.S. in bringing water catchment information to water professionals and other interested parties by organizing and conducting trainings, workshops, and conferences that broaden the safe and effective use of water catchment strategies. To help address increasingly urgent water resource challenges, ARCSA is expanding its range of educational and training services, technical focus areas, facilitation efforts, advisory functions, and its communications network to provide assistance to a much larger audience.

ARCSA's target audience is a broad cross-section of people and organizations who are interested in finding appropriate solutions to water resource challenges and being actively involved in implementing needed solutions. ARCSA is expanding its operations to provide important services to help people increase well designed water catchment efforts at ever larger scales to address pressing needs.

ARCSA's expanded target audience includes:

- Water resource managers
- Stormwater managers
- High-water use industries
- Agricultural operations and those who support them

- Householders, multifamily site managers, and commercial sites
- Managers
- Technical experts working with water system design, equipment manufacturing, and site maintenance
- Architects, engineers, site designers, and landscape designers
- Transportation designers and managers
- Local, regional, and state jurisdictions
- Government agencies and regulatory bodies
- Political decision makers addressing water problems
- Nonprofit organizations focused on water, sustainability, and the environment
- Educational institutions at all levels
- All of us, as water consumers

ARCSA envisions a world where every person knows how to harvest, maintain, and beneficially use rainwater and stormwater through the use of a range of safe and effective rainwater catchment strategies. ARCSA's goal is to provide the resources, expertise, education and training, and facilitation needed to enable sustainable water catchment practices to help solve potable water, nonpotable water, rainwater, stormwater and energy challenges throughout the world.

ENDNOTES

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2. Elkin, Lawrence, PE, CCT; Ulmer, Lauren E., AIA, CCCA LEED® AP, and Polk, L. Edward, RRC, RRO. Rethinking Gutter Design for Steep-Sloped Roofing, Interface January 2013, www.rci-online.org/interface/2013–1-elkin-ulmer-polk.pdf.

CHAPTER 5

Maintenance and Safety

"When you are looking at setting standards for water quality you need to think about two things. Obviously the major thing is to protect the health and safety of the end user. So you want to have minimum criteria for various indicators to protect public health and safety. So you look at things like fecal coliform levels in the water, BOD (biochemical oxygen demand), TSS (total suspended solids). These are all things that are very important to prevent people from getting sick. You want to take care of their microbiological aspects; however, there is another important aspect that is of course subordinate to the first concern, but nonetheless is significant. You need to take in to account the reactivity and the quality of the water so as to protect the end use device. . . . It is incumbent on us to get it right."[1]

—Shawn Martin, Director of Plumbing, Mechanical and Gas (PMG) activities in the Government Relations Group, Plumbing and Mechanical Code Developer for the International Code Council (ICC).

WATER QUALITY OF A RAINWATER SYSTEM

Both the environment in which a given system is located and the materials used to construct it affect the quality of harvested rainwater. As a result, it is imperative that designers and users of rainwater harvesting systems understand the potential contaminants associated with their use, as well as the impact of these contaminants and their interaction with each other and their environment. These interactions will often dictate the necessary design, treatment, and maintenance protocols to ensure harvested rainwater does not present a safety hazard to users and/or problems for the end-use equipment. The typical types of pollutants found in the environment that might become part of a stormwater or rainwater collection system include:

- *Gross pollutants* that are mobilized by roof runoff, such as litter, plant debris, and floatable materials. Gross pollutants often harbor other pollutants such as heavy metals, pesticides, and bacteria. They also pose their own environmental consequences such as wildlife habitat degradation, water quality deterioration, reduction in the aesthetic quality of waterways, and threat to wildlife safety via strangling and choking. The predominant type of gross pollutants commonly found in rainwater collection systems is plant debris that is deposited on contributing rooftops.
- *Sediment* is a common component of stormwater runoff that degrades aquatic habitat. It is detrimental to aquatic life by interfering with photosynthesis, respiration, growth, reproduction, and oxygen exchange. In some areas, such as the State of North Carolina, sediment is the largest contributor of pollution in surface waters.[2] Construction sites, roadways, rooftops, and areas with exposed soil are major sources of sediment. Sediment is a vehicle for many other pollutants such as heavy metals and hydrocarbons. Because of this, sediment removal is a good practice for the reduction of a broader range of pollutants. Sediment concentrations leaving roof surfaces are relatively minor compared to those from parking lots, sidewalks, and roadways; however, even these low concentrations can be problematic for some designated uses of systems.[3]
- *Oil and grease* include a wide range of organic compounds, some of which are derived from animal and vegetable products, others from petroleum products. Sources of oil and grease include leaks and breaks in mechanical systems, spills, restaurant waste, waste oil disposal, and the cleaning and maintenance of vehicles and mechanical equipment. Oil and grease are generally not constituents of concern for rainwater collection systems when collecting runoff from roof surfaces.
- *Nutrients* like nitrogen and phosphorous are often found in roof runoff due to atmospheric deposition of particulate matter that is generated by automobile emissions, industrial processes, and fertilizer applications. In water bodies, these nutrients can promote excessive and accelerated growth of aquatic vegetation, such as algae, resulting in low-dissolved oxygen due to eutrophication. Nitrogen and phosphorus concentrations in harvested rainwater are not usually a concern for rainwater harvesting systems. In fact, some users see their presence as a benefit when using the stored water for irrigation, as it provides more nutrients for plants than municipal water would.
- *Pesticides* (herbicides, fungicides, rodenticides, and insecticides) are often detected in runoff at toxic levels, even when they have been applied in accordance with label instructions. As pesticide use has increased, so have concerns about their

adverse effects on the environment and human health. Accumulation of these compounds in simple aquatic organisms, such as plankton, provides an avenue for bio-magnification through the food web, potentially resulting in elevated levels of toxins in organisms that feed on them, such as fish and birds. The aerial application of pesticides can lead to elevated concentrations within roof runoff and harvested rainwater.

- *Organics* can be found in stormwater runoff in low concentrations and include synthetic compounds associated with adhesives, cleaners, sealants, and solvents associated with various roofing systems. These chemicals are widely used and are often stored and disposed of improperly. However, they are typically not a concern with respect to rainwater harvesting systems due to low concentrations.
- *Bacteria* can enter runoff via sources such as animal excrement, decay of organic materials, and combined sewer discharges. When directed to surface water bodies, stormwater runoff containing high levels of bacteria can lead to beach closures and fishing advisories. Bacteria in harvested rainwater are often due to the presence of fecal matter on rooftops and in gutters. The presence of overhanging vegetation and notable animal activity (birds and squirrels, for example) on a rooftop indicate a higher possibility of significant bacterial concentrations within a rainwater collection system. So long as this water is not used for potable purposes, this is not a reason for great concern; however, if stored water is to be used for potable uses, it must be treated and disinfected to eliminate associated health risks.
- *Dissolved metals,* including lead, zinc, cadmium, copper, chromium, and nickel, are mobilized by runoff when it runs off of surfaces such as galvanized metal, paint, automobiles, and preserved wood, whose surfaces corrode, flake, dissolve, decay, or leach. Metals are toxic to aquatic organisms, can bio-accumulate in fish and other animals, and have the potential to contaminate drinking water supplies. Exposed metal on rooftops, in gutters, or in delivery piping for rainwater harvesting systems can leach metals into the stored rainwater. To prevent this, any exposed metal (such as roof flashing) should be coated or painted. However, most gutters and downspouts are factory coated. When delivery piping is comprised of metal, such as copper or iron, this may result in elevated concentrations of metals in extracted rainwater.
- *PCBs and mercury* are legacy contaminants that are typically found in low concentrations in soils associated with historically industrialized areas. Polychlorinated biphenyls (PCBs) and mercury can be controlled through design measures that limit the mobilization of these pollutants in contaminated soils. Some roofing materials may contain these constituents. These may be absorbed by water as it runs off the roof surface; however, there is currently no indication that concentrations are high enough to be a concern when designing rainwater harvesting systems.

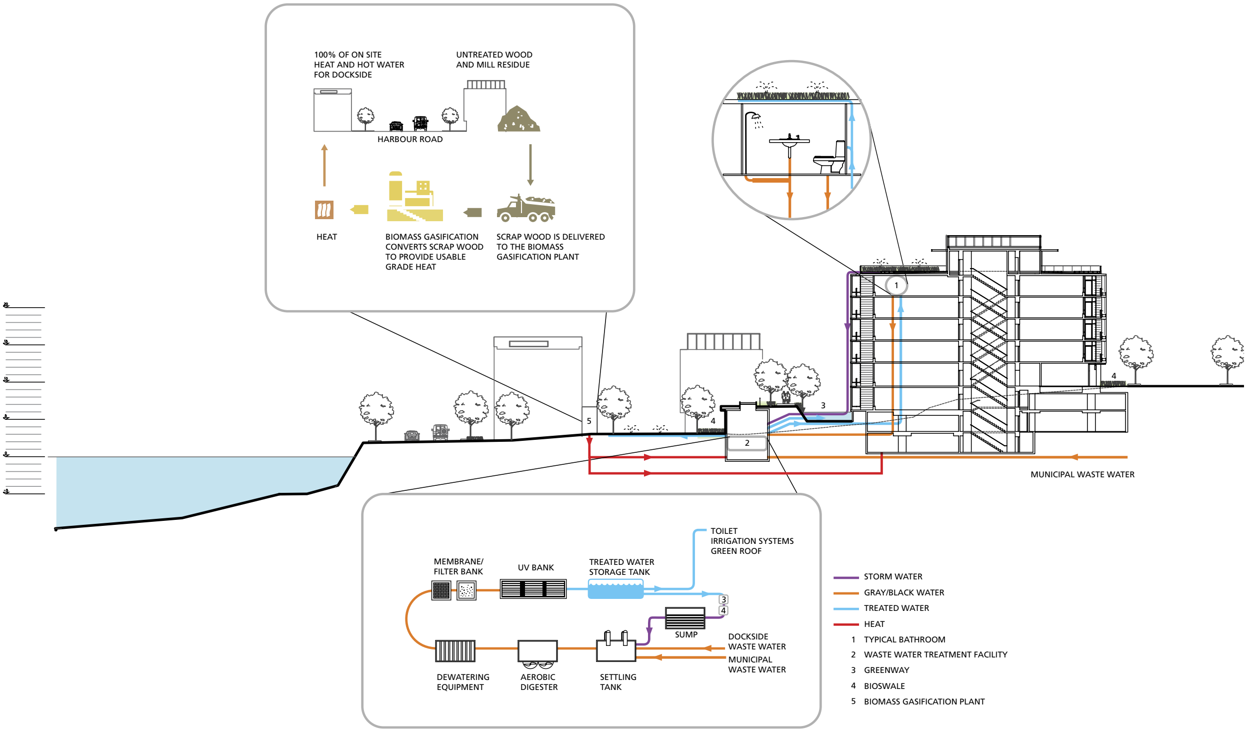


Figure 5.1 Complete rainwater harvesting system at Dockside Green in Vancouver, BC. (*Perkins + Will*)

SOURCES OF POLLUTANTS

There are numerous sources of pollutants that can affect the quality of harvested rainwater. Potential sources include rain, atmospheric deposition, roofing materials, overhanging vegetation, fauna, residue from delivery and distribution piping, storage tank materials, and sediments that have accumulated within the storage tank.

The quality of the rainfall falling onto a given surface is a key factor influencing the quality of rainwater leaving the catchment surface. The chemical composition of rainwater is influenced by a multitude of factors, such as geographic location and influences, prevailing meteorological conditions, and anthropogenic activities (agriculture, industry, motor vehicle emissions, and the like) and thus varies greatly by location, season, and even storm type.[4]

As rain droplets descend through the atmosphere, they dissolve gases, absorb aerosols, and collect other suspended particulates such as dust and ash.[5] The composition of precipitation is influenced by the proximity and strength of emission sources, chemical reactions occurring in the atmosphere, and the scavenging mechanisms of moving air masses.[6]

Acid rain is perhaps the most well-known phenomenon that can be attributed to the scavenging of atmospheric particles by rainwater. When rainwater absorbs sulfur and nitrogen oxides from the atmosphere, the pH decreases and the rain becomes acidic. The presence of sulfur and nitrogen oxides can be attributed to fossil fuel combustion (specific sources include motor vehicle emissions, combustion in building heating systems, and industrial processes).

Consequently, acid rain is prominent in regions characterized by high vehicle traffic volumes, high-density residential development, and industry.[7] In some areas of the world the pH of rainwater can be as low as 5.25 due to atmospheric pollution and regional geography.[8]

Acid rain is not the only environmental concern resulting from atmospheric pollution. High concentrations of heavy metals and nutrients have also been found in rain. Samples of rain were collected prior to landing on any surface in Selangor, Malaysia, and contained average lead (Pb) concentrations four times greater than the WHO drinking water guideline (see Table 5.4) of 50 μg/l, purportedly due to motor vehicle exhaust emissions from a nearby highway.[9] Rain concentrations of copper (Cu) and zinc in East Texas, U.S., exceeded U.S. Environmental Protection Agency (USEPA) freshwater quality standards of 0.013 mg/l and 0.12 mg/l, respectively, due to industrial emissions from petroleum refining, petrochemical production, and forest products production.[10]

In highly urban Beijing, 85 percent of rain samples exceeded the country's surface water standard of 2 mg/l for total nitrogen (TN)[11] and results from a study in Armidale, Australia, showed higher rain suspended solids concentrations in areas with industrial emissions as well as higher nitrate concentrations when fertilizers were used nearby.[12]

Dry deposition, a process by which particulates in the atmosphere that are generated via automobile emissions, industrial processes, and fertilizer applications settle out and accumulate on surfaces, can be a contributor of nutrients, sediment, and heavy metals in rooftop runoff. Constituents that have been linked to atmospheric deposition include total suspended solids (TSS), lead (due to heavy traffic or industrial emissions), chloride (Cl) (due to application of de-icing salts in the winter), copper, nitrates (due to agricultural fertilizer applications), nitrites, zinc, aluminum, Fe, and Ca.[13] Dry deposition can also include

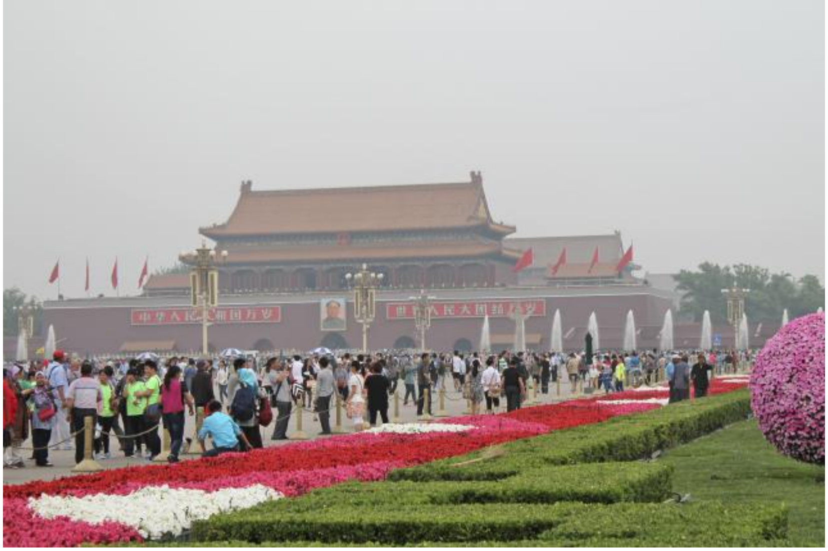


Figure 5.2 Atmospheric pollution and smog over Tiananmen Square during a heat wave, spring 2013, Beijing, China.

pollen, which can be a substantial nuisance with respect to rainwater harvesting systems.

Roofing materials can serve as a significant source of contaminants in roof runoff. Roof materials contribute dissolved and particulate matter to roof runoff due to weathering processes and chemical and physical reactions occurring between the rainwater and the materials.[14] Asphalt shingles can contribute substantial particulate matter to roof runoff via weathering processes. Figure 5.3 shows the accumulation of gravel in a gutter due to it washing off of the contributing roof surface.

Depending on the type of material, the pH of rainwater can either increase or decrease when it contacts a roof surface. As pH is a key factor in the chemical phases (e.g., dissolved versus adsorbed) of heavy metals, this has substantial implications for water quality.[15] Roofs comprised of uncoated metal (iron-zinc, aluminum, galvanized iron, zinc) or wood shingles have been shown to decrease the pH of rainwater (i.e., increase the acidity).[16] An increase in the acidity

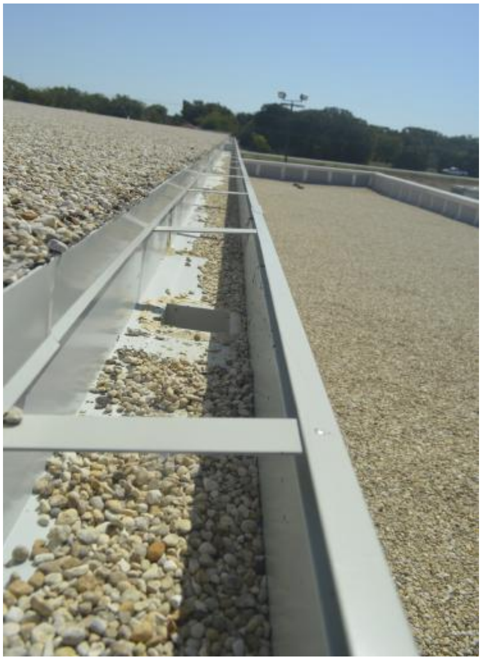


Figure 5.3 Accumulation of gravel in a commercial gutter and built-up gravel roof. (*Eddie Van Giesen*)

of water running over the roof surface increases the reactivity between the water and the roofing materials and particulates accumulated on the roof surface from atmospheric deposition, potentially causing leaching of chemicals and metals.[17] Contrarily, roofs comprised of alkaline materials such as concrete, gravel, asphalt shingles, clay, or pantile, instigate a significant increase in the pH of rainwater.[18] This increase in pH shifts the predominant phase for metals from dissolved to particulate, thereby facilitating precipitation and adsorption and the subsequent removal by filtration of these constituents from the water.[19] Dissolved contaminants are difficult to remove. Particulates can more easily be removed through filtration.

What Is pH?

pH measures the acidity or alkalinity of water on a scale of 0 to 14. pH values between 0 and 7 mean a solution is acidic, while values between 7 and 14 mean a solution is alkaline, or basic. Neutral pH values of freshwater, as shown in Figure 5.4, range from 5 to 7. Values outside of this range, such as those of acid rain, can result in the death of animal and plant life. Not only does the pH of rainwater affect biological communities, it also affects physical and chemical reactions that occur between water and pollutants. Water with lower pH values dissolves metals more easily, which can increase the concentration of heavy metals in runoff when it comes into contact with metal surfaces (metal roofing, metal storage tanks, and the like). When the pH of water is increased, its ability to "hold" dissolved metals decreases, and the metals precipitate, or "fall," out of the water. This results in decreased concentrations of dissolved metals within the water itself.

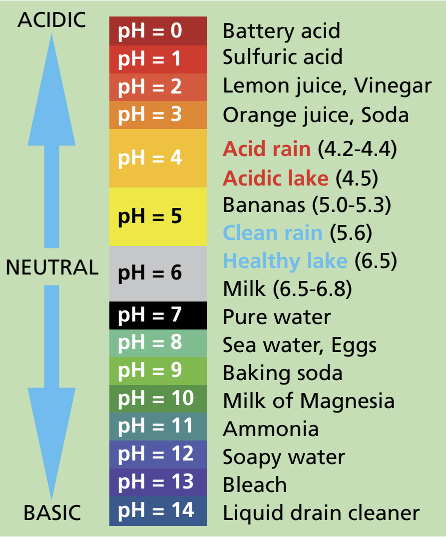


Figure 5.4 pH scale with examples of solutions with various pH values.[20]

As rain falls onto a roof surface, it washes off the particulates that have accumulated on the surface since the prior precipitation event, and adds these constituents to the roof runoff. A longer period without rainfall results in a greater amount of accumulated deposition and, thus, a higher concentration of pollutants in runoff during the next rainfall. Roof runoff also exhibits a "first flush" effect in which the majority of the matter collected on a roof surface is washed off during the beginning of a precipitation event.[21] This results in high initial concentrations of pollutants during the first 1 to 2 millimeters of runoff, followed by a rapid decrease in concentrations as rainfall continues.[22]

The type of roofing surface can have substantial impacts on roof runoff. Roofing surfaces such as asphalt shingles trap and retain particles and pollutants more so than smooth materials. When it rains, the trapped particulate matter is transferred to the runoff water and can have a detrimental effect on water quality.[23] As water runs over the surface of some materials (such as metal) it can dissolve some of the material, which then is added to the runoff. Thus, roofing materials that contain constituents prone to leaching, such as zinc or copper, must be accounted for when designing a rainwater collection system; although the presence of these dissolved metals may not adversely affect the use of rainwater for nonpotable applications.

In addition to the roofing materials proper, uncoated gutters can contribute significant amounts of heavy metals to roof runoff, especially zinc and aluminum.[24] For this reason, the interior and exterior of most commercial gutters are coated.

Distribution piping can be another significant contributor of contaminants within rainwater collection systems.[25] Talking with the manufacturers of system components regarding their fabrication methods can minimize the introduction of unwanted contaminants. In addition to piping, plumbing fixtures such as faucets, fittings, valves, pumps, and pressure tanks may be a direct source of metal loads to water during passage. Nickel plating and solder can increase nickel and lead concentrations, respectively, in water, especially in standing tap water. Aging galvanized iron piping can also contribute to elevated iron concentrations in tap water.[26] Given the possibility of substantial contributions of pollutants to harvested rainwater from pipes and fittings, plumbing materials should be carefully selected based on the hardness of rainwater in a given area to minimize the potential leaching of metals.[27]

Again, the focus of this book is on indoor, nonpotable uses of rainwater. Nonpotable applications, such as toilet flushing, with water that contains slightly elevated levels of the above mentioned contaminants, might pose no significant risks to either the health of the user(s) or the operation of the equipment. The design professional should keep this in mind when evaluating the potential for contamination within a rainwater collection system and assessing the treatment needed for certain designated uses.

FATE AND TRANSPORT OF POLLUTANTS IN A RAINWATER HARVESTING SYSTEM

After leaving the roof surface, rainwater enters the storage tank of the collection system. The storage tank provides an opportunity to improve water quality via increasing pH, the settling of sediment particles (sedimentation) that may have made their way through the prefiltration devices, and the precipitation of heavy metals. Sedimentation plays a primary role in the reduction of contaminant loads within the tank, as particulates settle out rather quickly once water enters the storage tank (though the long-term removal of sediment particles from stored water depends on quiescence being maintained within the tank). In addition to sedimentation, water quality improvement occurs via the settling-out of heavy metals, especially when the pH is neutral or alkaline. These treatment processes are most likely the cause of a generally better quality of stored water compared to roof runoff.

The storage tank material can substantially influence water quality. Storing rainwater

Figure 5.5 Contaminants building up on commercial roof.

in concrete or plaster tanks can increase the pH of the water, thus facilitating precipitation and removal of heavy metals.[28] Metal tanks can potentially leach metals into collected water, while plastic tanks may leach organic compounds if they are not manufactured to specific standards. Generally, tanks made from virgin resins have minimal leaching. When using metal tanks, it is highly recommended that a flexible waterproof (plastic, EPDM, or other material appropriate for the end use) waterproof liner be used to prevent the leaching of metals into stored water.

Despite the numerous opportunities for water quality improvement during storage, some studies have reported poor water quality in rainwater storage tanks. Long retention times (ranging from two or three weeks to several months) of stored water can be detrimental to water quality, especially if there is a large amount of organic matter being introduced into a system (such as pollen or leaf debris). The decomposition of this organic matter can deplete oxygen from water in the tank and result in an offensive odor and/or color to the harvested rainwater. This is one of the reasons that careful attention to prestorage filtration and tank venting is so important.

Figure 5.6 Sediments and organic matter accumulate on the bottom of rainwater storage tanks and can become a source of contamination. (*Kathy DeBusk*)

The precipitation and settling processes occurring within rainwater storage tanks in areas with heavy atmospheric pollution may lead to the accumulation of sediments in the bottom of the tanks. These sediments are often comprised of heavy metals such as copper, nickel, zinc, and lead.[29] Heavy metal contamination in sediments, although rare, can be severe enough to result in the sediments being classified as "contaminated" or "hazardous." In the United States, the Resources Conservation and Recovery Act (RCRA) regulates the management of solid wastes, including those that are deemed hazardous. Table 5.1 summarizes

Table 5.1 Concentration of Selected Contaminants That Results in a "Hazardous Waste" Classification (Values Reported in Mg/L for Use With the Toxicity Characteristics Leaching Procedure). For a full list of contaminants visit www.usepa.gov.[30]

Contaminant	Regulatory Level (mg/L)
Arsenic	5.0
Barium	100.0
Benzene	0.5
Cadmium	1.0
Chromium	5.0
Lead	5.0
Mercury	0.2
Selenium	1.0

the criteria for solid waste to be classified as hazardous waste. Once waste is characterized as hazardous, a plethora of requirements govern its transportation, storage, treatment, and disposal, including the cost and time associated with its handling.

Even if tank sediments do not meet the criteria of hazardous waste, their presence can degrade the quality of stored rainwater by releasing pollutants such as metals and chemicals. Removing sediments often to reduce their volume may help prevent or decrease contamination of extracted tank water, as well as prevent concentrations from reaching levels requiring specialized classification and disposal. Low pH levels (lower than 4.5) of stored rainwater can result in the release of heavy metals from these sediments. For systems located in regions prone to acid rain or receiving water from surfaces that tend to lower pH of runoff, choosing a tank made of alkaline materials (such as cement) can help raise the pH of stored water.

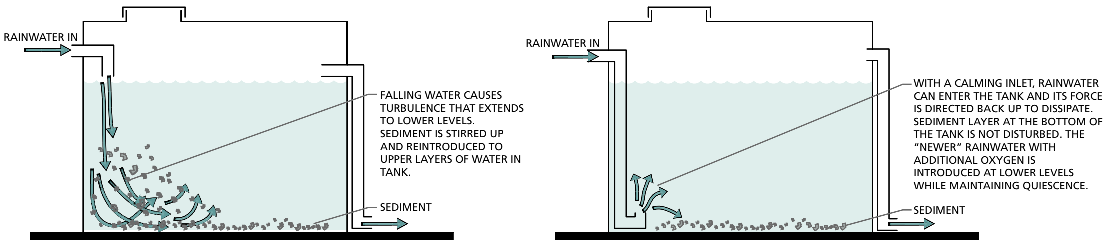
Capturing contaminants via sedimentation in the tank is important for two reasons.

1. Contaminants that otherwise wind up in receiving water bodies are now captured and removed from runoff, thereby contributing to stormwater management goals.
2. Contaminants are isolated within the tank and do not enter the post-storage filtration/treatment components ultimately removing them from end use.

There are several design options that may be used to minimize the introduction of these sediments to a storage tank or prevent their disturbance during rainfall events. One option used in smaller scale systems is to divert the dirtiest roof runoff away from a rainwater collection system thereby minimizing the introduction of particulate matter (after all, it is easier to keep them from getting into the tank than to remove them from the tank).

Positioning the tank inlet in the center of the tank, instead of adjacent to the wall, may also minimize the re-suspension of sediments that have already collected at the bottom of the tank.[31] More effectively, a "calming inlet" design (Figure 5.7) can be used in which the inlet pipe enters the storage tank and extends to the bottom of the tank where a U-shaped fitting then directs water flow upward into the tank. This calming inlet may be positioned anywhere in the tank and minimizes turbulence of the stored water, thus reducing the agitation of sediments that have collected on the bottom and the likelihood of releasing pollutants into the stored water.

As pesticides are often applied aerially in a diffuse manner, it is not surprising that their



By directing the force of flow upward, incoming rainwater does not agitate sediment on the bottom of the tank.

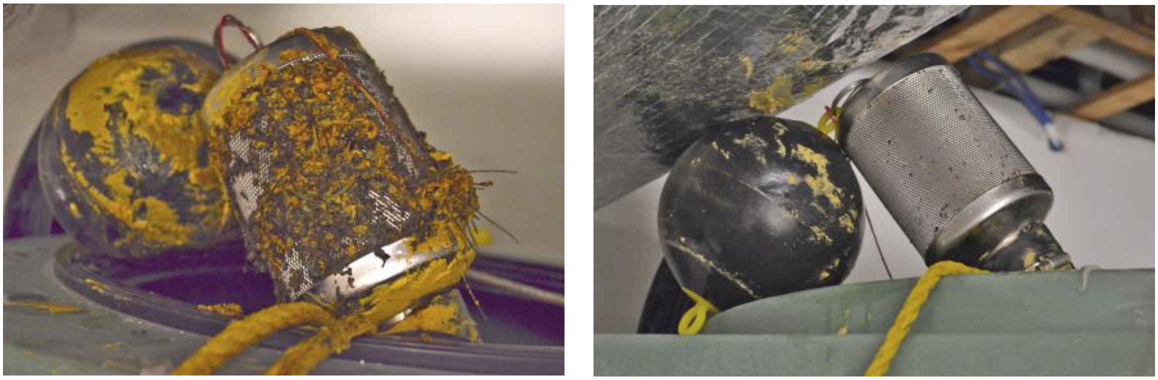
Figure 5.7 Purpose for Calming inlet.

presence is sometimes detected in roof runoff and stored rainwater. Physical transport of aerosol particles, volatilization into the atmosphere, and sometimes direct deposition onto roof surfaces can lead to rather substantial concentrations of pesticides, transformation products of the parent chemical, and other organic compounds in roof runoff.[32] The majority of compounds appear in rainwater or roof runoff during or immediately following their primary application period in spring or early summer. However, less volatile compounds can sometimes be detected weeks later.

Organic substances can make their way into rainwater and roof runoff as well and are often remnants of fossil fuel combustion or industrial processes. Rainwater harvesting systems in Dingxi County, China, contained over forty organic compounds originating from fuel leakage on roads and petrochemical and plastichemical industries.[33] Aliphatic hydrocarbons can often be found in harvested rainwater and originate from vehicle fuel leakage or the burning of oil and coal. Aromatic compounds and phosphate esters also appear in harvested rainwater and can be linked to crude oil, coal, coal tar pitch or creosote, and plastic film industries, respectively.

Pollen is more a nuisance than a hazard when it comes to rainwater harvesting systems. Despite the use of first-flush diverters and filters, pollen often makes its way into a system due to the fineness of the particles and the sheer abundance of pollen produced during the spring season. Systems with overhanging or nearby vegetation are likely to experience more problems with pollen than systems located away from vegetation. Natural byproducts associated with the decomposition of pollen can lead to offensive odors in the tank. Excessive pollen can clog pumps and treatment device filters and hinder movement of float switches.

It is often easier to reduce the entry of pollen into a system than to remove it once it is there. Many designers of small-scale residential systems suggest diverting roof runoff away from the rainwater harvesting system during the height of pollen season. This is particularly applicable where the collected rainwater is used for potable uses. Small cisterns should be emptied and cleaned in the event that pollen becomes problematic.



Figures 5.8a and b A floating extractor clogged with pollen after removal from the tank (a), and then later after cleaning and removing the pollen (b).

MICROBIAL CONTAMINATION

In addition to the various water quality constituents identified in the previous sections, a variety of microorganisms can be present throughout rainwater harvesting systems. These organisms range from indicator bacteria (such as enterococci, fecal coliform, and fecal streptococci) to pathogens (E-coli, Salmonella, Giardia, Cryptosporidium, and the like) and even viruses. While some of these organisms may be harmless, others warrant considerable concern with respect to human health.

A primary source of bacteria and pathogens in collected rainwater is fecal contamination from wildlife such as insects, birds, small mammals (bats, possums, squirrels, rats, and so forth), and small reptiles or amphibians (lizards, frogs) that is washed into the rainwater storage during rain events.[34] The presence of overhanging trees and significant animal activity on roof surfaces can greatly increase microbial concentrations within collected rainwater.[35] Animals that have been specifically linked to bacteria and pathogens (such as Campylobacter, Giardia, Cryptosporidium, Salmonella, and E-coli) in roof runoff include birds, possum, rats, hedgehogs, rabbits, ferrets, and mice.[36]

Microbial concentrations can vary based upon the contributing roof surface. Roofing materials with rougher textures (for example, asphalt shingle, wooden shingle) allow flora and organic matter to accumulate on the roof surface, which can harbor bacteria and pathogens. Metal roofs often produce roof runoff with lower microbial concentrations due to the smooth surface, relatively high temperatures at the roof surface, and the concentration of UV light on the metal.[37]

Conducting a visual assessment of a given rainwater collection system can provide a good indication of potential sources of microbial contamination. The following is a list of risk factors that increase the risk of contamination:

- Presence of fecal matter on roof surface or in gutters
- Plant debris, organic matter, or dust on the roof surface or in gutters

- Overhanging vegetation, presence of antennae or other perches for wildlife
- Manual extraction of water from the tank
- Defective access points in storage tank that allow for animals or insects to enter
- Nearby sources of pollution (brush fires, burning organic matter, agricultural operations)
- Chimneys or ash from fuel-burning stoves

To minimize the potential for microbial contamination, a system should be located such that overhanging vegetation is avoided or minimized, either through design modification or pruning. Other structures that would facilitate the perching of birds and other animals should also be avoided. Rainwater collection systems with inlet screens, tank covers, and other measures that prevent insects and animals from entering the storage tank have been shown to produce higher-quality water than those without.[38] The method of extraction and transport of harvested rainwater should minimize contamination. For example, the dipping of containers into a storage tank can introduce pathogens into a collection system and should be avoided if possible.

As with most pollutants, concentrations of bacteria and pathogens are notably higher in roof runoff during the first portion of a rain event (first flush). Thus, first-flush diversion on small-scale systems can be an effective method of reducing microbial contamination within a rainwater harvesting system, with a few caveats. This is described in greater detail in subsequent sections.

The amounts and sources of contaminants found in rainwater can seem overwhelming at first; however, it is vital to put all of this information into perspective. The issue with nonpotable applications is not so much the presence of contaminants in the water, but rather what the associated risks are to the end user(s). Microbial contaminants can be easily removed with appropriate treatment before using harvested rainwater, and dissolved solids and metals pose little threat to the end user for some applications (such as toilet flushing). Therefore, the presence of contaminants should not serve as a deterrent to harvesting and using rainwater; however, the designer should be aware of potential sources of contamination and ensure appropriate treatment is included in the system design. This topic is discussed in detail in the following sections.

> "There are a wide variety of public facilities that are flushing toilets with rainwater throughout the world under a variety of circumstances. As far as we can tell these facilities are not reporting any outbreaks that are likely associated with the water being used (rainwater). . .I feel very comfortable in saying that there is no significant [health] risk associated with flushing toilets with rainwater."
>
> Dennis Lye, Research Microbiologist, EPA Division: Microbiological and Chemical Exposure Assessment Research Division in interview with author in August 2013.

ADDRESSING WATER QUALITY FOR VARIOUS END USES

The potential of water quality contamination throughout a rainwater harvesting system necessitates the use of treatment options to produce water of suitable quality for potable and nonpotable uses. Potential treatment options for rainwater collection systems include both prestorage (debris screens and filters and first-flush diversion) and post-storage measures (post-storage filtration and disinfection).

First Flush

The first portion of a rainfall event produces the dirtiest runoff, as it washes off the material that has accumulated on a roof surface since the last rainfall. This dirtier portion of runoff is known as the first flush. Prestorage first-flush diversion can significantly improve the quality of collected rainwater and its inclusion in the design of a rainwater collection system should depend upon the size of the system. This technology can easily be incorporated into small-scale systems with a limited number of downspouts and a strict maintenance regime. Diverting the first flush can retard the buildup of particulates and sediments within storage tanks, prevent odor and aesthetic problems (e.g., coloration, visible organic matter), and improve overall water quality. It is also highly recommended as a method for decreasing the concentrations of pesticides and other organic compounds that enter the storage tank, as well as reducing concentrations of microorganisms.

Stan Abbott, Director of the Roof Water Harvesting Research Centre at Massey University in New Zealand, strongly recommends first-flush diversion in all smaller-scale applications, such as those serving families of four or five people. These applications typically have a limited number of downspouts, therefore requiring fewer first-flush devices. Additionally, it is more likely that the owners of a residence will follow the strict regular maintenance regime that first-flush devices demand. Abbott recognizes that larger commercial projects might be better served by other options of prestorage filtration. This is due to the impracticality of installing diverters on a large number of downspouts and following intense maintenance regimes that are required by these devices.

According to Lutz Johnen, Managing Director of Aquality Trading & Consulting Ltd., and a stakeholder in the development of rainwater codes in the United Kingdom and Europe, large-scale systems that do not include first-flush devices have been in service for years. These systems are providing rainwater for nonpotable water at acceptable qualities for the end use. The explanation for the success of these systems is the inclusion of high-quality prestorage filtration choices. However, it is important to realize that some contaminants and smaller debris may enter the tank even with the best prestorage filtration techniques. These successful systems have developed healthy biological and chemical activity within the storage tank, which is as important as prestorage filtration to achieve good water quality. Any shortcomings that might occur due to the lack of first-flush diversion are handled in pre- and post-storage filtration and treatment/disinfection processes that are used to achieve the desired water quality.

While the recommendation for including first-flush diversion is universal, the diversion volume recommendation varies greatly. The exact volume that can be considered of first-flush quality at any given time is dependent upon several factors, including the number of preceding dry days, amount and type of debris present on roof surface, season, and quality and type of roof surface.

Some examples of recommended first-flush amounts are: 40 L per 80 to 90 m^2 of rooftop, 200 L per 100 m^2 of rooftop, and 50 L per 100 m^2 of rooftop.[39] The American Rainwater Catchment Systems Association (ARCSA) recommends the diversion of the first 0.002 to 0.03 inches (0.05 mm to 0.75 mm) of rainfall.[40] In areas where there are frequent, low-intensity precipitation events, the lower end of these spectrums can be used. In some instances the use of first flush diversion may be impractical or unnecessary. Areas with less frequent, high-intensity rainfall patterns should use the upper end of these ranges.

Debris screens and filters can be used between the roof surface and the storage tank to prevent particulate matter (and contaminants adsorbed in particulate matter) from entering the tank. Debris filters should include a coarse filter to exclude leaves, pine needles, and other large debris, as well as a fine screen to exclude smaller particulates (such as asphalt shingle grit). Regardless of filter style (self-cleaning, basket-shaped), the following characteristics should be employed to maximize the effectiveness of debris screens:

- Filter should be easy to clean or largely self-cleaning
- Filter should not clog easily and clogging should be easy to detect and rectify
- Filters should be located at a position/height that is easy for system users to see and clean
- Filters should not provide an entrance for additional contamination (e.g., corrodible materials, openings large enough to allow animals to access the system, and so forth).

Particulate filtration (sediment filters, sand filtration, and other types of filters) can effectively remove particles and heavy metals and lower the turbidity of stored water. The

Figures 5.9a and b An example of a cascading type filter when dirty (a) and then after cleaning (b). (*Eddie Van Giesen*)

level of filtration needed for a particular system is often dictated by the requirements of equipment or a system's designated uses. For example, irrigation sprinkler heads will get clogged if water is not filtered to a certain level and large particles can damage moving parts of pumps. When using harvested rainwater for tasks such as vehicle washing, it is necessary to remove a sufficient amount of particles in the water to avoid damaging painted surfaces. The filtration level should also be appropriate for any subsequent treatment techniques. For example, if ultraviolet (UV) light treatment is being employed, particulate filtration to 5 microns is required, as particles larger than 5 microns may prevent the UV rays from disinfecting the water. Designers must be cognizant of water quality requirements for all post-storage treatment methods to ensure each device is performing as intended.

Figure 5.10a Inline filtration units are chosen for desired size of filtration screen as well as flow rate. (*Eddie Van Giesen*)

Figure 5.10b Water flow rates and intensity of UV light are matched to achieve disinfection. (*Eddie Van Giesen*)

Common disinfection methods include UV light, chlorine, and ozone. UV light can be used alone or in combination with other treatment options to disinfect harvested rainwater. A combination of sand filtration and UV light can be extremely effective in reducing bacteria concentrations in harvested rainwater.[41] This is also true for a 20-μm-particle filter/UV light treatment combination. Ozone may be used for disinfection as well. When designing an ozone system, one must ensure that it is an approved system for potable applications, the contact time between the water and ozone is sufficient for adequate disinfection, and that ozone gas is released to a safe environment.

Chlorination is an inexpensive and effective form of disinfection. Li et al [42] recommend concentrations of 0.4 to 0.5 mg/L free chlorine for proper disinfection. In addition, approximately 150 mL of bleach (assuming 4 percent active ingredient) can be added per 1 m^3 of storage tank volume to achieve a 0.5 mg/L residual after 30 minutes.[43] Chlorine levels up to 2 mg/L will effectively reduce microbial contamination, but regrowth may occur within 4 to 5 days; therefore, chlorine should be applied on a regular basis to maintain adequate disinfection. Local health authorities should be consulted when designing this aspect of the system to ensure compliance with applicable regulations.

Some parasites and protozoa have demonstrated resistance to chlorine, so filtration may need to accompany chlorination to ensure removal of all microorganisms. A drawback to using chlorine is the formation of undesirable and hazardous byproducts when the chlorine reacts with organic matter present in the storage tank. This can be avoided by applying chlorine after water is extracted from the tank, thereby reducing contact with organic matter.[44] Alternatively, chlorine dioxide or silver nitrate may be used in lieu of chlorine when byproduct formation is a significant concern. Some find the use of chlorine unacceptable due to taste and odor issues, in which case other forms of disinfection should be used.

The end use of a system often dictates the treatment options necessary to achieve a desired quality of water. Some water quality requirements for specific end uses are instigated by healthy and safety concerns, while others simply address aesthetic issues. Applicable regulations, cost, taste/odor preferences, and equipment requirements will also dictate which treatment options of those discussed herein are most appropriate for a given system.

New South Wales, Australia, has implemented a three-tiered classification system that assigns water quality criteria for recycled water based upon the exposure risk of various water uses. This type of criteria does not currently exist in the United States, but could be a valuable design tool when choosing the level/type of treatment for a rainwater collection system.

When used for potable applications, it is imperative that the harvested rainwater be treated appropriately to prevent human illness. Drinking water standards and guidelines are intended to ensure the water does not pose a short- or long-term threat to human health (Table 5.2). Some municipalities require harvested rainwater to be treated to near-potable water standards when brought into a house or building, even if it is not being used for potable applications; therefore, the local building code authority and the local health department should be consulted to determine whether or not a rainwater system is permissible in a given jurisdiction.

Table 5.2 Drinking Water Standards (DWS) and Guidelines (DWG) from Various Agencies

	WHO DWG[45]	**USEPA Primary DWS**[46]	**USEPA Secondary DWS**[47]	**Australian DWG**[48]	**EU Directive DW Guidelines**[49]
Aluminum	0.2 mg/L		0.5 to 0.2 mg/L	0.2 mg/L	0.2 mg/L
Arsenic	0.05 mg/L	0.01 mg/L		0.01 mg/L	0.01 mg/L
Boron	1.0 mg/L			4 mg/L	1.0 mg/L
Barium	1.0 mg/L	2 mg/L		2 mg/L	
Calcium	75 mg/L				
Cadmium	0.005 mg/L	0.005 mg/L		0.002 mg/L	0.005 mg/L
Chlorine	200 mg/L		250 mg/L	250 mg/L	250 mg/L
Chemical Oxygen Demand_{CR}	15 mg/L				
Color	15 mg Pt-Co/L		15 color units	15 HU	
Conductivity					2500 µS/cm
Chromium	0.05 mg/L	0.1 mg/L		0.05 mg/L	0.05 mg/L
Cryptosporidium		0			
Copper	0.05 mg/L	1.3 mg/L	1.0 mg/L	2 mg/L	2.0 mg/L
E-coli	0 per 100 mL	0	0 CFU per 100mL		
Fluorine	1.5 mg/L	4.0 mg/L	2.0 mg/L	1.5 mg/L	1.5 mg/L
Iron	0.3 mg/L		0.3 mg/L	0.3 mg/L	
Fecal Coliforms		0			
Giardia lamblia		0			
Hardness	500 mg $CaCO_3$/L			200 mg/L	
Mercury	0.001 mg/L	0.002 mg/L		0.001 mg/L	0.001 mg/L
Potassium	20 mg/L				
Legionella		0			
Magnesium	30 mg/L				
Manganese	0.3 mg/L		0.05 mg/L	0.5 mg/L	0.05 mg/L
Sodium	100 mg/L			180 mg/L	200 mg/L
Nickel	0.05 mg/L			0.02 mg/L	0.02 mg/L
Nitrate		10 mg/L		50 mg/L	50 mg/L
Lead	0.05 mg/L	0.015 mg/L		0.01 mg/L	0.01 mg/L
pH	6.5 to 8.5	6.5 to 8.5	6.5 to 8.5	6.5 to 8.5	6.5 to 9.5
Selenium	0.01 mg/L	0.05 mg/L		0.01 mg/L	0.01 mg/L
Sulfate	400 mg/L		250 mg/L	250 mg/L	250 mg/L
Total Dissolved Solids	500 mg/L		500 mg/L	600 mg/L	

	WHO DWG[45]	USEPA Primary DWS[46]	USEPA Secondary DWS[47]	Australian DWG[48]	EU Directive DW Guidelines[49]
Total Coliforms		0			
Total Nitrogen	10 mg/L	10 mg/L			
Total Phosphorus	n/a	n/a			
Total Thermotolerant Coliforms	0 per 100 mL				
Turbidity	5 NTU			5 NTU	
Viruses (enteric)		0			
Zinc			5 mg/L	3 mg/L	

Water Testing Protocols

The ARCSA/ASPE 63 Standard is a nationally recognized published standard specifically dedicated to rainwater harvesting. ARCSA is leading the drive to provide uniform standards for the safe implementation of rainwater harvesting or catchment systems.

> This Rainwater Catchment Design and Installation Standard (hereinafter referred to as the Standard) has been developed by a joint effort of the American Rainwater Catchment Systems Association (ARCSA) and the American Society of Plumbing Engineers (ASPE), with sponsorship support from the International Association of Plumbing and Mechanical Officials. The purpose of this Standard is to assist engineers, designers, plumbers, builders/developers, local government, and end users in safely implementing a 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 plumbing authority having jurisdiction regarding local conditions, requirements, and restrictions.
>
> —Draft Forward to the ARCSA/ ASPE 63 Standard[50]

Provisions for testing potable and nonpotable water are found in Section 3.9.2. Water Quality Maintenance of the ARCSA standard:

> "b. Non-potable water shall be tested every 12 months. Potable water shall be tested every three months."

This testing regimen is created so that the user can demonstrate that the resulting water from the installed rainwater system meets minimum water quality standards. The items of concern are the biological contaminants—bacteria, protozoan cysts, and viruses—and turbidity. Public health officials are concerned about human contact time and the associated health risks as a result of using nonpotable rainwater in the plumbing fixture. A manufacturer might be concerned about the degree of turbidity and the possible effects on the plumbing fixtures.

The ARCSA/ASPE 63 testing protocol is time-based; however, there are real concerns associated with this approach. Time-based protocols do not necessarily take into account the possibility that between testing times an inconsistent water quality (lower) may be produced. This is because an unsuspected overload of contaminants may enter the system and render the rainwater system ineffective in producing the previously obtainable results.

In contrast, a performance-based testing protocol, as an alternative, certifies that a given system can consistently produce water of a certain quality. This approach assures consistent desired results regardless of the time at which the test was conducted. Performance-based testing approaches are more likely to ensure that the rainwater system installed will produce the desired water quality consistently.

Plumbing manufacturers have a large stake in the quality of water supplied to fixtures. They are concerned that the presence of various contaminants and disinfectants might range beyond their design standards and negatively impact warranties. ICC code developer Shawn Martin believes that it is important to provide a system that protects people and provides the "maximum to protect the end-use device and avoid unintended consequences."[51]

Using a Bypass/Backup Water Supply

One of the more frequently asked questions regarding rainwater harvesting systems is how a system will be backed up in the event of low water levels in the main storage tank, the need for repairs, and/or mechanical failures. Outside of certain projects that involve LEED® credits (where only harvested rainwater can be used for certain functions), a method for backup supply (i.e., makeup supply or bypass) is often a necessary part of the system concept. Generally, where essential functions are being satisfied by rainwater, such as toilet flushing and cooling tower makeup, backup is a necessity. How this is best accomplished is worthy of considerable thought and planning.

When using municipal supply as a method of makeup or bypass, there is probably nothing more sensitive than the subject of possible cross-contamination. Water authority, plumbing, and building officials are charged with protecting the quality of municipal water supply. Anytime there is a "connection" to the municipal supply, the opportunity for the introduction of contaminated water is created.

Water, unlike electricity, flows in one direction when under pressure. Whenever the municipal water supplier pumps water into the distribution system, it will flow from high pressure to low pressure. So, when one opens the faucet, or when any plumbing device calls for water, water will flow in the direction of the demand. Since the water distribution is a closed system with water flowing in one direction, the only way that nonpotable water can enter this closed system is if there is a loss of pressure on the municipal water side (a break in a line, failure of pumps, and the like). This loss of pressure will cause the flow to go "back" toward the loss of pressure (backflow).

This flow is caused by siphonic action, and the water and plumbing officials are concerned that rainwater can enter back into the municipal system. Even if the rainwater system produces potable-quality water, the fact remains that the integrity of the municipal supply must be protected and maintained.

In other words, the rainwater must not mix with the public potable water supply. Consequently, it is common practice to establish individual, dedicated delivery lines for a rainwater system to prevent the possibility of cross-contamination with the municipal system. On the relatively rare occasion that cross-contamination does occur, the potable water supply can become contaminated and residents are advised to boil their water before drinking it.

When supplying bypass/backup water to a rainwater collection system, it is imperative that the design prevents backflow of rainwater into the potable water system.

Methods of Bypass/Backup

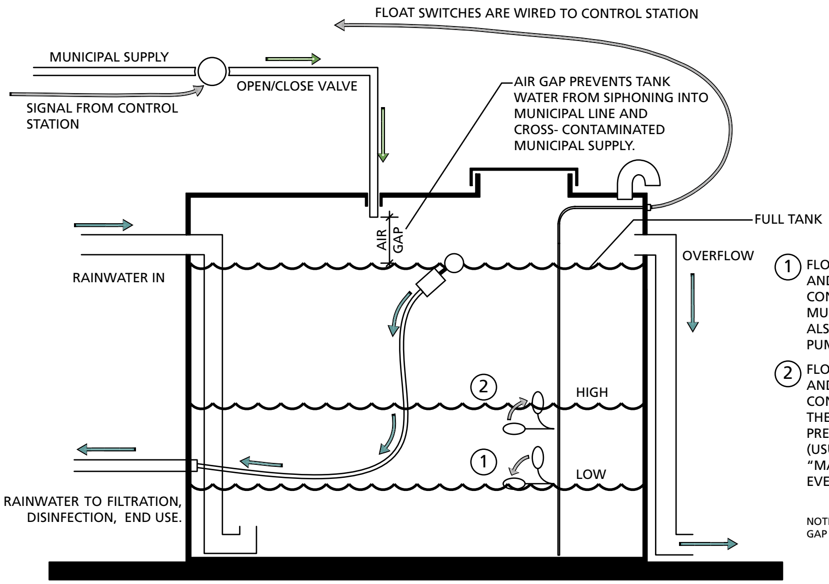
All of the following methods include systems with dedicated piping runs that have protected connections and do not allow for co-mingling of rainwater or alternative water with municipal water systems.

- Makeup water to storage tank via an air gap: In this method, municipal makeup water is added to the main storage tank.

  This method is frequently used with smaller residential and commercial systems and is a simple and straightforward method of supplying makeup water to the rainwater system. A float valve (similar to a toilet-flush filling valve) may be used to trigger the opening of a valve, which allows the addition of municipal water to a storage tank. This float valve is triggered when the tank water level reaches a certain low point (i.e., start trigger). Municipal water is added to the tank until a certain water level is reached, in which case the addition of water is ceased (i.e., stop trigger).

  When choosing the stop trigger, the designer must remember that a higher stop trigger will decrease the ability of the system to capture rainwater from the next rain event. Thus, adding only the minimal amount needed to meet daily designated uses will maximize rainwater capture and potable water replacement.

  Understanding the daily water uses of the building and the cycle of rainwater events is crucial to determining the optimum filling regime. A start trigger of 10 percent of the storage tank volume and a stop trigger of 20 percent of the storage tank volume is generally recommended. Of



① FLOAT-SWITCH FALLS TO LOW WATER LEVEL AND SIGNALS CONTROL STATION. THE CONTROL STATION THEN SIGNALS A VALVE ON MUNICIPAL SUPPLY MAKE-UP LINE TO OPEN. ALSO LOW LEVEL FLOAT CAN STOP POWER ON PUMP FOR DRY-RUN PROTECTION.

② FLOAT-SWITCH RISES TO HIGH WATER LEVEL AND SIGNALS CONTROL STATION. THE CONTROL STATION SIGNALS THE VALVE ON THE MUNICIPAL MAKE-UP LINE TO CLOSE. A PREDETERMINED VOLUME OF WATER, (USUALLY 1 DAY'S SUPPLY) HAS NOW BEEN "MADE UP" WHILE WAITING FOR NEXT RAIN EVENT.

NOTE: DETAILS OF FLOAT SWITCHES AND MAKE-UP/AIR GAP ARE SIMILAR FOR DAY TANK METHOD.

Figure 5.11 Typical make-up supply at tank with air-gap protection. Float valves are shown to illustrate a method of achieving optimum filling regime. (*Fred Smotherman*) course, this depends on the size of the tank. Every situation will undoubtedly be different and should be assessed individually.

Using an air gap prevents the introduction of rainwater into the municipal water line, so long as the pipe supplying municipal water is located above the tank overflow pipe. If the overflow pipe is not situated below the pipe that is introducing the municipal water into the tank, untreated rainwater could siphon out of the tank and backflow into the potable water line, thereby compromising the quality and safety of the public water supply. Some code officials may require a manufactured air gap device to reduce the chance of this occurring.

There is a disadvantage of adding makeup water to the main storage tank are twofold: Sending municipal water, which has already gone through disinfection, into a vessel which contains nonpotable water necessitates that the makeup water be treated and pressurized again before going to the end use.

- Makeup/break/day/buffer tank via air gap:

  One method of makeup is accomplished by sending municipal water into a day tank (also referred to as a break tank, makeup tank, or buffer tank). This tank is generally situated close to the rainwater collection system's pumping station and is smaller in capacity than the main storage tank. Similar in concept to the filling of the main storage tank, the municipal water line can be directed to the day tank as long as an air gap exists. This ensures that the municipal potable line cannot accidently intake nonpotable water in the event of a backflow situation.

- Direct bypass:

  Another method of supplying bypass water to a rainwater system is by a direct, protected connection of the potable water

Figure 5.12 Reduced pressure zone principle backflow preventer. (*Eddie Van Giesen*)

line and the nonpotable line. This occurs downstream of the entire rainwater harvesting system. The municipal potable supply is protected from cross-contamination by a backflow prevention device. There are many types of backflow prevention devices. Some of the simplest are swing check valves, which allow water to flow in only one direction. If the water attempts to flow in the opposite direction, the swing valve closes and the water is stopped. However, these valves can become compromised when debris may prevent the valve from completely closing.

The most reliable type of backflow prevention device is called the reduced pressure zone (RPZ) principle backflow preventer. These devices have a reduced pressure zone that will dump any water out to a drain rather than allowing it to flow backwards. They should be tested once a year to maintain efficacy and reliability. The advantage of these types of backflow preventers is that the municipal water can be supplied to the

Table 5.3 Maintenance Tasks and Recommended Frequency

Task	Description/Details	Frequency
Clean roof surface and gutters	Manually clean rooftops, gutters, and downspouts by hand, with hand tools, brooms, and rakes, pressurized air, or gas-powered blowers. If using water to flush rooftops, gutters, or downspouts, be sure to divert this debris-laden water away from the system. *Do not allow debris-laden water to flow into downspouts, filters, or the tank!* Inspect gutters for leaks and holes; repair as needed.	A minimum of once per month. For sites with overhanging vegetation after each significant rainfall event. This is especially important after leaf fall during the autumn season.
Inspect and clean debris filter(s) and first-flush diverter(s)	Disassemble, clean, and replace screens on all inlet filters as needed. Disassemble and clean as needed. Inspect all downspouts, clear any obstructions. Inspect all inlets and overflow pipe assemblies to ensure they are unobstructed and working properly. Check screens for holes/tears and repair as needed. Disassemble and clean as needed. Disassemble and clean the first-flush diverter; ensure the weep hole is open and unclogged.	After each significant rainfall event
Check all piping and valves for leaks; inspect all openings in storage tank	Check all piping and valves for cracks, holes, or leaks. Repair as needed. Inspect all openings in the storage tanks for leaks and gaps.	Annually
Clean/change pump filters and particle filtration filters/media	Clean/replace filters in inline pump filters and all particle filtration assemblies. Replace media in granulated carbon filters and/or sand filtration units.	Annually or as needed (follow manufacturer guidelines)
Check signs	Are all signs still in place and legible? Replace as needed.	Annually
Winterize the system	Ensure all exposed piping is adequately insulated. If decommissioning the system, empty all pipes of water, drain the storage tank and divert roof runoff away from the system. If possible, store the pump in an area protected from the weather.	Annually, prior to the winter season
Remove tank sediments	Remove sediments that have accumulated in the bottom of the tank. Be sure that all safety regulations are followed with respect to confined space entry. Dispose of sediment in the manner deemed appropriate by the local regulating authority.	Every 5 to 10 years, or as needed

end uses by using the existing water pressure from the city and not relying on local pumps. Additionally, this eliminates the need for duplicate or triplicate pumps for safety redundancy and local pumps can be repaired while the end uses are still being supplied with water. The result is huge cost savings for the owner in both pumping costs and initial capital costs for pumps.

Maintenance Considerations

The success and overall usefulness of the system will be largely determined by how a system is maintained. Downspout filters should be installed at a location easily seen and accessed by system users to facilitate frequent inspection and cleaning. Pump filters and treatment filters should be easily accessed and cleaned as well. Storage tanks should have access ways and drawdown valves to make tank cleaning and sediment removal easier. It is recommended to always isolate each tank within a system with a ball valve so that the tank may be taken "offline" for cleaning and maintenance without impacting the rest of the system.

Tasks that should be performed regularly include cleaning the catchment surface, gutters, and storage tank; cleaning filters, first-flush diverters, and debris screens; and inspecting the system for possible points of entry for mosquitoes and vermin. These tasks are described further in Table 5.3.

The importance of maintenance to the overall success of a rainwater collection system should be conveyed to property owners during the entire design process, from the initial design concepts to the installation. Design choices should be made to make maintenance as easy as possible to increase the likelihood that a system owner will follow proper maintenance protocols.

Establishing a maintenance contract between the owner and the system provider can reinforce the necessity of timely and thorough maintenance practices and protect the designer from system problems that arise due to lack of maintenance. Additionally, an owner's manual should accompany every rainwater collection system and should include detailed troubleshooting guidance, maintenance tasks and frequency, and replacement part component details.

CASE STUDIES—CAUTIONARY TALES AND PILOT PROJECTS FOR POTABLE WATER SYSTEMS

5 Seasons Brewery—A Cautionary Tale

Atlanta, Georgia

Owner and Chef Dave Larkworthy of 5 Seasons Brew Company is perplexed. His fine beer, brewed from purified rainwater, has been featured in news magazines, blogs, and even on CNN. RainHarvest Systems, located in Cummings, Georgia, provided the system and collaborated with the University of Georgia, who provided monitoring and testing for this unique application for rainwater collection. However, after two years of operation, despite complying with ANSI potable water standards for residential use and continued testing by the University of Georgia, the county pulled the plug on his beer tap.

The Fulton County inspectors were not engaged in the initial planning for the system and after learning of its existence on CNN decided that they were not comfortable with the safety and security of rainwater as a potable water source for beer making. Appeals to the EPA and other agencies were fruitless and Chef Dave is left with a very large decorative aboveground tank as a type of “sculptural ode” to rainwater beer making.

Rainwater beer was a huge success, as using pure rainwater left a sweetness and clarity to the brew. This environmentally savvy brewery also employed other sustainable practices, including water efficient fixtures and waterless urinals.

To meet the EPA standards for potable water, the filtered rainwater was designed to meet a pH of 7.8 and a hardness of 0.73 ppm. The six-stage filtration system filtered water to 5 microns, followed by a UV reactor to disinfect the water. The final product used in the beer process was colorless, odorless, and consistently tested for zero bacteria or microbial contamination. According to RainHarvest Systems, who supplied the system, “The system differs from a typical potable water system in that the processed rainwater is not tied into the building’s plumbing system. The processed rainwater is introduced to the brewery at a large tank where other ingredients are combined prior to the main brewing process.”[52]

The installed system consists of the following components:

- Preliminary leaf and debris filter
- 4-inch first-flush diverter
- Internal self-cleaning cascade filter for cisterns and tanks, suitable for roof areas up to 3,750 square feet
- Rainwater collection tank (an existing tank was upgraded to a larger size)
- 1-inch floating extractor
- ½-horsepower pump
- Pump controller
- Two 20-inch filter units (one 5-micron particle filter and one 1-micron absolute carbon block)
- UV pure dual-beam UV reactor

Test results from the University of Georgia are available at www.rainharvest.com/info/beer/#WaterTestResults. These tests demonstrated that the harvested rainwater tested at a higher quality than that from the Atlanta water system, which currently provides the process water for beer making at the pub.

Appealing to the EPA for clarification didn’t help resolve the regulatory log-jam. Although the EPA has standards for residential water use and both the EPA and the local county have testing regulations and standards for wells, they have not created a viable standard for the use of harvested rainwater for potable uses such as beer making due to concerns for public safety. Even though numerous commercial buildings located in rural areas draw water from wells that are only tested upon purchasing the property, the safety of rainwater is held as a more "suspect" source of water.

Chef Dave comments: "It is as if rainwater use is a form of witchcraft! It's all rainwater. This renewable resource has provided water for human consumption for thousands of years. Rain is the source for most drinking water, whether collected in streams, lakes, underground aquifers or tanks. Using well water for beer making is legal, but using rainwater is not. The different regulations are based on whether water is drawn from wells or treated and delivered to businesses by means of an aging piping system." By using pure rainwater that comes from his new roof and is treated, filtered, and tested, this system appears a safer, and also a tastier, alternative for his business.

Chef Dave is eager to bring this pure rainwater beer to Atlanta where they are still struggling with regulating this resource. He suggests that testing be consistent with well water standards and licenses for commercial use of well water. He also recommends that a system of regular testing be installed to assure that systems are well maintained and water quality is continuously monitored. If the EPA develops these recommendations, along with standard testing protocols, one of the advantages of new regulations will be that the sweetest beer in America will once again be brewed at the 5 Seasons Brewery.[53]

Moorhead Environmental Center: A Pilot Project

Avondale, Pennsylvania

Figure 5.13 Moorhead Environmental Center (*Dave B. Arscott*)

In the past few years, several research institutes have developed pilot projects that use rainwater harvesting. As an example, the Stroud Water Research Center is dedicated to the advancement of global knowledge and stewardship about freshwater systems through research and education. The Stroud Center is monitoring a pilot project at the Moorhead Environmental Center in Pennsylvania which incorporated rainwater harvesting in September 2012. Scientists at Stroud are collecting real-time data about the benefits and safety of rainwater harvesting.

The design goals for the Moorhead Environmental Center are clear: This project is to manage rainwater so that there was no runoff from the building into the nearby stream. In addition, this project is an active education center that provides research opportunities for scientists from Stroud Water Research Center. These scientists are examining water resiliency and how rainwater systems can provide stored and treated water for potable uses.

The client is currently seeking funding to test the water quality from the rainwater system over time to document the results that show that rainwater is a viable source for potable water. As part of this effort, architect Muscoe Martin, from M2 Architecture and Bernard Sweeney, Director of Stroud, were invited to present the project design to state and federal water officials, including the EPA.

The roof of the center is approximately 5,100 square feet and a 6,000-gallon cistern collects water that is used for flushing toilets, irrigation, and research. Scientists at Stroud are particularly interested in the comparison of the water quality of well water to rainwater. The building houses twenty-four full-time equivalent staff and an estimated seventy visitors throughout the week.

The system was designed and developed by multiple contractors. As a lesson learned, architect Muscoe Martin, AIA, commented that he "wished that there was a simpler approach to designing, specifying and installing these systems, such as a 'one-stop shop' that would assemble a system and ship to the site. Having to work with multiple design engineers and multiple construction subcontractors, makes it difficult to avoid some mistakes and errors."

SUMMARY OF DESIGN RECOMMENDATIONS

The findings and data discussed herein emphasize that harvested water quality is highly dependent upon design aspects of the collection system; design and composition of materials connected to the system (i.e., roofing materials, gutters, downspouts); local sources of pollution and contaminants; and geographic, meteorological, and environmental conditions of a given area. Appropriate selection of catchment and storage materials and the inclusion of pre- and post-storage treatment can improve the quality of harvested rainwater. Regardless of design and environmental conditions, good hygiene and maintenance of systems, including regular inspection of catchment areas and storage tanks, is essential in maintaining good water quality.

The following choices are important to ensure optimal quality of harvested rainwater. Water quality will be directly proportional to the number of these features employed within a system:

- A smooth roofing material with protective coating and with as little as possible reactivity to rainwater

- No lead flashing on roof surface or gutters if water is intended for potable applications
- Limit overhanging vegetation, antennae, or other structures that animals and birds could perch upon
- Plastic or coated downspouts
- Debris screens and excluders
- A first-flush diverter for each downspout for small-scale systems (typically residential systems)
- A concrete or plastic storage tank with a calming inlet design
- Regular use of harvested water to prevent long retention times
- Frequent maintenance to ensure proper function of all components

All openings and possible entry points within the system should be screened or sealed to prevent the entry of insects and animals, which has been linked to elevated microbial concentrations.

For potable systems, all harvested rainwater should be treated prior to human consumption to minimize the risk of illness. Treatment should include some form of filtration and disinfection. According to Mike Ruck, ARCSA AP, "good system design and education, whether providing potable water or using simple rainbarrels is the critical link to the widespread acceptance of rainwater harvesting."[54]

Center for Interactive Research on Sustainability

University of British Columbia, Vancouver, British Columbia

Case Study Provided by Perkins+Will Architects

From the CIRS Technical Manual—Rainwater, October 2011

Figure 5.14 Research on sustainability designed by Perkins+Will Architects has an extensive rainwater harvesting system. (*Centre for Interactive*)

Project Description

Located on a previously developed site at the University of British Columbia, the Center for Interactive Research on Sustainability (CIRS) houses researchers from private, public and non-government organization sectors, who work together under a common mission: to accelerate sustainability. Including lab space, academic offices, meeting rooms and social spaces, CIRS is organized around two four-story wings, linked by an atrium that serves as a building lobby, entry to a daylit 450-seat auditorium and "social condenser" space.

Rainwater Water System Overview

CIRS is designed to be entirely water self-sufficient. The rain that falls on the building roofs supplies all of the potable water used in the building. Through a simple system, rainwater is harvested from the roofs of the building and stored in a cistern below the building. The rainwater is filtered and disinfected onsite and distributed through the building for potable water applications.

Reclaimed Water System Overview

One hundred percent of all reclaimed water used at CIRS originates from the building and the campus sewer system and is treated onsite and reused within the building. A solar aquatic system is an ecologically engineered system based on processes existing in nature that consume human biological waste to produce clean water. The water is collected from fixtures throughout the building and treated water is reused within the building for irrigation and toilet flushing, creating a closed loop water cycle. This system is designed to mimic the purification processes of naturally occurring water systems in close proximity to human inhabitation, such as streams and wetlands.

Design Goals:

Project Overview

Targeting LEED Platinum and Living Building Challenge certification, CIRS was designed to put sustainable systems on display and to be "net positive" in seven different ways—net-positive energy; structural carbon neutrality; operational carbon; net-zero water; turning passive occupants into active inhabitants; promoting health and productivity; and promoting happiness. This "living building" harvests sunlight, captures waste heat from a nearby building, and exchanges heating and cooling with the ground—and returns 600-megawatt-hours of surplus energy back to campus annually. CIRS collects rainwater for potable use and purifies wastewater in an onsite solar aquatics bio-filtration system. More than a building, CIRS is a research tool that demonstrates the possibilities in sustainable design, serving as a catalyst for change.

Table 5.4 Project Goals and Targets Specifically Related to the Rainwater System

Category	Goals	Targets
3 – NET IMPACT	Eliminate onsite run-off.	
8 – RAINWATER COLLECTION & USE	100 percent of potable water requirements will be met with onsite collected rainwater	100 percent rainwater input.
10 – STORMWATER MANAGEMENT	100 percent stormwater will be treated, used or infiltrated onsite	Zero stormwater output from site.

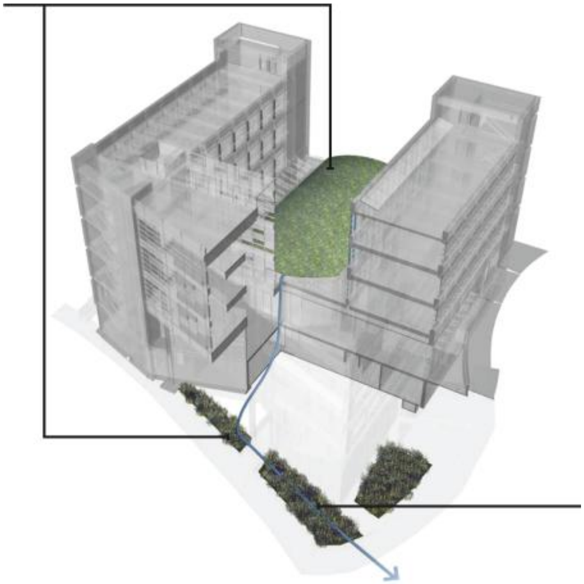
(CIRS Technical Manual—Rainwater, October 2011)

Table 5.5 Project Goals and Targets Specifically Related to the Reclaimed Water System.

Category	Goals	Targets
3 – NET IMPACT	Neutralize ecological impact onsite by having a net positive biomass and oxygen provided onsite. Eliminate onsite run-off.	
9 – WASTEWATER COLLECTION, TREATMENT & REUSE	All wastewater will be collected and treated onsite or within the "sustainability precinct." Recognize environmental opportunities in the management of human waste.	Zero wastewater output from site
10 – STORMWATER MANAGEMENT	Water leaving the site should be as good or better quality than when it arrived.	Clean 100% of water used onsite
12 – WASTE ELIMINATION	Zero waste	Zero operational waste.
18 – SEAMLESS DESIGN & OPERATION	The building will seamlessly integrate the design and ongoing operations.	
21 – COMMUNITY & EXTERNAL IMPACTS	Minimize external and community environmental impacts of CIRS's staff and visitors.	
22 – PUBLIC EDUCATION	CIRS will disseminate sustainable design practices, knowledge and experience as widely as possible.	

Stormwater Retention

CIRS captures, stores, and uses all stormwater and rainwater onsite from exterior and interior building process loads, eliminating the facility's dependence on municipal infrastructure. Features include: a rainwater collection system; ultra low flow water fixtures; gray and blackwater treatment; and stormwater collection and treatment.



Stormwater

Stormwater is collected from the living roof and landscaping.

Stormwater is channelled to a drainage basin, located to the south of the site on Sustainability Street. From there the water slowly filters back into the local aquifer.

Figure 5.15 Rainwater to stormwater system. *(Perkins+Will Architects)*

Preservation of Potable Water

CIRS has achieved over 100% water use reduction equal to a total annual volume of 5,177,711 L of potable water savings. The water use reduction was calculated in accordance with the LEED Canada-NC v1.0 by comparing a design case to a base line case.

Water Resiliency

Statistics:

This building houses 770 occupants and rainwater is used to flush 22 toilets, 7 urinals, and 21 lavs. In addition, there are four showers in the building. As provided in the LEED® summary, the architects estimate that irrigation accounts for 23,435 L (365 gallons). The total roof area is 1392 m^2 (approximately 1,500 sq. ft.). One-third of the roof is a green roof and the rest is used for rainwater collection. The roof cladding is a high albedo TPO Membrane and the estimate for the total water volume collected is 1,226,000 L or approximately 324,000 gallons of rainwater harvested annually.

There is one large cistern and one person is employed by UBC on a full-time basis to monitor and maintain CIRS water system. The area required within the building in the potable water room is 54.5 m^2, or 586 square feet. The solar aquatics room for blackwater treatment requires 88.5 m^2, or 952 square feet.

Overflow:

CIRS is located beside Sustainability Street on the UBC Campus, a vegetated swale-like public space that allows stormwater from multiple building sites to be infiltrated back into the ground. Despite CIRS's closed loop design, sometimes water needs to be sent to Sustainably Street due to Vancouver's climate with large rainfall events. Sustainability Street was designed with the capacity to accept the stormwater from a number of the surrounding sites. Conservative calculations suggest that 684 m^3 (180,694 gallons) of water is delivered annually to Sustainability Street from CIRS.

Water Treatment:

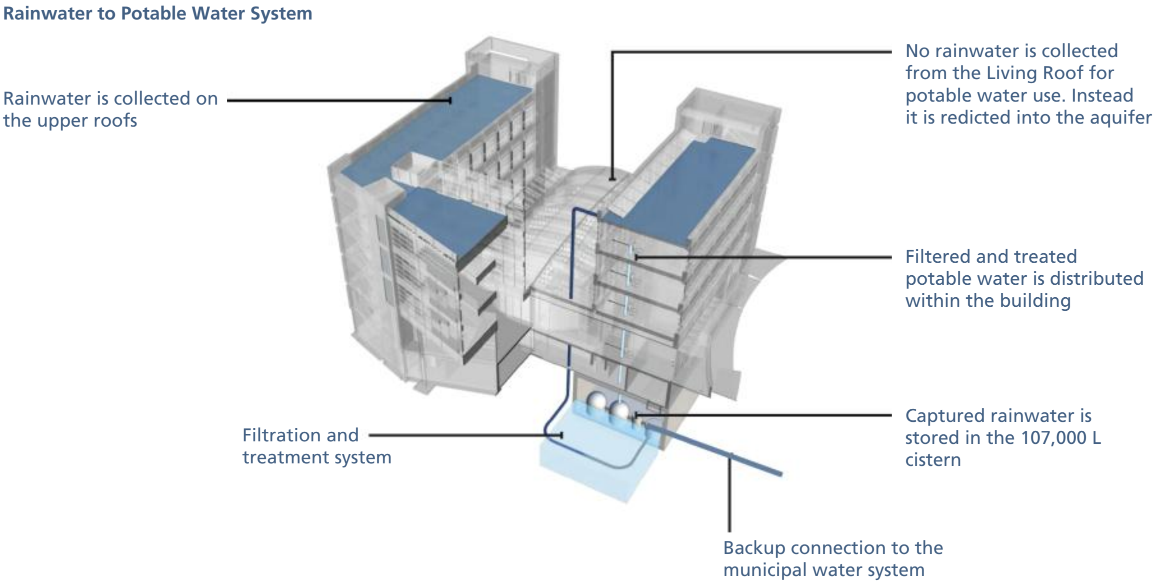


Figure 5.16 Rainwater to potable water system. (*Perkins+Will Architects*)

Potable (CIRS Technical Manual—Rainwater, October 2011)

Filtration From the cistern, the rainwater is filtered through a three-step process. The first step is a slow sand filter to remove larger particles, next is a fine filter to remove smaller particles and parasites, and finally an activated carbon filter, which removes metals and organic contaminants from atmospheric contaminants.

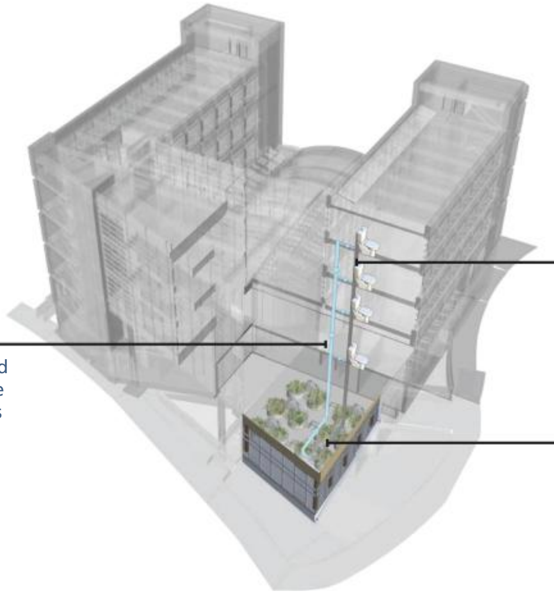
Disinfection After filtration, the water is disinfected through a two-step process. First, the water is exposed to ultra-violet light to render harmless any remaining pathogens, and then a small amount of residual chlorine is added. Residual chlorine is generally added to the municipal water system in small quantities, typically less than 2 parts per million. Its presence in the water provides a measurable assurance that the disinfection process is working.

pH Adjustment Rainwater in Metro Vancouver has a pH of about 4, which is below the regulated level for drinking water of between 6 and 9 pH. Sodium bicarbonate is injected into the water to adjust the alkalinity and reach the required pH level. pH is a measure of acidity or basicity (alkalinity) in water-based liquids. Solutions with a pH of less than 7 are considered acidic, solutions with a pH of greater than 7 are said to be basic or alkaline. Vancouver water is about 4.2, so it is acidic or "soft." Acidic water can corrode materials, damaging the infrastructure and picking up residual contaminants.

Treated Water Tank After the water has been treated, it is stored in two tanks and delivered by pump through the building using a pressurized bladder system.

Monitoring and Back-up

It only takes a couple of hours for rainwater to move through the treatment process. The system is continually monitored and the water tested. If a problem is detected, the rainwater treatment



Reclaimed Water

Black and gray water is collected from fixtures in the building.

Reclaimed water is pumped back into the building to be used for toilet flushing and to irrigate the living roof, landscaped areas and the living wall.

The Solar Aquatic System is based on naturally occuring biological processes. It filters and treats the water for re-use.

Figure 5.17 Reclaimed water system. (*Perkins+Will Architects*) system immediately shuts down, and water from the municipal system is supplied to the treated water tank and pumped into the building.

Reclaimed Water (CIRS Technical Manual—Reclaimed Water Systems, October 2011)

Step 1 – Collection/Buffer Tank The system collects all the wastewater from the building, supplemented in times of lower occupancy by the campus sewage system. "Mining the sewer" in this manner ensures constant and optimal levels of wastewater enter the system, and ensures a steady supply of water is always available to meet irrigation requirements. In addition, it reduces the burden on traditional infrastructure required to move and treat sewage in a conventional treatment plant.

Step 2 – Blending Tank The sewage is collected in a closed tank where added bacteria begin to digest the biological waste. The tank is constantly aerated to keep the bacteria in contact with the waste. Aeration also reduces any odor rapidly.

Step 3 – Aeration Tanks The wastewater, along with some bacteria, is then moved through a series of aeration tanks. These are open tanks populated on the surface with regionally acclimatized aquatic and terrestrial plants. The plants absorb a small amount of the nutrients from the sewage and process carbon dioxide, while most of the work is done by bacteria on the root systems below the surface. The roots provide a perfect habitat for the bacteria. The water in the tank is constantly aerated to promote contact with the bacteria on the root systems. Plants in the aeration tanks are self-propagating. They will not need replacement and can be composted or harvested for use elsewhere, including sale as garden plants or decorative flowers. As the bacteria grow and thrive they process the sewage as food. By the end of the aeration process the nutrients in the water become more available for reuse. Ammonia (from urine) is converted into nitrate and the phosphorous becomes more soluble.

Step 4 – Gravity Clarifier After the aeration tanks, the water moves to a Gravity Clarifier tank. The tank is cone bottomed with no air supply where the bacteria (sludge) settle in the bottom, separating from clarified water. The bacteria are then pumped back to the blending tank to begin the process again.

Step 5 – Sand Filter The clarified water moves from the Gravity Clarifier through a sand filter that mimics how water filters through a column of soil. The fine particles of the sand remove any tiny particles in the water.

Step 6 – Constructed Wetland From the Sand Filter, the water travels through an area of constructed wetlands where fecal coliform and some metals are removed from the water through contact with bacteria and plants.

Step 7 – Ultra-Filter The next step is an ultra-filtration system. This is a high-tech but very simple system of nano-materials where the water is filtered to a very high degree through screens of micron fibers.

Step 8 – Disinfection After filtration, the water is disinfected using a two-step process. First, the water is exposed to ultra-violet light to render harmless any remaining pathogens. Next a small amount of residual chlorine is added. *Residual chlorine is typically added to municipal water systems, as its presence provides an assurance that the disinfection process is working. Long-term system monitoring may be able to demonstrate that the system can clean the water to a satisfactory level without adding chlorine, and eventually eliminate this step.*

Step 9 – Storage and Re-use The cleaned, reclaimed water moves to storage tanks and is then pumped into the building for use as irrigation and toilet/urinal flushing. Flushed water then re-enters the system for treatment.

Step 10 – Compost (Future Development) Over time, as bacteria grow and replicate, there will be a build-up of sludge—large active colonies of bacteria—in the system. Typically, a composting process is created to remove and reuse the sludge, as it is rich in nutrients that can be absorbed by plants and returned to the biosphere. Composting is not yet in place for the CIRS treatment system, so excess sludge is simply removed and discarded. However, in collaboration with students and researchers, a composting process will be developed for reuse on campus.

Designed for Adaptation The Solar Aquatics System at CIRS is designed for ongoing experimentation and testing. It is arranged in two parallel trains, completely separate but identical, to allow for controlled experiments and comparisons, as well as for continued operations if one train requires maintenance or repair. The entire system is monitored at every stage, supporting ongoing measurement of water quality during each step in the process. The system is completely backed up by the municipal water supply and sewage system, with installed safety measures, allowing for a degree of freedom not possible in an isolated context.

CIRS was developed as a response to the challenge of creating a more sustainable society. This challenge acknowledges that the world's climate is dynamic and a changing place. Resources that were once used in plenty may have shortages; typical local climate characteristics may drastically vary from seasonal norms becoming more extreme. CIRS is attempting to demonstrate that buildings can live within the energy and mass flows available to them within their footprints. For water, CIRS self-sufficient closed loop design was created with resiliency in mind—operating independent of municipal systems offers the building maximum flexibility and agility to adapt to resource changes. Since CIRS operates as a closed loop system it has no water bill, which equals significant savings to the University of British Columbia.

CONCLUSION

While there are numerous opportunities for pollutants to be introduced to harvested rainwater, there are equally as many methods for filtering and/or treating water to acceptable levels. In fact, many studies show that collected rainwater can be of extremely high quality when systems are designed to minimize pollutant introduction. Designers should choose locations, roofing catchments, piping and tank materials, and prestorage treatment carefully to maximize water quality and place the least burden on the post-storage filtration/treatment devices.

Current technology allows for effective and efficient post-storage treatment for all types of end uses, making rainwater a suitable alternative for municipally supplied potable water. However, it should be fully understood by designers and owners that optimal water quality and the overall success of a rainwater harvesting system are fully dependent upon solid design, proper installation, and frequent, thorough maintenance of system components.

Architects all over the world are developing projects that incorporate rainwater harvesting systems as part of their building program. Examples such as the large CIRS in Vancouver and smaller examples like the Tyson Living Learning Center demonstrate that rainwater harvesting is a viable solution. Any associated fears about pollution or lack of water can be met with proper pre- and post-storage filtration and/or treatment, rigorous maintenance, backup supply methods, and safety protocols.

Figure 5.18 Tyson Living Learning Center uses rainwater as a source for potable water. (*Ralph Bicknese, Hellmuth + Bicknese Architect*)

Tyson Living Learning Center—Rainwater Success

Washington University, St. Louis, Missouri

Ralph Bicknese, AIA, LEED® Fellow

Hellmuth + Bicknese Architects

Project Description:

The Living Learning Center is a 3,000 SF research and classroom facility for Washington University Tyson Research Center, a 2,000-acre biology and environmental research site in Eureka, MO. The building houses a large multi-purpose classroom, a computer lab, three offices, and a 1,000 SF outdoor deck creating an indoor/outdoor classroom.

This building was tied with another (The Omega Center) as the first building in the world certified to the Living Building Challenge. The design goals include:

- Eliminate the concept of waste throughout the building project
- Zero net water to conform to requirements of the Living Building Challenge
- Demonstrate closed loop water systems including using captured rainwater to provide all water needs (potable and non-potable)
- Net positive impact of all water systems (including supply and "waste")
- Water resiliency

The occupants of this educational facility vary from 3–5 people in offices to visitors who attend occasional classes that range in size from 8 students to 40 (2–3 times a week) or occasional public meetings (3–6 times a year) that range in size from 25–50.

Statistics:

- Sinks: Rainwater supplies the potable water at two bathroom sinks and one classroom sink, non-potable water at one outdoor classroom sink.
- Two composting toilets—no flushing: The compost tank uses a mister that is adjustable to maintain proper moisture content for composting. There is no odor.
- Irrigation: Uses graywater collected from sinks
- Overflow: At times when the cistern is over full the water backs up the downspout and by use of the diverter valve is drained to the ground. The low-volume sheet flow drains to a constructed dry stream bed which in turn drains into the nearby intermittent creek.

The annual rainfall has a monthly precipitation average from 3.1 to 37" per 12 month year. 24.8" per year was used as an average for calculations due to disconnecting the collection system due to freezing for approximately 4 months during the winter.

The 2,160-sq.-ft. roof was constructed of a standing seam aluminum roof with fluoropolymer paint coating. The estimated total water volume collected was calculated at 33,393 gal. per year based on average precipitation and disconnecting the diverter/downspout for an average of 4 months/year during winter.

A 3,000-gallon cistern was sized to provide up to 60 days of water without additional rainfall. This means that the rainwater harvesting system is sized to exceed demand. Keeping demand low reduces the size and the cost of the system. In this case the system was sized to collect and store enough rainwater to meet a minimum of a 2-month demand without benefit of rain during that period. All the roof area was not needed or used for rainwater harvesting. About 1/3 of the roof was planned for a vegetated roof. Natural and naturalized plants were used on the grounds to eliminate the need for irrigation, low-flow faucets and composting toilets were also used to reduce the need for water. In over 4 years of operation the facility has never run out of harvested rainwater.

Water Treatment:

- The water collected from the roof is collected in a gutter and flows to a single downspout that contains a first flush diverter. The diverter is a pipe that holds the initial rainwater that runs off the roof—that would contain the majority of dirt and debris from the roof. Once this portion

Figure 5.19 Tyson Living Learning Center downspouts with rain diverter. (*Ralph Bicknese, Hellmuth + Bicknese Architects)*

of the pipe is filled a ball valve automatically diverts the following water to the cistern where it is held.

- The water then passes from the cistern to a series of filters. The water first passes through two filters to remove particulate as follows: 20 micron, 5 micron, next through an active carbon filter to neutralize taste and odor and then through the UV sterilization process that kills bacteria and other living microorganisms. After the UV sterilization process it goes through another 0.45 micron filter at each lavatory on the hot and cold side.
- The filtered water is tested monthly and tests cleaner than typical tap water in our area. (This is especially notable because the St. Louis municipal water has been rated to have among the best-tasting drinking water in the country.)
- Signage: Potable Water signs are provided at the sinks with drinking water. The sink at the outdoor classroom used to wash down plants, roots, etc. and hose bibs are listed with signage as non-potable water and do not have the final set of filters.
- Circulation process: The water circulates at 5 gallons per minute for 3 hrs a day. That's 900 gallons of purification a day on top of the water being re-purified every time the lavatories are used.

Maintenance:

- Maintenance: The UV light is changed annually. The 20-micron and 5-micron filters are changed every 6 months and the 0.45 micron filters at the lavatories and the carbon filter are changed every 3 months. The cistern is sanitized once every 6 months. The water in the cistern is chlorinated and remains overnight. The next day the water is rechlorinated and remains in the cistern for another 24 hours before it is pumped into the "constructed rock dry stream bed." The inside of the cistern is then power washed and filled half way with well water. The filters are replaced and the cistern is allowed to fill up the rest of the way with rainwater. The use of well water to partially fill the tank is a convenience and would not be needed if sufficient rainwater could be stockpiled separately to use to partially refill the tank (for instance, in a temporary smaller tank) before the tank was cleaned. Performing the cleaning process in a rainy season (typically Spring or Fall) allows less well water to be used for the partial fill because the cistern fills fairly quickly at those times.
- Water Quality Testing: The water is sampled monthly and sent to the Missouri Department of Natural Resources. The test that is performed is the same test MoDNR does for well water when required. Mainly they are testing for Coliform presence. The owner tests for Nitrate every 12 months.

Area within Building for Equipment:

The main filtration systems take up approximately 6 lineal feet of wall space and project from the wall less than 12 inches. Other filters are located directly below sinks and are approximately 10 inches tall by 4 inches in diameter. The cistern is located outside directly buried underground.

Separate Plumbing:

- All supply water uses the same system. However, graywater (used water from the sinks) is piped to a garden drip irrigation system. There is no sewage water in the conventional sense. Composting toilets are used instead of flush toilets. Black water (liquid, mostly urine) from the composting toilets is partially filtered and neutralized by running through wood chips. It then settles in the bottom of the composting toilet and is pumped into a separate tank for use as liquid fertilizer.
- St. Louis County officials required that a connection to the existing sewer be available should it ever be needed.
- Potable Water signs are provided at the inside sinks. A non-potable sign is posted above the outdoor sink and at hose bibs. However, the only difference between the water at the outdoor sink and indoor sinks is the exclusion of the 0.45 micron particulate filters at the outdoor sink which is used for washing specimens collected.

Permitting and Code Approval Process:

- The concepts were reviewed early with St. Louis County plumbing code officials before proceeding with detailed designs. They exercised a provision in the code that allowed exceptions for experimental systems under a variance.
- The Missouri Department of Natural Resources required that the tap water be sampled monthly and sent to them for testing. The results are returned to the owner. Over the past 4 years of continuous operation the tests have all indicated excellent water quality; cleaner than water treated by the local municipal water system.
- The water treatment system we utilized is an option consistent with treatment systems allowed for commercial wells that are used by the public. However, while most treatment systems utilize chemicals such as chlorine we elected to use a treatment system that did not use chemical treatment. This is in keeping with one of the intents of the Living Building Challenge—to eliminate harmful chemical exposure.

There were no incentives provided from the outside of the project to help pay for the system. However, a cost analysis showed that the rainwater harvesting system would have been similar in cost to installing a new cased well to commercial standards with a treatment system. Although there was an existing well that could have been used, the owner decided to go ahead with the rainwater harvesting system as an example to showcase this sustainable strategy.

The architects learned many lessons throughout this process. The rainwater harvesting was prompted as a means to contribute to meeting the net-zero water imperative of the Living Building Challenge (LBC) and has been successful in achieving those goals as proven by over 4 years of operation. Composting toilets a graywater irrigation system and site stormwater management systems were other components of the net-zero water systems.

To the extent possible they attempted to emulate nature's closed loop water system. This building was tied with another (The Omega Center) as the first building in the world certified to the LBC. The building is zero net–water, –energy, and –waste, eliminates the use of the 16 Red List Chemicals and meets a host of other very "bright green" initiatives.

The architects recommend that the owner provide commissioning on the system following start-up to insure all systems have been installed correctly, are operating correctly, and the system has been properly sanitized. In addition, design professionals should assure that they allow time to review their system closely with local code officials, the department of natural resources, and the owner. Proper operation of the facility is vital to safe water. The system requires significantly more maintenance than water delivered by a municipal water supply so the facility staff needs to be properly trained and budget adequate time to provide monthly and semi-annual maintenance procedures.

They also learned that the first flush diverter needed to be bypassed every winter to avoid freezing of the water that is held in the diverter and allowed to drip out slowly. Otherwise the frozen water could split the diverter valve and the 4" copper drain line that leads to the cistern. To get around that the owner removes the ball at the valve and opens the end of the first flush diverter drain pipe, allowing the water to bypass the cistern. That could be counterproductive in a dryer climate but they are able to have enough water because of low demand and sufficient fall and spring rainfall.

They recommend gutter guards or another "first filter" is necessary to block the leaves and reduce the pollen sacks from the surrounding trees from getting into the system which otherwise would have clogged filters up quicker. The first flush system is intended to filter out small debris. It allows water in that portion of the pipe to drain slowly to the ground and pass small debris through the small diameter opening. The gutter guards do a good job of blocking larger debris. However, if larger debris were intended to flush through the system the first flush diverter would need to be modified to allow the debris to go onto the ground by opening up the diverter all the way for a time.

They recommend that professionals install a failsafe for the recirculation pump and pressure pump to cut off if the cistern runs out of water. Otherwise the pumps will seize up if the system runs dry for any reason; an empty cistern or ruptured pipe, or if there is a prolonged pressure drop for instance from a faucet or a hose bib is left open for a long period.

The owner determined that they did not have to recirculate nearly as much water through the system to maintain water quality as originally intended. They had started circulating 12 hrs/day, dropped to 8 hrs, then to 6 hrs, and eventually to 3 and were able to maintain high water quality. This saved considerable pump energy, reduced wear on the recirculation pump and greatly reduced the frequency that filters have to be replaced. A major focus of the building is to "eliminate the concept of waste," therefore, considerable effort is made to see that the building and systems conserve energy, water and materials.

Architect Ralph Bicknese had hoped to duplicate this project in Kentucky with a new rainwater harvesting system for the Berea Deep Green Student Residence. The Kentucky project was to use rainwater for a student dorm with 120 rooms at Beria College in Berea, Kentucky. In Berea the State of Kentucky denied both composting toilets and graywater for flushing toilets. They did allow captured rainwater for irrigation.

At The College School Discovery and Exploration Center (TCS), in rural Jefferson County, Missouri, they are using captured rainwater for irrigation and using composting toilets and a graywater irrigation system very similar to one at Tyson. At TCS regulators required that the architect drill a well instead of using treated rainwater for potable water.

This property is 29 acres containing woods and glades and two creeks; one named LaBarque Creek and the other is an unnamed creek that they are starting to refer to as Don Robinson, or

Robinson Creek. LaBarque Creek is one of the most pristine and healthiest bodies of water that flows into the lower Meramec River with the most fish and amphibian species. Sandstone bluffs border both creeks and join at their confluence. The architect is designing a "Learning Center" building and a pavilion that will be an outdoor classroom. Rainwater collected from a portion of the roof will fall into a basin at the top of the wall, the top of the wall is channeled to hold water and curves and winds to mimic a stream as it slopes down to a play pool for young children. The play pool overflows to a series of rain gardens to filter and absorb the water.

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CHAPTER 6

21st-Century Interviews

The following interviews were conducted by co-author Eddie Van Giesen with national and international professionals in diverse fields, who nonetheless, relate in one way or another to rainwater harvesting.

These interviews deliver a wealth of knowledge that is only obtained through real life experiences. The diversity of the interviewees' backgrounds reflects the multifaceted aspects of the world of rainwater harvesting.

The interviewees demonstrate that, beyond the mastery of their own careers, they are teachers at heart. We are honored by their willingness to share with us their wisdom and expertise.

We have the pleasure to introduce our interviewees:

Stan Abbott, MSc Director of Roof Water Research Centre at Massey University in New Zealand, is a Senior Lecturer in Microbiology and Communicable Diseases.

John Apostolopoulos, LEED® AP Engineer Principal at Vanderweil Engineers in Boston, specializes in water conservation technologies, including rainwater and graywater systems.

Alf Brandt, Esq. serves the California State Assembly as an expert on water resource law and policy. Brandt has developed and analyzed California water legislation, including the Assembly Bill 1750, The Rainwater Capture Act of 2012.

Bob Drew, president of SERHSA (Southeast Rainwater Harvesting Systems Association), is the founder of Ecovie Environmental, an Atlanta-based company that focuses on rainwater collection systems.

Nicole Holmes, P.E. LEED AP, Project Manager at Nitsch Engineering, is a speaker at regional and national conferences on rainwater harvesting. She is also the co-creator of a software program for calculating rainwater capture.

Bill Hunt Ph.D. P.E. is a Professor and Extension Specialist at the Biological and Agricultural Engineering Urban Stormwater Management for the North Carolina State University.

Lutz Johnen, Director of Aquality Trading & Consulting Ltd, a rainwater and graywater technologies company in the United Kingdom, is a member of the Green Building Council in the United Kingdom, the FBR (German Rainwater Harvesting Association), and the ARCSA.

Heather Kinkade, FASLA, LEED AP BD+C Executive Director of ARCSA, is a Faculty Associate at the Master's Program in Landscape Architecture at Arizona State University.

Kevin Kirsche, a LEED® Accredited Landscape Architect, is Director of Sustainability at the University of Georgia.

Billy Kniffen, National Director of ARCSA, is the Education Committee Chairman and Educational Development Leader at ARCSA.

Dennis Lye, Ph.D. research microbiologist at USEPA (Cincinnati, Ohio) is currently promoting the collection and use of rainwater and/or stormwater runoff as alternative water resources.

Shawn Martin, Director of Plumbing, Mechanical and Gas (PMG) activities in the Government Relations Group, is Plumbing and Mechanical Code Developer for the International Code Council (ICC).

Neal Shapiro CPSWQ® CSM, is ARCSA Secretary and Watershed Management Program Coordinator for the City of Santa Monica, California.

David Stooksbury, former State of Georgia Climatologist, is Associate Professor at Driftmier Engineering Center at University of Georgia, and he specializes in wind and solar resources.

Dave Viola, Senior Director of Technical Services, a twenty-four-year veteran of model construction code development, is responsible for IAPMO's sustainable activities.

STAN ABBOTT

Figure 6.1 Stan Abbott

Van Giesen: Stan, you are known internationally as one of the experts in rainwater harvesting from your work at Massey University and from your international lecturing. Your expertise is vital for those in the design community who don't have your depth of experience.

What were some of the big obstacles that you overcame in New Zealand that previously prevented rainwater harvesting?

Abbott: In rural New Zealand, more than 10 percent of the population are already on rainwater tanks and use roof water as their sole supply, especially on farms, lifestyle blocks, and so forth. Although not an obstacle other than the poor quality of the water in many dwellings; they were already collecting the water. Likewise, in Australia, 17 percent of the population has rainwater tanks already.

The problem was to convince people in urban environments, even in so-called water-rich New Zealand, where we appear to have plenty of water, to utilize roof water. Recently, with climate change, even in New Zealand we now have many areas that are prone to drought. Many academic institutions like ours [Massey University] are encouraging councils and local authorities to install rainwater harvesting tanks, especially in urban environments, for supplementing the mains municipal water supply. The roof water that they collect can be used for secondary uses—for flushing toilets, taking showers, washing machines, watering the garden, and so forth.

The biggest obstacle was changing what we call "institutional inertia," that is, changing the mentality of the people working in these institutions. They were talking about all the types of contamination that you could get from roof water, and they forget that there are many people on sole supplies. We have shown that the risks can be very low. We had to convince the city planners that this is a viable economical option toward sustainability. The cost was a big factor here and so we looked at financial returns and payback period. So, we encouraged the councils to give the homeowner some motivation or financial incentive toward installing their tank.

Van Giesen: Can you elaborate on some of the motivations and rebates?

Abbott: The drought was a big motivation, especially this past year (2012). Many areas in New Zealand were declared drought stricken with huge economic impacts and if people had put in their rainwater tanks before the drought, there wouldn't have been such a drain in the municipal supplies. Even in places like urban Wellington, there were water restrictions in place. And this is in the so-called water-rich New Zealand. The water restrictions were one of the reasons that encouraged the collection of roof water, whether it be in a 1,000- or a 5,000-liter rain tank.

The other main incentive was earthquake vulnerability. In February 2011, we had a huge earthquake in Christchurch and people realized the value of water. One-hundred-eighty-four people lost their lives. After an earthquake, the most important thing is access to water. Even 100 days after the earthquake, people were queuing fifty deep waiting for up to four to five hours sometimes for trucks delivering water. If everyone had a rainwater tank, even a small 250-liter tank, there would be less reliance by the householder on the municipalities or the local authorities to supply water during an earthquake.

We worked with the councils and the municipalities in the Wellington region to create education programs. Although the councils might not encourage rainwater collection by giving financial incentives, they started putting websites up telling people how to put rainwater tanks in and what sort of building permits they needed. Many places are following what you are doing in the United States, programs like LEED® Building, and here we call it Five Star Green Building. Builders will only get a Five Star rating for a commercial building if they include a rainwater tank in their projects. There are quite a number of commercial buildings here in New Zealand with huge rainwater tank storage, anything from 16,000 to 75,000 liters.

Van Giesen: Stan, we know the misery level is always highest after a disaster as a result of the lack of water. You may remember that in the aftermath of Hurricane Katrina in 2005 in the United States the greatest amount of misery suffered by people was due to the lack of safe water, when paradoxically they were inundated with water. The point is rainwater tanks can buffer the effects of disasters.

Abbott: If you go to certain places in Auckland now, and I am aware of at least one building official, who will not give consent to start construction on any private dwelling or commercial building unless they put in rainwater harvesting tanks. And I think that day might come when you will see this throughout the country [New Zealand] when every new building must have a rainwater tank, be it as a part of foundation under the building, or be it an aboveground plastic or concrete tank.

Van Giesen: I think that it is absolutely the future. And if you look into places like Malaysia or Singapore, and a number of other places in Southeastern Asia and India, rainwater cisterns are part of progressive policies that are being implemented right now.

Abbott: Thailand and Korea are very progressive as rainwater goes. There are huge rainwater harvesting systems in urban environments being done in these countries.

Van Giesen: There is a problem that we encounter as manufacturers and designers on a regular basis, which is the argument that, "You can't store the rainwater for very long, because the water goes bad." How do you address that statement, so we can separate fact from fiction?

Abbott: It depends on what you are using the water for. I don't think it matters one iota if it is going to be flushed down the toilet or going to be used in the shower. It's only a problem if it goes bad and you use that water as your sole supply, for drinking or for food preparation. The only reason why it will go bad is if there's not enough turnover. It's only going to go bad if you have not taken some precaution to prevent undue contamination of that supply. In other words, if you don't have a proper air vent, the tank water can't breathe. If you don't have a calmed inlet, then you will be getting lots of sediment and anaerobic process is taking place in the bottom. Very rarely have I seen well-maintained tanks where the water "can be described as going bad."

Van Giesen: You have written numerous papers on the subject of the first-flush mechanism. Can you elaborate on the appropriateness of this technology based on the scale of the project?

Abbott: If I had my way, I would make first-flush diverters absolutely mandatory and in some parts of Queensland, in Australia, they are. But I'll qualify that: When I say mandatory and essential, I'm talking here about private and individual supplies. First-flush diverters have been shown to be effective for tanks of around 25,000 liters for a family of four or five. But obviously there are certain situations where you cannot use first-flush diverters, for example, in large commercial buildings because they might not be maintained properly. Of course, other types of filters may be better utilized. There are many types of filtration products. First-flush diverters are essential for small units or homes, but I accept that in some situations there might be better options than first-flush diverters, especially if it is in a large commercial building.

Van Giesen: There seems to be many different opinions about techniques and strategies on the way rainwater systems are designed. Are there some fundamentals that all professionals would agree on?

Abbott: Often times the design is influenced by the close proximity or the association of the researcher to one company or a company's product.

Having said that, there are many strategies and materials that are accepted by the rainwater community. Researchers and scientists agree on the type of roof that you can use and the certain types of materials that you can't use. Also they agree on the size and type of material that you use on your downpipe. With tanks, there is no sort of universal agreement on whether you should use a Ferro cement or a corrugated iron tank or whether you should use a polyethylene tank. There are about five or ten different types of materials. There is no universally agreed upon size of tank. Obviously, the bigger the tank the better, or you can have two tanks or even better still, you can put them in series.

The choice of materials is often driven by the local commercial supply house and the market share that they have. There are some companies in New Zealand that make excellent products. With all of these different search engines people can see all of the products that are available and also look at expert opinions.

Van Giesen: Stan, you are on the cutting edge of rainwater industry. Can you shed any light on some of the latest technical advances in the industry in terms of components, strategies, or techniques?

Abbott: I think the biggest advances are nothing newer than first-flush diverters, but we have learned more about them and I am not pushing one kind more than another. Research shows repeatedly that it is advantageous to flush away that first flush of contaminated water, regardless of what sort of flush you use or what sort of proprietary device you use. There are lots of arguments as to the exact volume of water that you need to flush, but everyone universally agrees that first-flush diverters, in some situations like I mentioned as in family tanks, do work.

The other thing that has also been shown is that if you put your two tanks in series and your water comes into your first tank via a calmed inlet where it comes from the bottom, then you take that water out of the first tank from the top with a floating valve out-take and send it through the second tank, the quality of water will improve. We have shown over and over that, thanks to first order kinetics and all of the science behind it, because you have connected your two tanks in series, that water in your second tank is very good. If you can put them in series, and if you can put in three tanks and draw the water off the third tank—that would be ideal.

Many people on rural water supply are gung ho and they do not take the precautions and more should be done to protect the supply from contamination.

The other advance that has been quite phenomenal is the publications and articles that come out now worldwide. There are quite a lot from America now that the value of roof water harvesting in urban environments is gaining traction in the United States. The amount of papers published in the last five years on this subject and the contributions to sustainability have been enormous.

Van Giesen: What did you mean by the term "first order kinetics"?

Abbott: It's an engineering term that is also often used in wastewater ponds and in wastewater treatment. It indicates that you get a massive order of reduction of your E-coli count due to this process called first order kinetics because you have diluted the water considerably by the time it gets into the second and third tanks.

JOHN APOSTOLOPOULOS

John Apostolopoulos is a principal at Vanderweil Engineers. He manages the Plumbing Division for the firm and he specializes in water conservation technologies, including rainwater and graywater systems.

Figure 6.2 John Apostolopoulos

Van Giesen: Thank you for taking time to talk with me about your role and perspective on the subject of rainwater harvesting systems. I would like you to give a brief introduction of yourself and your position at Vanderweil Engineering.

Apostolopoulos: I am a mechanical engineer in the field of plumbing and piping with Vanderweil Engineers. I joined the company in 1989. I specialize in rainwater harvesting systems, and I also work in the area of graywater systems, recycling effluent from lavatories and showers. We are interested in all technologies related to water conservation.

Van Giesen: You have been involved in the design of rainwater systems for some time. What were some of the motivations to develop expertise in this area?

Apostolopoulos: In early 2000, when LEED® was introduced to our line of business, our office started applying the knowledge we had about water conservation on most of our projects. It is important to address that at the time, engineers from Vanderweil's office were involved with USGBC performing different tasks. We took this opportunity to start developing rainwater reuse systems. We started educating our clients and property managers about sustainability and new technologies. In addition, we started developing small systems for some of our clients, including the property on which our company resides. The building currently has a condensate recovery system. Since the year 2000 we have designed dozens of successful rainwater and condensate recovery systems.

I got very motivated early in my carrier when I realized the amount of drinking-quality water mechanical systems were using for cooling and fixture flushing. The amount of "clean" water such as condensate and stormwater introduced to drainage systems for disposal was astonishing. Once two and two are put together, it makes sense to develop and maintain water reuse systems. Understanding the location of a property, the amount of rainfall into that area, and the amount of condensate that you can retrieve from equipment is extremely important.

Van Giesen: Yes, that's right. Obviously we are not dealing with a fixed amount of water—it is climate determined. What's the role of the project engineer and of the design engineer in a rainwater harvesting project? Are the projects typically initiated at the engineer level or at the architect level?

Apostolopoulos: It definitely helps when a client is educated and motivated. *But in my opinion an enthusiastic and creative engineer can make all the difference.* An engineer can bring a lot to the table at the very beginning of the project. Water reuse systems should be addressed from day one as any other building system. If the client is not familiar with these types of systems, then it should be the responsibility of the engineer to educate his client and further explain the value these systems add to the property.

The next step would be to turn theory into a product. Calculate the annual volume of water for reuse, tank sizes, pump capacities, and develop a first-pass system diagram.

Van Giesen: In general, how do you determine volumes needed for flushing or cooling tower? Since typically water is not metered individually for the separate end uses, are there some general conventions that you use or do you rely on experience from other projects?

Apostolopoulos: That is a good question. There is data available especially for projects constructed in the United States. It becomes more challenging with international projects, because most of the time the data is not available and the amount of water utilized from one culture to the next is different.

In the United States, the Environmental Protection Agency has guidelines that address water use in different types of buildings. The EPA has performed studies for a number of years and has developed usage numbers per person for different types of buildings and applications. The data is available in the EPA wastewater manual. When engineering these types of systems it is very important that the data is solid, from a code or reputable source. Personal opinions and good engineering practices are not adequate and should not be applied. The EPA data was established based on the 1992 energy policy and helps establish effluent in gallons per day generated from a building. In our opinion, the data should be discounted by 20 to 30 percent when the engineering team is using high-performance fixtures.

Van Giesen: What about cooling towers, for example?

Apostolopoulos: Cooling tower makeup is typically more straightforward. The HVAC engineer will typically calculate the rate of evaporation, blow-down flow rate, and then determine the water makeup flow rate.

Van Giesen: There seem to be many approaches to designing rainwater harvesting systems in the engineering community. Why do you believe this is so?

Apostolopoulos: As long as these approaches meet the same goal—to "design a safe and reliable system" that is code compliant, in my opinion this is a good thing. Not too long ago regulatory requirements did not exist in model codes, thus it forced the engineers to become more creative, and use loose guidelines to try to come up with bulletproof systems. Lately, model codes address these systems by introducing minimum requirements. The requirements are somewhat flexible allowing the engineers to explore different technologies that suit the project best.

Van Giesen: What are some of the most common reasons that a rainwater harvesting system gets value engineered [removed] out of a project?

Apostolopulos: First it has to do with the cost of municipal water. Water is still too cheap in most parts of the United States. With the exception of some states, you can probably count on one hand where water and sewer charges are above $10 [per thousand gallons]. Water and sewer rates are relatively low. Providing water is not just a service, it's a business and it is treated like a business, benefiting the large-volume users. If the cost of the water were higher, our clients and property managers would probably not have to think twice about reusing 2 to 3 million gallons of water per year generated from rain and/or condensate. The second item is the first cost and maintenance costs of a rainwater harvesting system. Depending on how the system is designed, it could be costly to purchase and maintain.

Van Giesen: You hit the nail on the head. I know that overseas and in places such as Australia they pay several times more for water than we pay in the United States.

Apostolopoulos: Yes, that's why the rain barrel is still common in parts of Europe, in Africa, in India, and in other countries. In the United States, collection methods such as rain barrels for residential applications did not become popular until a few years ago. With proper education, water shortages, and restrictions, you see many more rain barrels nowadays, especially in the suburbs.

Van Giesen: What is your methodology for sizing a cistern?

Apostolopoulos: It's a water balance issue. Understanding the source of available water, the volume of collected water, and how much water is required for the applications, whether it be cooling tower makeup, flushing of plumbing fixtures, or other uses, the first step is critical. As a company we have developed our own software that computes supply and demand at the same time. Then we introduce different tank sizes to see how much water we can save monthly and annually. At times, the primary tank size is defined based on stormwater management practices by the civil engineer. Even then we review the proposed tank size to be sure it satisfies the building demands.

I think we all know that the secret to water reuse is volume; however, as I mentioned above, understanding your source and use points is critical. For example, if the source of water is condensate from air-handling units and the application is water introduced to cooling towers, then the tank can be a lot smaller because as the water enters the storage it can be transferred into the cooling towers. In such a case, the water reuse system can be small and very efficient. If the goal is to provide water for flushing toilets, then a week's worth of water should be more than appropriate.

Van Giesen: What do you consider the most important aspect or aspects of a well-constructed rainwater or condensate collection system?

Apostolopoulos: Reliability and water quality are critical. We are still in the infancy of properly designed rainwater pre-engineered systems. Engineers still are heavily involved in designing systems from scratch because they are not satisfied with available pre-engineered systems, selecting components and materials in order to provide a detailed design. We have had issues in the past with level switches and controls. These are typically the first components that will fail. Introducing reliable components and controls is a must. Moisture in the tank affects these devices and must be accounted for.

The development of rainwater guidelines has been important in the improvement of the rainwater reuse industry.

Van Giesen: There's no better teacher than experience in the industry.

Apostolopoulos: I don't think anything can substitute for experience. We have to keep designing systems, learn from our mistakes, and then fine-tune our designs. In my opinion, staying in touch with the equipment users is important to see how these systems perform long term.

Van Giesen: Where do you see the future of this technology? Do you see this industry as a trendy thing or is the use of site-collected water here to stay?

Apostolopoulos: I am of the opinion that in order to be successful these systems must exist in large scale. In some parts of the world they use rainwater and graywater systems simply because the infrastructure does not exist at the municipal level. In Singapore, for example, wastewater is treated to meet drinking water–quality levels and then is bottled. In the Middle East, wastewater is treated for landscape irrigation reuse at the municipal level.

However, in older cities like Boston, for example, the likelihood of recycling rainwater or wastewater at the municipal level is probably not feasible because of the required infrastructure. Currently wastewater is treated to great levels and then disposed into the ocean. With this in mind we believe that smaller rainwater harvesting systems are always going to be there. In a city like Boston, the size of the cistern is not going to be as big as maybe something that I could design in some other place, because of the amount of property that would need to be dedicated to a rainwater system.

Van Giesen: Anytime we can treat and deliver the water closer to its source there is an inherent energy savings.

Apostolopoulos: We need to focus on the bigger picture. Let's review the current process as it stands now: Water is extracted from a source and it is transported to a treatment plant. Once the water is treated, it is pumped to the building through the municipal network. Water is used in a building and as a result, wastewater enters the sewage system. At some point, wastewater will have to be pumped again to a sewage treatment plant. Conserving energy, and recycling water is a no-brainer.

We are currently using drinking-quality water for cooling equipment and toilet flushing. The planet population is rising and the demand for clean water is constantly increasing. As a result the cost of water will go up because the water treatment costs will increase due to shortages of clean sources of water.

ALF BRANDT, ESQ.

Alf W. Brandt serves the California State Assembly as an expert on water resource law and policy, as well as being Executive Director of the National Judicial College's Dividing the Waters Program. Brandt has developed and analyzed California water legislation, including playing critical roles in the development of the 2009 Delta/Water Legislation and the 2007 flood protection package. In 2007, he chaired the American Bar Association's 25th Annual Water Law Conference.

He earned his JD in 1988 from University of California, Berkeley (Boalt Hall School of Law), and his BA–magna cum laude in 1983 from UCLA.

Figure 6.3 Alf Brandt

Van Giesen: You have been involved in the politics of water for a number of years and have successfully ushered a bill related to rainwater harvesting in California law in 2012, specifically Assembly Bill 1750: The Rainwater Capture Act of 2012 (AB1750). Your perspective from the political end of things is valuable for our readership. You currently work in the State Capitol in Sacramento for Assemblyman Anthony Rendon. Previously you worked for Assemblyman Jose Solorio. You are widely known in the State of California as one of the experts on water and the history of water in California. Why is the discussion concerning the widespread use of all available water sources gaining so much traction in public policy circles?

Brandt: People in California are encountering climate change in more personal ways, and are starting to recognize the risks of climate change in our water supply and the availability of water. Californians are more conscious as to the need for conservation and careful use of every last drop.

Van Giesen: California is not a state known for its water supply, but uses a lot of water. Can you describe a little of the differences between the northern part of the state and the southern part regarding the water sourcing and usage?

Brandt: California is not as water-short as some of the other western states. In Northern California, we receive a good amount of precipitation in the form of snow and rain. The top third of the state gets two-thirds of the water supply. The bottom third of the state, which includes Southern California and some of the agricultural areas of the Central Valley, uses about two-thirds of the water. That is a historical fact known for many years. That's why we have built the most sophisticated water system in the world to store water and move it hundreds of miles through natural channels and rivers, and also through artificial conveyance pipelines and canals.

Van Giesen: So, water in California tends to shift from one basin to another. I sense a little bit of tension when I speak with people in the policy level in Northern California over how much of their water goes to the southern part of the state. These were plans developed early in the 20th century, is that correct?

Brandt: It started 100 years ago at the turn of the century, when some of the big cities went out to the Sierras to draw their water. Los Angeles went to the Owens Valley and San Francisco went to the Yosemite National Park for the Hetch Hetchy Water System. The East side of San Francisco Bay Municipal Utility District went to the Calgary River of the Sierras for its water supply. That's how it started. The water system kept being built so that all parts of the state are interdependent. The federal government built the Central Valley Project based on a state plan adopted by the legislature in 1933 and then we built the State Water Project. This project won all kinds of awards at the time for taking water from Northern California and moving it down to the Bay Area, on to Southern California, the Central Valley, and San Joaquin Valley for agriculture. This is the kind of engineering that made California famous for its water system.

Van Giesen: I remember in the lead-up to AB1750, it was mentioned that climate change is affecting storage in the reservoirs that feed Sacramento and the Bay Area. Could you elaborate on this?

Brandt: California's biggest reservoir is its snowpack. It allows us to be so productive on our water supply because it persists in the form of snow well into the summer, allowing that water to come down more slowly to be used for irrigation. Eighty percent of the developed water supply is used for agriculture. So the snowpack is critical for our storage supplies. As climate change evolves the expectation of its impacts are already starting to change.

For example, in 2007, I spoke to the Merced irrigation district as part of a testimony that I gave in Congress on climate change and water. They asked for help in dealing with the Corps of Engineers because their peak snowmelt days have moved up two weeks in ten years. That's from about 1997 to 2007. It has changed so quickly that they need to deal with their storage and to be able to store more water earlier than what was required by the Corps of Engineers. In 2007, I testified to the House Committee on Transportation and Infrastructure Committee on Climate Change, and my panel was about water. I presented to Congress a graph forecasting expectations that by the end of the century we will have some parts of the Sierra with only 11 percent of the snowpack left.

Van Giesen: Do you feel that the adoption of AB1750 will positively affect the adoption rates of rainwater harvesting in the State of California and surrounding regions?

Brandt: I think it is an important part but not AB1750 alone; it is all of the things happening around AB1750, including the California Building Standards Commission adopting building standards for rainwater capture. The Rainwater Capture Act gave Assemblyman Solorio the opportunity to talk about rainwater capture for three years. We took three different versions to two different governors (Schwarzenegger and Brown). The first two versions of the bill were vetoed for a variety of reasons, and that gave us a three-year opportunity to maintain a conversation. When it finally passed it had less substance than the previous versions; nevertheless, it provided a major message that the California legislature and the governor supported Californians capturing rainwater.

Van Giesen: Can you tell us about some the obstacles related to the passing of the AB1750?

Brandt: Well, there were a number of minor obstacles that we addressed in amendments to the bill over the years related to the governance: Who is in charge, who controls what aspects of the installation, what is the responsibility of the water agencies that have drinking water systems, and who will watch over these rainwater systems? We had to address issues related to responsibilities and authorities involving the rainwater systems. The biggest obstacles were those individuals who perceived rainwater capture as a risk to public health. Despite a number of studies that challenged this statement, they remained firm and concerned, especially about the decision of allowing rainwater capture inside buildings. That is why, in the end, AB1750 was narrowed substantially because of the opposition from public health advocates and certain committee staffers as well.

Van Giesen: I do a lot of work around the United States and I see the same kind of fears brought up again and again, and the same kind of arguments have to be used in order to show that rainwater capture is safe and that there is a lot of evidence to suggest that.

Brandt: Let me emphasize that. With the development of the buildings standards and public health requirements, rules have become clear as to what protects public health. These rules give confidence to the public officials that as long as they comply with the regulations, rainwater capture is no longer a public health issue.

Van Giesen: That confirms that the development and construction of the California Plumbing Code was able to quell some of the fears about this technology. In a previous conversation, you mentioned that one of the top public interests in Solorio's district, which is in part of Orange County was rainwater harvesting. Can you elaborate on this topic?

Brandt: When Assemblyman Solorio first introduced rainwater capture legislation, he was intrigued about management of water in Southern California. He had been on Water Boards and dealt with stormwater issues and stormwater quality. He saw the opportunity to use rainwater to help on the supply side as well as on the water-quality side. As time went on, he kept running into ordinary constituents in his district who would talk to him about how wonderful rainwater capture is and how it is taken for granted.

In 2010, he conducted a poll and one of the questions was, what was the most important thing that Solorio had done. Rainwater capture came in number two among twenty-five issues. Fifty-five percent of the people who answered that survey stated that rainwater capture was one of the top three most important things that Jose Solorio had done. It came in number two, just behind dealing with gang-related violence. That was a significant push and made him think, " I guess people really do want this," especially in ethnic communities, like the Vietnamese community, which is rather large in Orange County area. Vietnam has a strong history of using rainwater, and when they come to this country they ask, "Why aren't we using it here?" This community in particular gave a lot of support for AB1750.

Van Giesen: I think that this is a fascinating statistic. How important is it to maximize local resources before spending lots of money? For example, a reservoir is built at the bottom of a watershed to collect water that is to be distributed from a central location, and this water may travel long distances. What are some of the benefits of sourcing this water locally in conjunction with, or as an augment to, sourcing water from distant places?

Brandt: California has built the most sophisticated water system in the world. I don't think we will ever walk away from that investment; it will continue to be an important part of the way we get water. Rainwater capture can be a significant piece. Look at what is happening in the City of Los Angeles as far as their estimation of rainwater and stormwater, and how much it might be able to produce in terms of water supply in the coming decades. We will not be able to rely on rainwater capture completely, especially in places like Southern California where an average precipitation of 14 inches per year is just not enough to provide water supply. In Southern California we get a third of our water from the Delta. Rainwater capture can be a significant part to improving regional self-reliance, which is a part of California law about reducing reliance on the Delta [Delta Reform Act of 2009]. Water self-reliance is also about investments on the local and regional water infrastructure, and that is something that Assemblyman Anthony Rendon is advocating. A piece of regional self-reliance is rainwater capture.

Van Giesen: Can you elaborate on the lateral legislature efforts that support what you are talking about?

Brandt: I don't know whether there will be legislation specifically targeted to rainwater capture, which would include property by property. Legislation may be directed to projects like stormwater capture. These projects might include the capture of water that originates in Southern California, directing it toward settling basins and groundwater. That may be a part of what we are looking at, in terms of legislation in California concerning water.

BOB DREW

Bob Drew is founder of Ecovie Environmental LLC, a water management company focusing on rainwater collection systems. In addition to leading Ecovie, Bob is president of the nonprofit organization, SERHSA (Southeast Rainwater Harvest Systems Association) and is a former member of the board of directors of ARCSA (American Rainwater Collection Systems Association).

Bob Drew has also worked closely with the City of Atlanta Department of Sustainability on the ordinance for residential potable rainwater. He holds a BS in Chemical Engineering from the University of Wisconsin and an MBA from UCLA.

Figure 6.4 Bob Drew

Van Giesen: Speaking as a business owner in the rainwater harvesting field with an engineering background, tell us a little of your experiences with architects and engineers on the projects you've been involved with. Please elaborate on how future designers can build better systems.

Drew: As an engineer, rainwater harvesting looks pretty straightforward and pretty easy and in many ways it really is. However, there are a lot of little things to know to make this system work reliably to meet particular applications. My main point here is to encourage prospective architects and engineers to work with experienced designers and installers before jumping into the design of a rainwater harvesting system. You need to learn those little tiny things that can trip you up and make the system a headache to work with, and you need to make it work really, really well from the start. It goes back to basic design.

The other point is to think about all the different people who will come into contact with the system. What are the maintenance requirements? Is the system easy to maintain? Is the system easy to understand by the users? Is it an apartment building or a private home for indoor nonpotable use? Is it really kind of easy to understand and hopefully trouble shoot? Some projects are over-engineered. My advice is to keep the design as simple as possible, make it reliable, and make it so it works and meets whatever the needs are of that specific project.

Van Giesen: You touched on something that's fundamental in an emerging industry: a multidisciplinary approach. Who are the major players who would typically be involved in a rainwater harvesting system?

Drew: We work with MEP contractors, mechanical and electrical plumbers, on the inside of buildings. For outside of the building, we work with civil engineers, because of course, rainwater is a BMP for stormwater management. The general contractor's people may have a little less intricate knowledge of the specifics of the system than a professional installer. Of course, at a higher level, the architect tries to integrate the design into the overall building design and coordinate that with the general contractor.

Van Giesen: Do you interact with mechanical engineers on some of your projects? Or do you more so with the contracting end of the project as an installer?

Drew: I interact more with the contractors who are at the lower level, except when we are talking directly to architects at the front end. I very much prefer to be involved as early as possible in the process.

We've come into many projects where we're brought in too late, and a lot of decisions have been made and we have to undo things that are just plain wrong, and will not work, primarily drainage. We are also called when systems have been over-engineered or overbudgeted, particularly in stormwater management. We also are contacted when rainwater harvesting is an add-on after the fact.

Van Giesen: So, early involvement in the design as early as possible, like any good solid design, helps in developing a better plan.

Drew: An early review of drawings to see where rainwater would fit in would not take a lot of effort or money and would probably save a lot of capital cost and a lot of headaches down the road.

Van Giesen: What are some of the more common commercial indoor nonpotable uses for rainwater?

Drew: Toilet flushing is probably first and foremost for indoor use. I'm not sure if you count cooling tower makeup as indoor or outdoor, but that certainly would belong on the list. We have been recently more involved in combination rainwater/graywater systems for laundry applications like hotels, coin-laundries, resorts, that sort of thing, where rainwater can augment the recycling of used water from the building to be treated and be brought back into the building.

Van Giesen: Can you provide your perspective on the definition of reclaimed, reused, recycled water versus rainwater?

Drew: Well, whenever I hear the word "reused" I automatically think of graywater or blackwater, for example, recycled water. Reclaimed water primarily makes me think of wastewater treatment plants. Rainwater collection is not "re" anything, any more than other typical water sources like water from reservoirs or wells! If you call rainwater collection recycled, *all* water is reclaimed, recycled, reused, because hydrological cycle being what it is, it's all been used or done something in the past.

Van Giesen: I think that's important if you would agree with the definitions. If the rainwater is referred to as reclaimed, reused, or recycled, it may have to adhere to certain protocols that may not be appropriate or necessary.

Drew: Let me just diverge a bit. I have a background in process engineering in the paper industry. The way you optimize water use in a paper mill, which can use millions of gallons a day per paper machine, is to match the water quality requirement to the way you treat it. So you don't use super clean water with something that can get by with something not as clean, and that has an impact with conserving chemicals and water. That applies very well to what we're talking about here.

Any water supply can be treated to potable use. In the current typical surface water system, rain falls on the ground, goes in a river or reservoir, gathers a lot of junk, and then requires a higher treatment than if you collect it and use it right away. With rainwater, you match the treatment and use requirement. You shouldn't need to treat things to potable, or microchip treatment levels, if you're just watering the lawn or flushing toilets.

Van Giesen: Do you see any future technologies that might improve the industry?

Drew: One big thing that I see happening is a lowering of the cost of a system. There have been changes with filtration, treatment, tanks, and pumping systems that are reducing costs. Equipment, pumping, controls, and backup systems are becoming more reliable and require less maintenance. As the number of systems installed increases, the number of people who know what they're doing increases as well.

Van Giesen: Vendors sometimes quote just the installation of a part of a system such as a tank or filter but not the pumps. How would you advise the consumer or design professional who is proposing a rainwater harvesting system?

Drew: They need to know that a complete rainwater system includes collection, conveyance, pre-filtration, storage, delivery, and in the case of indoor non-potable, probably treatment. You have to have all of these elements, or it's really not a viable rainwater system.

Van Giesen: You have been involved with some policy work on rainwater harvesting and you were instrumental in the development of the potable rainwater policy for the City of Atlanta, which was the first municipality in the United States to have its own potable rainwater code. What are the major obstacles you've encountered, not just from a client basis, but also with policy makers and higher decision makers?

Drew: In almost every case, it always comes back to having the appropriate knowledge. Many people believe that water falling from the sky is toxic and it's going to hurt you. They believe that if you can't do the magic that the guys at the water department know how to do, it will hurt you. They also believe that rainwater collection just means rain barrels, not a water supply big enough to really make a difference in a property's water supply. Water departments, big civil engineering firms, reservoir builders are not necessarily on board with changing the way we are receiving our water now. Rainwater should not be a threat. It is both water supply and water management for stormwater.

Van Giesen: There is a difference between how practitioners who work in stormwater management and those who develop rainwater harvesting systems designs for first-flush water on a site. How do you design for first flush?

Drew: From a stormwater management perspective, the first inch of rain that falls is considered first flush. Stormwater management usually requires the water to be captured and cleaned naturally through infiltration basins and by the natural environment. From the rainwater harvesting perspective, system designers often recommend discarding the first flush of a rain event.

First flush depends on rainwater patterns, as an area with frequent rain will have a cleaner roof surface. For example, in the Atlanta area where it rains hard every ten days on average, a rainwater system may not require first-flush diversion. If you're in Texas, where you might have three months without rain, "stuff" (bird droppings, dirt) accumulates on the roof.

An estimated ten gallons per one hundred square feet is used to estimate first-flush loss if the water is discarded. First-flush capture and treatment is usually important when designing a potable system or to maximize the amount of water collected. Basically, this concept and the resulting system design is very regional and depends on whether the system is for potable or nonpotable uses.

I've heard of systems where a first-flush tank is included in the system, but that requires maintenance and cleaning and so forth—a whole different can of worms. I do not recommend first-flush release universally, as you may not need it for nonpotable systems, but I do always recommend pre-filtration.

Van Giesen: Tell us your thoughts on return on the investment of rainwater harvesting systems.

Drew: The ROI of a rainwater harvesting system beats the stock market and has less risk in many cases. It is very important to include all the actual cash flows of a system that include the avoidance of the capital costs of stormwater management and savings on your water bills.

NICOLE HOLMES

As a Project Manager at Boston-based Nitsch Engineering, Nicole's primary focus is on green infrastructure, stormwater master planning, and innovative stormwater design, and is a frequent speaker at regional and national conferences on topics including green infrastructure and rainwater harvesting. Nicole is co-creator of a software program that simulates scenarios to optimize rainfall capture and reuse systems.

Figure 6.5 Nicole Holmes, PE, Leed AP

Van Giesen: Regarding civil engineers' involvement with the Clean Water Act and regulations concerning impervious surfaces, what is the role of the civil engineer in relation to watershed management?

Holmes: Civil engineers are responsible for designing site drainage and water and sewer systems. We've been responsible for providing a stormwater management strategy for a given project. Historically that's been somewhat lax, where we've basically been responsible for just minimizing impact of the development, designing things like detention basins to prevent downstream flooding and match the stormwater impact. However, the sustainability movement and the strengthening of regulations are really helping to raise global awareness and to encourage or require civil engineers to responsibly manage stormwater. We are responsible for obtaining permits for stormwater management systems and permitting is getting more difficult due to strengthening regulations.

Every time it rains, water and any pollution that it contains is captured and, in urban locations, sent through piping systems through streams and rivers. On an undisturbed, natural site, that first inch or so of rain would be absorbed and you would not get any runoff. So the question is, how can we mimic that condition? What we engineers do is take that first inch or so of rain and reuse it or get it back into the ground and evaporate it, and in essence, not discharge it. Engineers who have worked on green building projects, those who have a high aspiration for achieving LEED® or some other sustainability goals, understand this new practice. In the future, these new stormwater practices are anticipated to become mainstream.

Van Giesen: Historically, stormwater management schemes, on the parcel level, have focused on detaining water for a certain amount of hours, and then slowly releasing it, not so much focused on getting it back into the ground. Have you seen in your career a change, strengthening, or tightening of restrictions as what could be done on the parcel level?

Holmes: You know, nationwide there's a federal rulemaking in the works and it's based upon some of the work being done in the Chesapeake Bay, by the Center for Watershed Development. The concept is to manage the first portion of the rain, referred to as the 90th or 95th percentile (around an inch to an inch and a half of rain). With the president's Energy Independence Security Act, EISA, all federal buildings above a specific size are required to retain, infiltrate, and evaporate, or reuse the rainwater that falls onsite. The draft LEED® version (it will be out soon), has also adopted that requirement.

Van Giesen: What do you do in highly impervious urban areas where water infiltration is difficult? When the soil condition is not available, but you still have to meet those requirements, what are some of your options?

Holmes: In these cases, the design engineers' options become much more limited. However, that's where development is occurring, redevelopment in most of our urban areas. Nevertheless, whatever site you may have, you can specify pervious surfaces or porous pavement. You can design a green roof, or you can harvest rainwater, or you can provide a combination of both. In many cases, poor soils actually restrict infiltration, especially in some urban areas. Rainwater harvesting is one of the top choices on the list, if you want to meet this goal.

Van Giesen: Focusing on rainwater harvesting, what are some of the bigger obstacles you see to being able to use collected rainwater back inside the building?

Holmes: One of the biggest issues is with the stormwater design because now the civil engineer actually can't deal with this system on their own. It has become part of an integrated design process within the green building systems; it takes a team effort to design a stormwater management project. Now civil engineers can't work in their silo next to the plumbing engineer, next to the architect, next to the owner, next to the person who is going to ultimately operate this system. We actually all need from day one to sit around the same table, and figure out how we get this thing to work. In the end, yes, the civil engineer will perform the stormwater management calculations; however, others on the team will have an equal hand in the design, the permitting, and other various elements. In the end, in order for a project to be successful, it needs to be integrated.

Van Giesen: This collaborated interdisciplinary effort is very good. We were chatting earlier a little bit about the concept of first flush. Could you briefly define, from a conventional stormwater perspective, what first flush means for a civil engineer?

Holmes: The term "first flush" is a relatively typical concept in the world of civil engineering. If you say first flush to a civil engineer, they will think that you mean the volume or the depth of rainfall that falls on a given site and picks up the majority of pollutants from the surface when it is converted to runoff. The first-flush volume is the amount of runoff you need to treat. For example, if you would ask me what the first flush is in the State of Massachusetts, under the Wetlands Protection Act regulations, I'd say half an inch for all areas, and one inch in a sensitive area next to a wetland. Many times, we address treatment through infiltration or some sort of other volume-reducing BMP. We can simply design a package treatment system, a manufactured treating device to treat the first half-inch or inch of water to remove 80 percent total suspended solids, or 40 percent phosphorus (these are terms you hear when talking about stormwater); however, many studies prove that landscape and soil-based systems, such as bioretention, are most effective at addressing water quality. Removal of this volume of stormwater through reuse is also an effective treatment strategy. Stormwater regulations require you to achieve a certain amount of treatment. The volume of water that we need to treat to a required water quality standard is what we refer to as first flush.

Van Giesen: So is there a particular period within which that water must be dealt with if it goes into an infiltration? How many hours must it take to completely infiltrate, to be ready for the next rain event? Are there any details related to that or any time frame?

Holmes: If you're designing infiltration and detention ponds as BMPs, almost all of the regulatory manuals require that the runoff be managed in a typical period of seventy-two hours, arranging between a two to four-day drawdown required for infiltration type BMPs. It's not yet clear, and I don't necessarily know if it would be as specific of a value when you talk about rainwater harvesting, because it would vary. For example, in Boston we can conceivably say that we get a precipitation event every four to five days. It could be 0.1 inches on Monday, and then 0.2 inches on Friday. I would argue that it's acceptable to justify using a rainwater harvesting system as stormwater management if you can figure out the average frequency of rainy days and show that you're removing your volume based on the amount of demand within that period. I think the whole seventy-two-hour drawdown has a lot more to do with the science of soils, and being able to dry out enough to accept the next amount of water. However, I think that the debate about the appropriate drawdown period is yet to be determined in the world of rainwater harvesting and stormwater calculations.

Van Giesen: So the main point is to leave some space, so to speak, either in a container, or in the soil, that the new or next rainfall can go into. As you know, the American Rainwater Catchment Association and practitioners use the term "first flush" in a slightly different context. If you could, please speak about how those two interpretations can potentially conflict and differ from one another.

Holmes: I have only recently become familiar with the ARCSA term, and at first, it was confusing. When I actually looked into what the devices were, I realized the other word sometimes used is a roof-wash system. In any case, it's obviously a far lesser depth of rainfall when rainwater harvesting systems refer to first-flush treatment or capture. It's really about what's the appropriate depth to flush out those initial solids from the system, not necessary all the pollutants. I think that they drastically differ and they need to be clarified. It would be a huge mistake if someone mistakenly sized the ARCSA first flush as a half-inch or 1 inch, because you would no longer have a rainwater harvesting system. For example, in the Northeast, 90 percent of rainfall events generate 1 inch of rain or less. If you start pulling that out of the system, you might as well not have a rainwater harvesting system. That frequent small depth of rain over your rooftop is what's going to sustain and fill the tank repeatedly. You almost want every drop of water; I understand there may be a fraction of inches that may potentially be diverted. I would argue that there's better ways to get what you don't want in the tank out.

Van Giesen: Some of the origin of that concept of the first flush in terms of technology comes from a lot of research and studies done in Australia; it simply indicates that if you can remove that first flush of the relatively more dirty water from the cistern, you're better off. However, as we move into larger commercial systems, it's significantly more problematic, both for the practical implementation of the technology as well as for maintenance. From your perspective, what are some of the more innovative technologies for stormwater management that you have seen?

Holmes: There have been combinations of stormwater management integrated with rainwater harvesting that I think are interesting. In one of my projects, we worked with a very multidisciplinary team; we had a very strong focus on sustainability in the building as well as this functioning landscape to also address stormwater. On that given project we actually did divert the first-flush stormwater, the first half an inch. We had water coming from a portion of the roof from the plaza area into a pipe. Then we actually diverted the first half an inch through a water element that had floating aquatic plants that provided a treatment function, and allowed additional solids and sediments to settle along the bottom of the water. The water that overflowed was clean and introduced into the tank.

We invented this first-flush concept in collaboration with the architect and landscape architect; we didn't lose that water. Maybe we did lose a little bit due to evaporation; however, we used a natural system to do our filtration as opposed to an off-the-shelf system. We were sort of mish-mashing concepts that we're familiar with in environmental engineering, such as phytoremediation, with the types of devices that we use to pre-filter the water, and we were very comfortable with the quality of the resulting water.

Van Giesen: I think those are the types of technologies that are going to drive these innovative projects. Sometimes the most unlikely technologies can be employed to reduce the suspended solids, dissolved nutrients, and even dissolved minerals that might come off these surfaces.

WILLIAM (BILL) F. HUNT III

Figure 6.6 William Hunt

Van Giesen: You've been involved in the design of stormwater systems for some time now and you are one of the authorities in the field. You teach, you write, and lecture on the subject, so what were some of your motivations for developing expertise in this area?

Hunt: My job is to look at the whole breadth of potential stormwater management practices. I got into it around 2004, 2005. Two years prior we had a modest drought. It dawned on me that rainwater harvesting systems might have some stormwater benefit and they could be used in the humid southeast. The main reason is I thought it might be another tool that our designers and our stormwater practitioners could use to manage stormwater runoff.

Van Giesen: When most people think about rainwater harvesting, they think water supply, and certainly that's an important point. But you're touching on something that's important as well, the connections between rainwater harvesting and stormwater management. What is the short version of how that ties in?

Hunt: A rainwater tank can have multiple purposes, although supply is perhaps the primary driver. There are many potential stormwater benefits associated with rainwater capture, such as peak flow mitigation, reducing flooding and also nutrient reduction. You collect the water, then you can use it for landscape irrigation and that water soaks into the landscape. Or, you can flush toilets with the collected rainwater. That's water that's no longer in the stormwater runoff. If you use math at a big scale you realize that your piping conveyances can shrink and all of the infrastructure can get much smaller. So the trick is that stormwater/rainwater harvesting systems are probably going to be configured somewhat differently. They are still going to have a tank, they're still going to have a pond, they're still going to have gutters and collection system, but the way you design the storage and even the size of the storage may be different if you're going to focus on stormwater management. You can have a dual purpose system (i.e., stormwater management plus water supply).

Van Giesen: I was recently doing a public presentation to a non-professional audience in terms of rainwater and stormwater. We installed a small rainwater/stormwater catchment system on a church, and I was going through the presentation and found that it was very difficult for the public to grasp the concept that the tank needs to be empty before the next rain event. They asked: "Why would you waste water?" How do you explain this concept for the general public?

Hunt: First, you know that most of the people that install a private or residential rainwater system are almost always doing it for the water supply. I don't even fight that battle. Honestly, what they want more than anything else is a reliable water source. The water is there when they need it.

The concept of emptying the tank before the next rain event is really for the next level up, small commercial sites or for extremely big systems such as a big industrial park. It is for those projects that have to comply with nutrient removal requirements because of watershed protection rules.

In North Carolina, for example, people do generally relate a little bit more, because it has been a big issue in our state since 1995 or 1996 with fish kills. Now many people know that nutrients caused it. So the fact that the states can also manage stormwater does make sense to a person in our field, because we've been trying to capture and treat it for nutrient reduction since 1999. It actually has a profound impact on the use of these stormwater management systems.

But to convince them, it comes down to saying, "O.K. you're building this new building in downtown Raleigh, or downtown Charlotte, and the rules say you need to treat the stormwater runoff." Well, the designer will be scrambling for a solution. Maybe they don't want to put in a pond, or the site might be too urban to put in a rain garden or a bio-retention cell. They might look at a green roof, which is a possibility, or something else, and that something else is a rainwater harvesting system, which is designed specifically for stormwater management with the idea of supplementing potable water. One good thing about a rainwater harvesting system is that it can eventually pay itself back.

Now, whether or not it's on a reasonable lifecycle or a payback period, is a different question. But at the minimum, at least it can partially pay for itself. And once people start doing the math it's not hard for them to say, "I think I want to use a rainwater harvesting system." That is the most economical alternative. That is the key for me.

Van Giesen: There are a number of different code bodies and code organizations and I'm involved in some of them at the committee level, and they are working on the definitions of rainwater and stormwater. Water from the roof which is directly tied into a downspout, which is tied directly into a stormwater system; will that water carry the same types of nutrients water from a downspout flowing out onto the ground?

Hunt: I pretty much live up to a universally accepted term in government and academia. We have defined rainwater as being roof top runoff. Stormwater (rainwater is included in it) falls on the driveway, on the grass, on the field or whatever. When we say rainwater harvesting we are restricting the exposure of water to rooftop surfaces, which are by and large free of certain pollutants at high concentrations, whereas the stormwater can have certain pollutants at very high concentrations, which leads to the next question.

Unless the roof is made up of materials like zinc plate or something, water that comes off a roof is going to be subject to two pollutant loads that may be comparably high in a standard landscape. One is nitrogen, and numerous studies in Louisville, KY, Charlotte, NC, and Austin, TX, have shown that between 70–90 percent of nitrogen in an urban situation is atmospherically deposited. It means that when we drive a vehicle, we're releasing nitrous oxide, and that stuff is going to precipitate. It's in the rain, and it's in what you call dryfall, it's in the dust. It doesn't matter if it hits a roof, a parking lot, or a driveway, the nitrous oxide will be there. The second pollutant is pathogens, mainly because of birds. *Basically every other pollutant that comes off a roof, generically, is lower than what you see in standard stormwater runoff.*

Van Giesen—So what you're saying is that we can sequester some of that nitrogen by capturing it and bringing it back into the building and flushing it through the sewer system, and some of the nitrogen will be treated at the plant.

Hunt: That's right, it will be treated at the municipal waste water plant. We are often seeing some nitrogen settling and transforming in the tank, so as the water sits, it also has the ability to loosen the nitrogen concentration through dilution. The tank itself provides some of the treatment.

Van Giesen: I was not aware of the nitrogen atmospheric deposit. You actually covered a number of questions in that one response. So, to segue a little bit, what do you see as some the latest technological advances in the industry at large in terms of components, strategies and techniques?

Hunt: I will talk about strategies. You are going to see rainwater harvesting in big scale in urban and sort of the ultra-urban environments, especially where they have combined sewer overflows, CSO's. These are more common in the northeast or the Rust Belt. CSO's occurs when the rainwater and the sanitary sewer merge and all that water goes into the treatment plant. That's fine in small storms, because the treatment plant can handle a small storm runoff.

Basically, the sanitary sewer mixes with rainwater and stormwater and is treated. But if it's a big storm, it overwhelms the capacity of the wastewater treatment plant. For example, if this water shoots out to Lake Michigan, it can have a huge public impact with health implications. It's important to note that the amount of water that a wastewater treatment plant can handle is flow based. If you can spread water out, then a wastewater treatment plant will be able to accept a larger fraction of the storm, perhaps the whole storm, without causing a public health issue associated with discharging raw sewage mixed with stormwater.

Why am I giving you this background? Because there are technologies associated with rainwater harvesting that allow the tanks to draw water out *in advance* of storm events, which is pretty important because even though you are releasing water out and you are combining it with the sewer system, it's going at a time when there is no other contribution of rainfall. So, if you know it's going to rain one inch and your tanks don't have a potential to catch one inch, then real time controls will actually draw the water down, so that this full inch of rain can be captured in the tank. It's drawing the water down by releasing the water in advance of the storm arriving, let's say in the city of

Chicago or the city of Milwaukee. That means that the wastewater treatment plant is seeing water at an elevated level because the tanks are drawing down, but not at the level that would overwhelm the wastewater treatment plant. We will see a lot of this technology in the future. We will see big underground rainwater harvesting systems and cities are going to take advantage of this smart release of water.

Van Giesen: So, what kind of technology is going to be employed to control those release mechanisms?

Hunt: First of all, you have to know the level of water in your tank. Then you need a system (a computer) that talks to the National Weather Service, which became very good at predicting upcoming rainfall amounts, particularly outside the summer season.

Van Giesen: Are these predictions inside a certain number of hours?

Hunt: Yes, within 30 to 36 hours. For example, the Weather Service will communicate to the computer in the tank that there is a 30 percent chance that we are going to have ½ inch of rain. Let's assume that ½ inch of rain delivers 2,000 gallons of water, but right now the tank only has capacity to collect 1,200 gallons. That means the free area is only 1,200 gallons. So based on the number of gallons in the tank, the computer in the rainwater system will open up a valve that will spew the equivalent of 800 gallons of water for the next 20–24 hours, *in advance* of the rain event. This way the tank can get its full 2,000 gallon storage need, which was what was predicted by the National Weather Service 30 hours prior.

Van Giesen: Are there professionals who can actually program these things?

Hunt: Absolutely, and right now there are not many of professionals in the game, but as this becomes more popular, you're going to see more and more people offering these services.

Van Giesen: I am familiar with the Boston Sewer Commission, stormwater requirements in Philadelphia, New York City, and cities on the east coast.

Hunt: Right, CSO cities. You go to New York, and you design a stormwater system, all they care about is the flow rate. So if you get 1 cubic ft./second/acre, all systems have to be designed to release water at that rate. A rainwater harvesting system can be designed with smart control and other passive devices. In New Zealand we see these very popular systems called dual-purpose tanks. It comprises of a tank that is divided into two different quadrants. One is a reservoir for harvesting water, and the second one is a combined retention release/harvesting reservoir. How they do that is by drilling a hole in the tank. I've oversimplified it, but basically you put a very simple device, that has a hole in it, and that hole is designed to let water out over a three-day period.

Van Giesen: So, in these types of systems being able to use the water indoors is almost like the icing in the cake.

Hunt: That's right, the icing! If you can combine a real-time control device on your tank, and at the same time you're pulling water from your tank to flush toilets, for example. That means that you would use your real-time control a lot less frequently, because your tank or system may have excess capacity to capture more of the next rain event. More and more people want to bring rainwater inside, they say, "I don't want to have to restrict myself to only outdoor use." As codes change you're going to see more indoor usage for collected rainwater.

Van Giesen: Let's assume the definition for stormwater is water that has already left the roof and may have flowed over parking lots, walking surfaces, or what have you; is it possible to treat that water onsite to level that it could be used for non-potable use indoors? Do you see that happening?

Hunt: Yes, I do, but will not be convenient at every site. You may not be able to get a simple filter that can treat that water.

Van Giesen: You've seen a lot of different types of systems here in North Carolina; what do you perceive as the most important aspect of a well-constructed rainwater harvesting system?

Hunt: I think the most important aspect is a reliable demand. I'd much rather see a system that uses all the water from the tank than have to dump it in the advance of a storm event. The lack of reliable demand has led us down to these other designs ideas, which I think have their place, trust me. But having a reliable demand is what makes the best system the best.

Van Giesen: That's very interesting, reliable demand. What are the most common mistakes you've seen during conceptual planning related to this technology?

Hunt: People just underestimate what their demand is or flat out don't know what their demand is, and the tank runs full. From a stormwater management perspective, having that tank run full 50–60 percent of the time, even from a financial standpoint, is not efficient. We had a tank that over the course of one year just spent three days at 30 percent full, and the remaining of the year was sufficiently higher. We had another tank that spent almost a month at 45 percent full, and during the other months it was 50 percent full. That means that the tanks are not being used, and that you spent a lot of extra money in getting these bigger tanks. Two things are clear, one, the tank could've been 45 percent smaller, for example, and the other thing is, from a stormwater management perspective it does me no good, because if the tank remains full then the rain is just going to bypass.

Van Giesen: What role do you see higher learning institutions playing in the promotion of this technology?

Hunt: Higher institutions of learning should try to marry disparate ideas and share them. We have looked at water systems and water supply and now look at stormwater management as a part of it. The role of a higher-level institution is to push ideas and determine if these ideas are going to be potentially feasible. In the end, the marketplace determines what is feasible. The university needs to produce technologies, whenever possible in concert with the private sector and push technologies to see how well they work. We need to disseminate ideas, make sure the public knows about them, and not just other academics. Let the public who know a thing or two about the market see how good these ideas are.

Concerning the rainwater industry we need to devise reliable and small technologies that clean water to the point where it can be potable. If we devise a way to treat sufficient quantities or flow rates and make them potable, that will be fantastic! That's the type of thing that's actually beyond what I do; it is in the realm of the electrical engineering or hardcore environmental engineering perspective. Those are the types of things that universities should do, bring new technologies out, study them rigorously so that they're well vetted from a physical or pollutant removal standpoint, and then make sure that the business people have the opportunity to market these products. Let the market determine whether the ideas are worthwhile or short-lived.

LUTZ JOHNEN

Lutz Johnen is managing director of Aquality Trading & Consulting Ltd, providing rainwater harvesting and graywater technologies to the United Kingdom and French markets. He has more than eighteen years of experience in advising engineers and architects on rainwater/graywater system designs and integrating these new water technologies into, for example, attenuation and fire-fighting systems. Lutz was chairman of the UK Rainwater Harvesting Association (UKRHA). He is a member of the Green Building Council UK, the Fbr (German rainwater harvesting association), as well as American Rainwater Catchment Systems Association. He is a member of the British and European Standard Committee on rainwater harvesting and graywater recycling.

Figure 6.7 Lutz Johnen

Van Giesen: How important is rainwater as a source of water both in the United Kingdom and in Europe in general?

Johnen: Most of the United Kingdom relies on rainwater as a supply source because the reservoirs are one of the main sources of main water supply in the United Kingdom. Therefore the United Kingdom heavily depends on rainwater, which is very nice because it rains on average twelve days a month all year long. There has been a nice replenishing rate but unfortunately, due to climate change, the reservoirs are not replenishing as they should. So, whenever we have a dry spell over a couple of months, it immediately causes big issues for the water companies. On the continent [Europe] it's not as bad because countries like Germany rely on other sources such as groundwater (aquifers) as supply, and therefore it's not immediately noticeable when there's a dry spell. Nevertheless, we all depend on rainwater to replenish aquifers so over the long term it will have an impact. The predictions are that we will see more water problems in Europe because of climate change. Wetter winters and drier summers will be more common along with heavy storm events as opposed to nicely distributed rainfall.

Van Giesen: Historically, what are some of the obstacles that you've faced over the years to wider-spread adoption of rainwater harvesting?

Johnen: Historically, it's probably the fear of using nontraditional water sources. One point is probably industry related, that you have water companies running the water supply as a centralized organization. They don't want anyone to interfere with what they do. Especially because they have all the infrastructure already built. So the biggest barrier was that the water companies were trying to not allow rainwater harvesting, although the people like the idea of recovering rainfall from roofs and using it. The water companies put up a big barrier, especially in Germany, under the banner of water quality–related issues and possible contamination of the mains water supply, which of course in the past was a big problem. The industry had to educate the public in the beginning by giving constant seminars on how the systems work and how reliably they perform to overcome the obstacles.

The second point was probably the payback periods because here in the United Kingdom the water prices are quite low, compared to some other areas in Europe. Therefore, a lot of people concluded that it doesn't make much sense. Developers, the driving force of the building industry, don't see rainwater systems as something they can sell to the end user. The other element that water companies introduced as obstacles was energy consumption. But since the industry published the standards, it's been easier to talk about rainwater harvesting as a proper technology.

Van Giesen: Has the installation of more and more rainwater projects caused a larger degree of acceptance in the public realm?

Johnen: In France, rainwater harvesting was forbidden, because the water companies were concerned that they wouldn't get paid for any water mains connection. You might know that France has four dominating water companies. It is almost a complete monopoly.

The water companies were lobbying on the governmental side against rainwater harvesting. However, what started to dribble in was that all of the surrounding countries were supporting rainwater harvesting. Luxembourg, Germany, and Switzerland—they all had financial incentives in place on the governmental side. There was a little bit of a discrepancy between countries. On one side of the border one country says, "You can't do this at all," yet on the other side, the other country will give you money to do it. That's where the French policy started cracking because the French individuals do not like to be told by the government what to do. They like their freedom. People started installing rainwater systems on their properties without telling water companies. The government started to be more aware of the issue and even they realized, "Well, it can't be that bad." So they turned around and allowed it for domestic use but didn't allow it for commercial issues. Now, two years down the line, they are revising that, so commercial use is allowed. So, that's just an example from France.

Van Giesen: It's interesting that you recount the story, because water politics is big money in United States as well.

Johnen: Any water company that tells me that they love rainwater harvesting—I always ask why. Here in the United Kingdom, water companies are forced to implement and invest money into water efficiency measures. They are supposed to support and not discourage water efficiency measures. But behind the lines these same water companies create obstacles and say something like: "Oh well. . .you need to consider the energy elements associated with rainwater harvesting and the water quality issue. . . ." So they are not officially saying that it is bad, but they try to counter it on a different level, by putting fear into people.

The German water companies tried to do the same thing—they put out newsletters printing parts of the standards out of context and literally turning them upside down as a way to make people afraid of rainwater harvesting. The German Rainwater Association had to clarify that the standards were misinterpreted and taken out of context. These are some of the barriers that we are getting from some circles.

Van Giesen: At the 2011 ARCSA conference in Portland, you gave a public policy presentation. In that talk, you gave some history about the disparate codes and policies in various European countries. Are some of these issues still ongoing?

Johnen: Unfortunately, it's still going on. Some water companies are investing in research to find out if there is potentially real money in rainwater harvesting. The third biggest water company in the United Kingdom is conducting a four-year university research program to study the economic impacts of introducing rainwater harvesting on a large scale. They calculated that they would need to install a system for £700 (approximately $1,085) to make it viable as an option compared to a new reservoir. They interviewed about 4,000 customers to find out if rainwater harvesting is an effective option or not. Two or three out of sixteen water companies are conducting similar research.

Recently, a competition law came through which was designed to break the water supply monopolies. Now the companies are allowed to go into other companies' areas and attempt to sell to their clients and therefore the water companies are also looking for different ways to protect their territories or potentially to enter other territories. One way is that they are looking for ways to sell a single rainwater harvesting system or group of systems to residences. But I don't think we will see this yet on a big scale for a couple of years.

Van Giesen: As a business owner, do you see your involvement in policy issues as an important aspect for the longevity of your business?

Johnen: Absolutely. From the start, I saw it as one of the big things in rainwater harvesting. You have to be a little bit of a pioneer; you have to go out there and "preach" and tell people what's so good about rainwater harvesting. The market in the United Kingdom is at the moment only 5 percent of the German market, although we have the same amount of construction activity. We still have a long way to go.

Van Giesen: It requires a lot of marketing and education to change minds in a new industry. What is your best method to size a cistern for a rainwater harvesting system?

Johnen: First, you have to separate the different types of buildings according to their sizes. You will base the amount of time you will spend calculating the tank size based on the size of your project; for example, if you are working with domestic single-house dwellings, or middle-sized commercial, or a large-scale commercial. In terms of sizing cisterns, there is a fine line between the time and money that you can spend in designing the tank.

In a domestic home where a system can cost £2,000 (approximately $3,000), you can't spend £500 (approximately $800) just trying to figure out what the tank size is. On a commercial-sized system, where you are looking at a £100,000 (approximately $155,000) or a £300,000 (approximately $470,000) project, it may be worthwhile to spend £1,000 (approximately $1,600) on calculating a cistern size.

The British standards publication has simple graphs for domestic applications that will point you to certain tank sizes. You can take certain constants, such as four people per home with a certain roof size, then it will give you a certain tank. At the end of the day, it doesn't really matter if you're sizing a tank at 4,000 liters (approximately 1,000 gallons) or 5,000 liters (approximately 1,300 gallons), which in terms of price is £100 (approximately $156). It doesn't really change much in terms of water quality and everything else. But if you're looking on the commercial side, there is a significant price difference at 100 or 200 cubic meters (approximately

26,400 and 52,800 gallons, respectively). I think that's one of the basics that one would have to look into.

Van Giesen: So the conclusion is that the scale, the scope, and the budget of the system will determine how much time and effort you should exert in coming up with an accurate water accounting.

Johnen: The amount of intelligence you can put into designing or sizing a tank can vary significantly. You can make quite a big calculation. In large commercial jobs, you start modeling the potential demand in the building (constant) against the yields (supply), over the year even with peaks in certain months. So, you're looking at potentially monthly rainfall figures, where in domestic (residential) it doesn't really matter that much.

Van Giesen: What do you see, from your European perspective, as some of the most effective ways to utilize rainwater in a medium to large commercial context?

Johnen: It depends on the type of building you're looking at. First of all, rainwater harvesting can play a role in reducing flooding problems, and at the same time providing an alternative nonpotable water source. Consider the example of a cooling tower for a data collection facility with a large roof area, where they need to use a big tank for flood prevention (stormwater management). The stormwater tank can serve more than one purpose: stormwater control and water supply. Because of the flow rate that a cooling tower needs in terms of water supply and the amount of storage that they are already installing for the storm control, there is a potential that the same level of liters per second that would have to leave the stormwater tank, might be close to the amount of water that the cooling tower could require.

We have a couple of jobs in London where we are coming down to zero discharge of rainwater and no rainwater is leaving the building envelope/site. At the same time, rainwater is soft water, which is really good for cooling towers. The characteristics of rainwater play an important role in the decision to use the rainwater as alternate source water. There are other buildings of course that do not have cooling towers, where toilets consume high volumes of water. Distribution centers have a lot of tray-washing that consumes large volumes of water. They employ large washing machines. Using soft water is good and they have large consistent demands. Distribution centers have massive roof areas and they have storm control tanks and rainwater can play a very important and effective role with the advantage of supplying soft water.

Van Giesen: Is there a hardness scale used for these cooling towers, and are there instances where the municipal water is simply too hard?

Johnen: Yes, because you need to use salt for water-softening devices when the municipal water is too hard. A simple example, a cubic meter (1,000 liters) (approximately 264 gallons) in a cooling tower costs roughly 20 p (approximately

31 cents) just on softener salt to turn the water to an acceptable quality. By saving on salt, they can save 20 p for a cubic meter of water. In addition, they don't have to pay for the water because it falls on the roof; normally that would be £1,20 in addition to the amount for the salt. So you're saving £1.40 (salt + water) per cubic meter.

Van Giesen: I would like to revisit the sizing calculations subject. I know that a number of engineers and design professionals have propriety software that they have created for calculating cistern sizes. Are there any general rules of thumb that are used when a designer wants to create his or her own sizing calculation charts?

Johnen: There are certain elements that every function should have: roof size, roof type, and location. These elements are important to understand the yield factor, in terms of rainfall averages. The larger the building, the more attention you want to pay to the rainfall. The problem with rainfall is that in certain areas it can differ significantly from one side of the mountain to the other. For example, let's say people from some place up north in the Lake District want to calculate the amount of rainfall. They choose one particular weather station to be the one point of reference for the whole area, but you would be surprised how much variation there is in a relatively small geographic area, which I think in the United States would be similar, with a lot of difference between one state and the next or even within a large state.

Van Giesen: Well not even in one state. In the Southeast we have extreme differences from one part of the city to the other, due to the nature of a semitropical climate.

HEATHER KINKADE

Figure 6.8 Heather Kinkade

Van Giesen: Heather, you are the author of two books on rainwater harvesting; what was the reason for wanting to write on this subject?

Kinkade: I was a landscape architect working for developers, mainly doing a lot on auto malls. They wanted me to get them more parking spaces, and I said, "Well, I can't. You have to have these large basins for your stormwater runoff and the only way to get rid of the water is to put it underground." We couldn't do that per some of the codes so I started looking into how we could put the water underground and either let it infiltrate or reuse it and I found rainwater catchment in a lot of the European environments.

There wasn't anything in the United States about it and the only place I could find information was Germany, England, some in Australia, and a little bit in India. I started putting all the information together and used it for one of my classes. And what came from all that information was my first book, *The Forgotten Rain*. The book is about discovering rainwater catchment and it won several awards, which was really fun and encouraged me a little bit more. I tried to publish it, but there wasn't enough interest on the part of the publishers. So I self-published it and took it to the USGBC Greenbuild Conference and talked to a publishing company from Canada and asked them if they would be interested in doing a rainwater harvesting book. They got rather excited and said, "Oh, we've been looking for somebody to do one." I said, "Well, I have one, and I am looking for a publisher." So we used a lot of the information from my first book and, augmenting that, we came out with *Design for Water*, which includes rainwater harvesting, stormwater catchment, and reusing all types of alternate water.

Van Giesen: What are some of the most influential changes you've seen in the rainwater industry over the past seven years?

Kinkade: One of the biggest problems historically has been accessing equipment here in the United States. A lot of the initial materials we had to work with needed to be "jerry rigged" in order to work. Sometimes we had to piece together different parts. Get a part from here, get a part from there—but now we are able to order equipment that's found and manufactured in the United States specifically for rainwater harvesting systems, which is a significant change.

Nowadays, people don't want to just go to workshops. They want a deeper level of understanding of rainwater harvesting. For example, they want to know much more about water quality—"What's in my water versus any alternative?" People have gone from just the very basics of having someone say, "My neighbor had a system in their backyard or she had a rain barrel" to "Wow! I really want to do this. I need that water. It's something I really need to do." I think we've come full circle, which is great. I've been waiting on that for years.

Van Giesen: It seems there's a critical mass here. As a landscape architect, how important do you see rainwater harvesting in sustainable design?

Kinkade: Rainwater harvesting is one of the main components of the sustainability cycle. As landscape architects, we are training people to see the big picture. I've been pushing landscape architects and irrigation consultants, and telling them they are the ones who need to be doing it first. Rainwater harvesting, both passive and active, is totally the landscape architect's responsibility and they need to be pushing the engineers to design the land, the parking, the sidewalks, and the building so that everything drains to the landscape. The landscape architect can then take that water and reuse it more efficiently. Rainwater harvesting brings us back to learning to live with the resources we have. It brings us back into alignment with nature and that is what landscape architecture is about.

Van Giesen: What role do you see higher learning education facilities playing in furthering this technology?

Kinkade: Their greatest contribution will be introducing the whole subject of rainwater collection to students. A lot of my students have no idea what it's about or that they can be using this water. They grew up with the water running across a site, so why not keep the design the same? It's important to introduce them to all the different types of alternate water sources and uses, air-conditioning condensate, cooling tower blowdown, and reusing stormwater in a more permeable site and using it to irrigate their vegetation instead of pushing water away from vegetation. Civil engineers, not only mechanical engineers, need to be learning about the components, pumps, tanks, and putting a whole system together.

I don't know if the schools are doing that yet. I think the University of Texas is already teaching it and a lot of its master students are learning a lot of it on their own. I don't think it's in the core curriculum. At the ASU Landscape Architecture school, a water component is required by the accreditation board as part of the master's graduate program. I don't know that any other field or any other profession requires that.

Van Giesen: Very interesting. What are some of the new research areas in rainwater harvesting that you believe are important?

Kinkade: We need to be looking at water quality. We need to be looking at "tank" water and what level in the tank is of a different quality. The best water may be just below the surface or 6 inches below the floor of the tank. No one has proven that and there's nothing precise out there that states it's 6 inches above or below—just a lot of opinions.

We need to do more research about the effect of the tank material on the water quality in the tank, so that we can all understand it better. A lot of people have started research on this subject and the biofilm in a tank. We need to have some specific information and the support of the larger research groups that can back up our information instead of someone just collecting information in someone's backyard or a county extension office.

Roofing material is another big area for future research. We need more research on catchment surfaces and roof surfaces. Everyone is saying that the steel roofs are the best, but there's no research that actually says this type of surface is the best.

We need some cost benefit numbers, carbon reduction numbers related to rainwater systems, and some energy water nexus numbers. There is a lot of work to do in research and we need to start putting all the research into one location, such as a library.

Van Giesen: Are there any components of rainwater harvesting strategy that are new?

Kinkade: Some equipment, for example pumps, are getting more refined. They are being designed to meet the specific needs in a rainwater system, instead of the installer using a well pump. There are more complete controls for rainwater systems, so the user can know what's going in and out of their tanks. Now there are computer programs that can put all that data together for you. I don't think tank design has really changed much. I think there are specific tanks that have evolved that are made of material for potable storage and some tanks now have interior coatings, but they're still all the same type of tanks we had before.

Van Giesen: What role do you see ARCSA playing in advancing the rainwater industry?

Kinkade: ARCSA needs to primarily focus and specialize on education and secondly focus on rainwater research. I do believe ARCSA needs to contribute to construction codes being set for rainwater systems and rainwater use and that is currently underway. I don't think ARCSA needs to do too much legislative lobbying because the states will work through licensing of rainwater professionals like they have for other professions. We need to support the people who are working in the rainwater catchment industry, but I'm not sure that ARCSA needs to be focused on the licensing of its professionals. We do maybe need to help with the criteria for the education levels that need to be met for the licensing and possibly the testing of the professionals.

Van Giesen: What is the reason for being an ARCSA member?

Kinkade: Well, we just did a survey of our members and one of the biggest advantages to members is that ARCSA provides education and distributes rainwater harvesting information on codes, new equipment, new projects, and general rainwater news. That goes back to the focus areas. I don't think that there's any other entity out there actually focusing on rainwater quality and use. The main reason that people come to us is to receive their continuing education units and to learn more about rainwater to advance their own knowledge. People appreciate having a way to validate their experience and rainwater knowledge. The accreditation process and providing a way to show more advanced experience via our Master's Program has proven to be very valuable to our members.

KEVIN KIRSCHE

Kevin Kirsche serves as Director of Sustainability at the University of Georgia. Established in 2010, the Office of Sustainability coordinates, communicates, and advances sustainability initiatives at UGA, seeking to create a model for healthy living on campus and beyond. Kirsche is a registered landscape architect and LEED® Accredited Professional with years of experience in campus planning and sustainable design.

Figure 6.9 Kevin Kirsche

Van Giesen: Along with any new technology in construction comes unique challenges. I know that University of Georgia has a number of rainwater harvesting systems installed on campus. What were some of the challenges that you encountered as these projects were being implemented?

Kirsche: We had our fair share of challenges during some of these first projects. Initial systems were cobbled together without a holistic design approach and items were simply missed. Inadequate filtering was a challenge. Other challenges related to specifying the most appropriate pumping system.

I think the biggest challenge was obtaining buy-in from all responsible stakeholders. In any new or innovative practice you're going to face challenges along the way. Commitment from all parties involved—from funding and design to construction and long-term maintenance—is critical for problem-solving and troubleshooting as issues arise.

Van Giesen: I think you touch at the heart of something that every facility owner questions: How do you rationalize the return on the investment? What do you do to try to convince those holding the purse strings that this is a worthwhile investment with your money? What are some of the talking points you use?

Kirsche: The governor's challenge to reduce water use was significant in justifying projects that had a longer monetary payback. We all rely on water as a critical resource for life. It certainly has an economic value, but sometimes it is worth more than just dollars would convey. One simple example is the overall health and appearance of campus landscapes. We value our cultural heritage and the historic landscapes that help create the legacy of UGA, and those landscapes need water to continue to thrive.

Van Giesen: So, there was something intrinsic about landscapes that needed to be maintained.

Kirsche: Yes. We also have stated goals in the university's strategic plan to reduce potable water use by 40 percent by 2020 and to infuse sustainability into formal and informal educational opportunities throughout the university. Rainwater harvesting is an effective and visible strategy that we can employ to meet water resource goals, but also to make a visible statement regarding the University's commitment to sustainability and implementing best practices on campus.

Van Giesen: Well, one of the most recent rainwater systems on North Campus is located at the College of Environment and Design on Jackson Street and includes an aboveground cistern. Was that type of tank chosen specifically for education, for some educational component, or precisely for the building?

Kirsche: The College of Environment and Design is specifically focused on teaching the next generation of landscape architects and environmental planners to develop the built environment in a sustainable and responsible manner. We wanted to not only employ best practices, but to make them visible as well. The aboveground cistern serves as a pedagogical tool to assist the College of Environment and Design in achieving their academic mission.

Van Giesen: I know that there is a dashboard with information not only on the rainwater system but also about the building at large. Could you speak on that for a moment?

Kirsche: The Jackson Street Building is a historic rehabilitation of a structure originally constructed in 1962. As part of the renovation we wanted to effectively communicate the sustainable design features incorporated into the project. Through the dashboard we can show in real-time the ways that we are conserving energy through efficient HVAC and lighting systems, generating electricity through photovoltaic panels on the rooftop, and conserving water through rainwater harvesting.

Van Giesen: That's very good. I know University of Georgia is assuming a leadership role with regard to rainwater harvesting. What role do you see higher learning institutions such as University of Georgia playing?

Kirsche: Higher education and university campuses should function as living laboratories where we research and practice responsible methods for meeting the needs of our current generation without compromising the ability of future generations to meet their needs. A university campus is the perfect living laboratory to investigate and implement innovative practices.

Van Giesen: A number of systems have been built at the University of Georgia; lots of different styles, different uses, indoor use, outdoor use, and so forth. What are some of the more successful or more noteworthy of those projects?

Kirsche: There were challenges and lessons learned on our first rainwater harvesting project on campus, but it was significant for two reasons. It was the first, and it was able to keep lush and vibrant a valued campus landscape while other parts of campus didn't fare quite as well due to drought conditions.

Another significant project was the Tate Student Center, where we installed a much larger system to collect and reuse rain and condensate water from two adjacent buildings. The water is used for landscape irrigation, toilet flushing in the Tate Student Center, and makeup water for heating and cooling systems. That project took rainwater harvesting to another level at UGA, including a much larger volume of water storage and a more sophisticated system for both indoor and outdoor use.

BILLY KNIFFEN

Water Resource Associate with the Texas A&M University Extension Service, National Director of the American Rainwater Catchment Systems Association (ARCSA), Education Committee Chairman, and Educational Development Leader (ARCSA), Billy Kniffen and his wife, Mary, have lived in a home solely dependent on rainwater for over ten years.

Figure 6.10 Billy Kniffen (at far right during a rainwater inspection at Choctaw Nation). (*Billy Kniffen*)

Van Giesen: Billy, you've been involved in the rainwater industry for a number of years, and you are considered one of the early pioneers and one of the experts in rainwater in the United States. You live on rainwater as your sole means for water supply, and teach and speak extensively on the subject. You've also written a number of different manuals and guides, and currently serve on the American Rainwater Catchment System Association board, known as ARCSA. Through all of this experience, what have you seen as some of the most significant changes over the past couple of years?

Kniffen: One of the significant changes is probably the awareness that rainwater collection can be used as a substitute for municipal water or well water, making it another source option. You find rain barrels in green technical magazine and even popular magazines, so it has become a central part of the green initiative. I think that, as Americans, we want to do good things and rainwater harvesting is one of them.

A positive aspect is that rainwater harvesting is one of the tools that we can use in reducing the stormwater runoff. A lot of professionals, engineers, architects, and designers who are in the stormwater management industry are interested in rainwater catchment. As a result, vendors and manufacturers of products get interested as well. I see the involvement of these other industries and professionals as extremely significant.

An important point is related to the design and installation of sophisticated quality systems, which have kept moving the industry forward.

Van Giesen: Do you see it [the rainwater industry] moving away from the do-it-yourself to more sophisticated residential and commercial systems?

Kniffen: Most of the residential and commercial systems are constantly improving, and have moved forward, but I still see lots of do-it-yourselfers and beginners. The industry has to have all phases of it. As the knowledge base grew, rainwater harvesting professionals started to design and install sophisticated systems for commercial and institutional applications. I see all of the phases as important steps to help get the industry where it needs to be.

Van Giesen: Knowing that you live in Texas and source your water entirely from aboveground rainwater tanks, have you seen climate change impact the analysis of the climate data? Have you noticed any changes as you travel around the country?

Kniffen: I don't know whether it's climate change, or normal weather cycles, but we have seen more extreme droughts in the last five to ten years than we have seen in recorded history. When you look at the Great Lakes, Georgia, Colorado, California, Texas, Arizona, and all the western United States, extreme drought has really impacted much of the population. It is interesting to note that Midland-Odessa [geographical area in West Texas] has hooked up to the aquifer that supplies Eunice, New Mexico, and has basically taken all their water away from them. Eunice is complaining and Odessa said, "you can just buy the water from us." I can see that there are going to be huge water wars in the future. Population growth combined with more droughts and extreme weather will cause more water disputes. It's the old saying that, "whisky is for drinking, and the water is for fighting."

Van Giesen: How important do you see roof-collected rainwater as a water source in the United States? How significant do you see it now or into the future?

Kniffen: If water is going to be an issue, which it is in almost every city in the United States, then rainwater harvesting is going to be the major tool to teach water conservation. This is one of the most important roles of rainwater harvesting, to make us aware of our water consumption. By installing a rainwater system, it makes us look at our water demand. In this way rainwater harvesting becomes a major player in the water conservation effort.

The reduction of the current available water supply and the need of expansion of infrastructure are great motivators pointing to rainwater catchment as one of the ways to solve these problems. I see cities right now adopting rainwater collection because it is the cheapest way to get people to utilize less water and avoid depleting or polluting our rivers, lakes, and aquifers.

On a smaller scale, we have water quality and water quantity issues. Rainwater collection can help people who do not have enough water—it can save them and allow them to live wherever they may already be or choose to be.

Van Giesen: I don't know if you've seen some of those reports from Stan Abbott; he wrote recently about the positive impacts of rainwater harvesting to alleviate suffering after earthquakes or other disasters.

Kniffen: I was in New Zealand last year at a conference with all the major decision makers, and using rainwater collection in the aftermath of an earthquake was discussed. All of the emergency personnel met with Stan Abbott. We have to address this type of usage here in the United States as well.

Van Giesen: We don't tend to think about it that much here in the United States. A major cause of misery after a major natural disaster is the lack of potable water.

Kniffen: When I visit the West Coast, I certainly bring that up. There's a 5 to 10 percent chance that they will have an earthquake in the next fifty years. Having each home with a rainwater collection system will prevent a lot of the suffering, as we have seen in Haiti, or Christchurch, or other major places that have had earthquakes.

Van Giesen: What is the role that you see higher learning institutions playing in this technology?

Kniffen: That's one of the reasons I visited Stan Abbott in New Zealand. I went there for a week to learn about Abbott's research and to see how he's doing it; to see the materials he uses to accomplish what he's doing, and bring it back to Texas University in hopes of influencing them to get involved with more research. Unfortunately, that has not happened; changes in our directors and changes in economics have prevented us from stepping forward. We're still trying to develop an Urban Resource research center in Dallas. We will probably have our Rainwater University at that research center next spring. We need the decision makers and regulators to ease up on some of the regulations, as well as change codes in order to encourage rainwater harvesting.

Van Giesen: What are some of the major obstacles you encountered over the years, and what are the arguments that really won the day, so to speak?

Kniffen: One of the main obstacles is just apathy because water is so cheap. "Why should I do it, if it is not costing hardly anything (the water bill)? It's cheaper than anything else I pay for." There isn't any encouragement or incentive to do it, so the apathy plus thinking that "the government is going to take care of my water needs and I don't have to worry about it." These are all reasons that contribute to the lack of interest in rainwater catchments: the cost to install the system, the space needed, and the necessary planning. Then there's the lack of codes and regulations which can discourage rainwater harvesting.

Van Giesen: Of course we know about the unsubstantiated fears associated with indoor use of rainwater, even for nonpotable uses.

Kniffen: I think the cross-connection scare potential is one that [here in Texas] really limits rainwater harvesting. Then there are the "what if's." What if I put in a collection system, put a pump on it, then hook it back to my faucet, and then bring that into my house? People are scared of things that probably could never or should never happen and what the hazard would be. The scare tactics from those who don't want rainwater used affect all of us in the rainwater industry.

Van Giesen: What are the best ways that you found to overcome these fears?

Kniffen: We have to be professional, and our relations need to be professionally done. If someone is going to install a system, and that system is not put in correctly, and the water becomes either septic or then anaerobic, those few bad systems muddy the water for all of the great systems. The education and professionalism are critical when moving forward. Then we have the question of who's going to do it? In Texas, fortunately for those people who have been installing outdoor nonpotable systems for years, they will continue to be able to install these systems. But a plumber is going to be required to install systems for potable use indoors. I agree that once it's in the house it belongs to the plumber, it's their territory, and outside is under the care of the other professionals, whether it is the irrigation contractors or the rainwater harvesting professionals.

Van Giesen: Even for nonpotable applications, once it penetrates the envelope of the building, in Texas, that is in the realm of the professional plumber?

Kniffen: That's correct, but if it's a system with municipal water backup, the plumber has to be involved in the whole system, whether it is indoor or outdoor, potable or nonpotable. That's the only instance besides the indoor applications where the plumber will be involved in the system. If it's going to be outdoor nonpotable use without municipal water backup, then it does not have to be hooked up by a plumber, but once it goes indoors, it's under the responsibility of the plumber.

Van Giesen: So currently in Texas a rainwater professional or landscaper or irrigation contractor could install the tanks, pumps, and piping if it's outside of the house. At the point when it hits the house then the licensed plumber takes over. Is that correct?

Kiffen: Yes, that's going to be the general rule, especially in cities and municipalities. When you enter rural areas, which are very common in Texas, it may not be a requirement of the county or city. It all depends on the jurisdiction.

Van Giesen: You see a lot of systems and talk to a lot of people, what are the most common mistakes that you see made that usually cause the system to fail?

Kniffen: It has to be allowing too much debris and trash getting into the collection tank. Everything from mosquitoes to too much organic matter that turns the water anaerobic are the things that cause a system to fail. From a municipality point of view, that's the kind of thing that they will throw back at you as well. When I talk to the architects in San Antonio about rainwater systems, the thing that they bring up is the first system that was put in at the city library about 15 years ago. It didn't have any screen or filter before it went into the tank, it turned out anaerobic, and they have discouraged the installation of systems ever since that. I was in Colorado 3 weeks ago. The state allowed rainwater harvesting in 2009. They said that they would permit 10 subdivisions to install rainwater systems for outdoor use. The first system that they installed on the first model home malfunctioned, and they decided that they didn't want to be involved with rainwater anymore. So it is very important that those very first systems that go in are put in correctly. The key is to make sure it's put in correctly.

Van Giesen: I couldn't agree more. I've seen that with my own eyes. Too much organic debris can cause bad water. So one last question: What are the most important aspects of a well-constructed rainwater system?

Kniffen: The first thing you have to get is quality water into the storage tank, then utilize it in an appropriate way, with the proper disinfection or treatment to meet the end use. Another thing is keeping it simple, because maintenance is going to be key to any system. If you don't have proper maintenance, it's going to fail. So those are the two keys, first getting quality water into it, then good maintenance of the systems.

DENNIS LYE, PHD

Dr. Lye has been involved in monitoring the microbial quality of water for more than thirty years and is currently a research microbiologist with the USEPA, Microbiological and Chemical Exposure Assessment Research Division in Cincinnati, Ohio. Dr. Lye has published numerous scientific articles and his laboratory is currently assessing virulence potentials of microorganisms common to drinking water systems with an emphasis on developing animal models useful for testing pathogenic capabilities. Within the Safe and Sustainable Water Research group of USEPA, Dr. Lye is currently promoting the collection and use of rainwater and/or stormwater runoff as alternative water resources within modern urban watersheds.

Figure 6.11 Dennis Lye in the Laboratory

Van Giesen: We know that there are a lot of unsubstantiated fears associated with indoor use of rainwater, even for nonpotable uses such as toilet flushing, cooling towers, janitor sinks, and so forth. In your opinion, what drives these concerns and more importantly what are some of the best ways to overcome them?

Lye: The concerns that people have, related to risks of infections and contamination or getting some type of disease from rainwater, is a perception of risk more so than the actual risk. People are concerned about things that are beyond their control. People are not very concerned about installing a rainwater system of their own and using it to flush their own toilets, because they know what has happened each step of the way. So it is not so much about the individual users but about the rules and regulations that are defining exactly what is being done with this particular resource of water. What really drives the questions about alternate sources of water is the perception of risk that is out there.

We do not even know the risks associated with flushing the toilet with clean municipal water. I want to make sure that you get that into your book. In fact, the studies that we are doing now on rainwater harvesting and its use in the flushing of toilets will probably lead us to an understanding of the risks that are involved not only with rainwater but with also the treated municipal water. There are a wide variety of public facilities that are flushing toilets with rainwater throughout the world under a variety of circumstances. As far as we can tell, these facilities are not reporting any outbreaks that are likely associated with the water being used (rainwater). This is an area where government agencies and universities have to do a lot more research.

I feel very comfortable in saying that there is no significant risk associated with flushing toilets with rainwater. We experts can argue about "significant risk." The public perception is that there is a "significant risk," but the scientists suggest that there is not a significant risk. That's where a lot of trepidation about risk comes into play.

Van Giesen: You touched on the notion that we don't even know about the health risks associated with flushing toilets with municipal treated water—what are you referencing there?

Lye: Think of any kind of scenario that would happen surrounding a flushing toilet, for instance, an aerosol dispersion. Some scientists have published articles that document the inherent risk depending upon if there is a loose stool that has been deposited versus a solid stool. The evidence suggests that you get more aerosolization of contaminants from a loose stool than from a solid stool. There may be other scenarios especially involving aerosolization and contact with this aerosolization with toilets. There have not been enough studies on this subject.

Van Giesen: In policy discussions that I have been involved with, in a number of different states, I have anecdotally referred to scenarios like you described. The human stool in the toilet may be potentially more dangerous than the rainwater itself. I didn't know that there was science behind this.

Lye: Yes, I get this question all the time, so I try to keep up with this subject. A couple of years ago there was a study, not made in the United States; they were actually able to show that the presence of a loose stool material was much more of a risk than a regular stool movement in the toilet environment. It's all interesting.

Van Giesen: You bring a unique perspective with your background in microbiology and your experiences working at the EPA to this discussion about rainwater harvesting. Your leadership and ongoing participation in the American Rainwater Catchment Systems Association (ARCSA) affords you a wide lens. You were a former past president of ARCSA, correct?

Lye: Yes, I was president of ARCSA for one year, sort of in a holding pattern. A few of us were in the initial organization and we were trying to come up with ways to involve more people. I make no great claims to making any great strides as a president of ARCSA. We were all more or less taking our turns.

Van Giesen: Well, what has been the biggest change in ARCSA? How long have you been involved?

Lye: Let me give you a little historical perspective. I'm a microbiologist and I've always been interested in microorganisms. At first, my interest was in aquatic microbiology and then I moved to Northern Kentucky University in 1984 and this area (Northern Kentucky, Southern Ohio, Western Virginia) has a multigenerational cultural history of collecting rainwater and they've been doing it for hundreds of years.

I am not from this area, but it [rainwater harvesting] was of interest to me. In 1984 when I moved into the university office, I hadn't yet unpacked my books and the biology department got a call from some local residents. It was a microbiology question so the biology department referred them to me. They wanted to know what they could do about their rainwater system; it had gotten sour and it had developed smell and taste problems and they wanted to know how it happened and how to remedy it. This was an area of interest to my local clientele from the very beginning. That was my first start in 1984.

In the '80s there was no literature about American rainwater systems and I considered it a big accomplishment when I got a paper published about water resources in 1987. It was the first peer-reviewed article about American rainwater systems. As a result of that, I published a subsequent review article in 1992. In the article I was able to find a total of 12 peer-reviewed scientific articles at that time, and that was worldwide.

Most of the discussions about rainwater harvesting were occurring in other parts of the world—Australia, China, Germany, Korea—and even there, they were not occurring in mainstream science. Most of them were occurring in graduate thesis books, conference proceedings, or technical reports from some water research center somewhere, so yes, I got involved very early. I was the first one who began discussions about American rainwater catchment systems in the '80s, and even in the '90s there still wasn't much occurring.

But the big catalyst was the LEED® program that was formed in 1993 that started emphasizing sustainable design in buildings. The other thing I'd like to point out, in 1994, Dr. Hari J. Krishna, who I'd been corresponding with and working together with at the University in the U.S. Virgin Islands, had moved into the Texas bureaucracy. He understood the lack of education in the United States [concerning rainwater harvesting] and so he started the ARCSA organization.

I think these two events, the grassroots involvement of individual users and the LEED® program, really started us down a path where there was a lot more interest in rainwater collection. So the first years the obstacle was just a lack of education, lack of information about the science of rainwater—not so much anecdotal information but the actual science of rainwater. With the formation of ARCSA we created an association that provides answers to questions by actual policy decision makers, which were Hari and Bill Hoffman and a federal scientist such as myself. It was a baby step but I consider an important step for rainwater harvesting in the United States.

The second obstacle was that most of the important policy decision makers in the United States had no experience with alternate water resources. In my area we certainly had experience, but in the rest of the country, and that's true even today, there is not much awareness about rainwater harvesting.

So who are those policy makers in America? They are the trade industries, for example, plumbing industries, industries involved with building code, architectural industries, state governments' health departments at all levels, and federal agencies like the EPA. At the time, none of these organizations had previous experience with alternate water resources. That was an obstacle then, and to some degree it still is. As a result, there was no national, state, or even regional leadership. That was a real obstacle that we had to overcome.

We had to become more national. I moved from the university position over to the EPA position to begin having more of a national impact. Recently, probably 2008, the EPA began embracing the concept of sustainability and green infrastructure, which will help the cause of rainwater harvesting. EPA put out a manual by Christopher Kloss on managing wet weather with green infrastructure in 2008.[1]

Lye: At that time, it was probably good that there was no national agency saying that you have to do it this way or that you had to follow these particular guidelines. I think the decentralization of policy decision-making is good for this aspect of alternate water resources. But we can leave those questions to the office of water policy.

There's been a literal explosion in the last ten years. While my first review article listed 12 articles in referred journals, nowadays there's probably 5 or 6 each month [rainwater-related articles] in the scientific discussions and journals. I think the compelling arguments right now are discussions about climate change, of course. We are having water shortages around the world and even here in the United States there are water-rich regions that suffer from water shortage on a chronic basis. We are beginning to discuss the economics of water, which is of great interest to EPA.

We now have carbon credits and there are discussions about having water credits. EPA has been always involved from the very beginning in discussion about water quality. There are a lot of reasons why the rainwater industry is going to be very viable in the future.

Van Giesen: That brings me to another question. There are two parts to the water puzzle, the first one being the water that we source (supply) and the second being what do we do with the water once we've used it? There is also a third part, the question of the relationship of rainwater and stormwater to impervious surfaces: What is the EPA directly involved with?

Lye: We are certainly doing research here, but oftentimes it takes decades to produce the actual data and to figure out solutions that will be economically viable for the industries involved. This idea of maintaining the water that we've used onsite is a decentralized condition and it is certainly what we are interested in and encouraging here. EPA is going to be heavily involved.

Van Giesen: When people from other countries come to the United States, one of the things they complain about is the complexity of working across state boundaries. For most Europeans, a national standard, a national code, and national guidelines work from the top to the bottom of the country, but not in the United States.

Lye: That's where I'm going to have to defer to the Office of Water other than saying that I don't think we're going to have national regulations but I think that there is a place for national guidelines. That is something that the policy makers will have to decide.

Van Giesen: Exactly, Dennis. We talked about how ARCSA ostensibly started out as an organization that was primarily involved with potable, smaller, individual systems.

Lye: Potable systems, individual systems, you are correct. Mostly it was just the clearinghouse of information.

Van Giesen: I've observed, working in the industry for 5, 6 years, the disproportional amount of dollars spent on larger commercial systems versus residential systems. Public safety buildings, stadiums, dormitories, large hundred-thousand-square-feet-plus facilities are using rainwater to flush toilets. This has opened up a completely new sector of the industry and is requiring new policies to be written that will allow for these larger flows. Have you seen new technologies on the horizon, even experimental, that might change the game, so to speak?

Lye: I agree with you, the commercial industry is going to drive things any time we discuss about alternate water sources. For this to work, incentive programs are very necessary. Just as there are incentives for other industries (solar is a good example) there need to be incentives in place for alternate water resources. We need to have a discussion about the true cost of water. The water is subsidized in the United States, so it is not as expensive as it should be. That's something that we will have to work around. The commercial systems are the way that we're going to be able to move the industry forward. The economics of scale will favor these systems.

There are many technological advances in the industries that are involved in rainwater harvesting. For instance, there are advances in roofing materials and types, such as new architectural shingles, green roofs, blue roofs. These things will be useful and actually advantageous in the future. Almost every aspect of a rainwater collection system has some sort of innovative component. For example, in the diversion materials, we now have filters placed around the gutters and downspouts. There are many different types of first-flush diverters, which I think are being designed and in some cases being required. I believe in the future we will have a much better understanding on how much we need to divert to increase the quality of the stored water.

Aboveground tanks, belowground tanks, collapsible tanks, multicomponent tanks, tanks that you can take apart and reassemble for easy transportation, and so forth—these are all things that I'm seeing now that will impact future treatment techniques.

We are certainly pushing UV light treatment for nonpotable uses. We are trying to find ways to work around the requirements that one has for potable uses—that's a whole other ball game. There are new treatment technologies out there. Bromine treatment is very promising and we will probably be seeing more of it in the future.

Van Giesen: In the last part of the interview I would like to touch on something I come against on a regular basis and that is most health authorities and many engineers who are unfamiliar with the practice want to “sterilize” the entire storage tank. These especially involve municipal water purveyors with large tanks that need to keep chlorine from stratification. In this context the water is mixed so that the chlorine residual is constant. The concept of the beneficial biofilm is very foreign for municipal water purveyors. Can you briefly elaborate on the beneficial nature of biofilms? In the context of rainwater harvesting, are they typically beneficial to the health of a tank?

Lye: We are actively doing research in biofilms (biofilm formation) with the express goal of determining risk that is associated with biofilms. The people who work with this and actually do the science suggest that biofilms are not harmful. That does not mean that they could not become harmful, but a nice active biofilm in a well-designed, well-maintained system is beneficial.

All of my comments from here forward are based on the premise that a system is well-designed and well-maintained. There are different types of biofilms. We have not found any risks associated with biofilms that are formed of prokaryotes. My laboratory has taken the prokaryote organisms (the bacteria) that you find in biofilms and we have done animal studies on them and we have not been able to make the animal sick in any way, shape, or form. We have injected into their peritoneal cavity; we have made them drink it. Biofilm organisms in the natural environment are not harmful and do not seem to have very much risk.

But there is another biofilm that has eukaryotic organisms. These are the biofilms that have algae and protozoa. These biofilms do have some risk associated with them, so you have to maintain a good biofilm and not let it develop into a bad biofilm. That’s sort of what we’re trying to understand here and work with. The more surface area you have in a tank, the more biofilm area you’re going to have. There have been studies that show the shape of the tank has an effect on the water quality. The reason it has an effect on the water quality is because these organisms are competing for the nutrients that are in that water. Rainwater has a lot of nutrients. It has more nutrients and more turbidity then you might find in some other types of water. It is really that you may not want to have a competition between biofilms and organisms in a storage tank.

The healthier the biofilms, the better. We have done studies where indicators decrease over time when you have a nice healthy biofilm. The indicators are supposed to be indicators of pathogenic organisms. So by extrapolation you could say that if you have a good biofilm, then if you did get an entry microbial organism that might cause an infection, it would suggest that this organism would have a much harder time surviving in that particular environment.

Going back to your comment about terminologies, they are very important here. Sterilization means the complete absence of life. I don't think that most people are suggesting you should sterilize the tank; they are probably suggesting that you should disinfect the tank. Disinfecting means decreasing the numbers of anything that might be there to levels that would not cause any kind of infection.

Is it necessary? Research performed in our EPA laboratory would suggest that it is not necessary to disinfect a tank unless you start having problems with it. A risk of infection is usually preceded by palatable problems such as taste, odor, and color. When you see obvious deterioration of your water quality, then you should do some kind of disinfection.

Van Giesen: Absolutely, this methodology (taste, odor, color) goes all the way back to Roman times. I've been doing research, and taste, odor, and smell were some of the first ways that the Romans used to analyze water.

Lye: Yes, that's correct. I've been on some of these flavor profile analyses where there are about seven people and they give water to each of them with a chemical in it. Some of them don't smell it and others won't even put it up to their nose. Everybody's different as far as odors and taste go.

Van Giesen: I would like to go back to the biofilm question. How do you know that beneficial biofilm is going to inhabit that nitch? Can we model that out; is this the kind of research that you are doing?

Lye: In fact, that's what we're doing now. We can control it by the kinds of materials you have there, the type of aeration, the dissolved oxygen levels, the movement of the water that you were keeping in the tank. So we do know certain aspects; for instance, bad biofilm builds up in sealed containers. That's why most of the storage systems have an opening to the atmosphere so that they are not completely sealed containers, because you can run into problems with sealed containers that do not breathe. We have very elegant sophisticated tools that in essence can tell you if a eukaryote is present in a biofilm. So right now (and I do not want this to appear as though it is EPA policy, because there is a lot of discussion and disagreement among us), I suggest to people if there are eukaryotes present there may be problems with the water.

Biofilms will build up most rapidly in water stored under stagnant conditions. An association was made between dental patients being infected with Legionella (Legionnaires disease) and dental offices that did not flush their dental instruments on a daily basis. We participated in a study determining the role of flushing dental water lines for the removal of microbial contaminants.

We did some studies on dental lines and we were looking for legionella, and we normally found legionella accompanied by eukaryotes, because legionella has to have eukaryotes in order to develop.

A biofilm is a community of microorganisms. Again, we have very elegant, sophisticated techniques through which we can tell you exactly what is in the biofilm. They are costly right now, and it is not something that you might be able to order from a laboratory somewhere. But in the future you will be able to do that. That's what our project in Austin, Texas, is all about with our residential rainwater system. We are sequencing all the bacteria that are present in that particular system, before and after treatment.

SHAWN MARTIN

Figure 6.12 Shawn Martin

Van Giesen: What has the development of the international codes (I CODES) done to promote the wider spread implementation of rainwater harvesting?

Martin: The I CODES are the most widely used model codes in the U.S. The ICC has a family of 15 model codes in the U.S. Model codes acts as a template or a starting point for communities to adopt codes to provide safe and healthy living environments. Many jurisdictions will amend them, model codes are intended to avoid having each jurisdiction come up with their own individual code from scratch.

ICC's building codes have been around for a long time, and are being in use in all 50 states, and our residential code is used in 40 states. They are very widespread and come about as an outgrowth of what were formally regional codes, from organizations such as BOCA (Building Officials and Code Administrators International), Southern Building Code Congress International (SBCCI), and ICBO (International Conference of Building Officials). When these codes merged, they became the I CODES. These regional codes have been in existence for a long time.

So what that means is if there are no provisions for rainwater harvesting in those base codes the local jurisdictions are left to either create their own code, or have nothing. In fact, many of them have had nothing. There are examples of those who have created codes but it takes a lot of time and effort to do this. Moving a topic like rainwater harvesting into the base codes means that when all of these jurisdictions update their codes and they come across this new version with rainwater harvesting in it, they are forced to deal with it. They can exclude it, cross it out, and not use it, or they can implement it. But for the first time they'll need to grapple with it.

Van Giesen: So why specifically did the ICC get involved with rainwater harvesting? What was the main reason for getting involved with the code.

Martin: There's a common misperception that the ICC writes the codes. In reality the ICC doesn't write the codes. The ICC is the steward of the code writing process. We operate through the public consensus process. We rely on building safety officials and the public throughout the country. They are then reviewed through this consensus process, and if the consensus is that they should go into the codes, then they will. That said, anyone could have proposed the inclusion of rainwater harvesting, but no one did until recently.

The development of the IGCC (International Green Construction Code) was a defining moment. This document was meant to be an overlay, meaning it worked on top of the existing safety codes. It did not replace the existing codes; it just worked with them. So if you had a community that wanted to establish some sustainability thresholds or requirements, they could adopt the green codes in addition to the other codes. The green code had a chapter on water efficiency, obviously alternate water sources are a big part of that, and that's where you finally saw the text for basic minimum rainwater provisions for the first time in the ICC codes. A lot of the stakeholders recognized that there was a lot of interest in moving the green code into the main body of the code. The green code would tell you when you needed to put in the rainwater system, and the main plumbing code would tell you how.

In 2012, the rainwater harvesting provisions made their way into the green code. In the following year, during the 2015 cycle, the material in the green code was used as the basis for a change to the ICC plumbing code (IPC), which added a whole new chapter on non-potable water. There was widespread support for this among the membership, which is testament to how far this topic has come.

Van Giesen: This provision passed last year in Portland, is that correct?

Martin: Yes that is correct. In this particular case the code proposal was submitted by a committee [formed by] many people who [got together and] had worked with the IGGC material and refined it further for use in the plumbing code. And then it got a lot of support, frankly more support than I expected. Rank and file members voted for it, even though initially the technical committee did not support it. The members needed a two thirds majority and they got it. They overrode the committee, which is something some people really did not want.

Van Giesen: What are the next steps in code writing in relation to rainwater harvesting?

Martin: There is a lot of confusion among code officials concerning what exactly is rainwater and when it becomes stormwater. In the codes, we have dealt with stormwater for a very long time. They are the basic tenant of building safety. The challenge is going to be refining the interface between rainwater harvesting systems and the conventional stormwater management provisions within the code. Not only to get better alignment, but also get commonality on terms and also to explore opportunities. Probably stormwater can be used as an alternate source of water.

The other side of things that we need to look at is product specifications. There are some interesting components within a rainwater harvesting system that currently don't have minimum safety requirements and performance requirements that are usually in a standard. I'm thinking of things like debris excluders, first flush devices, if they're used, and tanks. There aren't sufficient provisions for onsite storage tanks, the calming inlets, and so forth. In the plumbing code there is a requirement that every component contained within must be third-party certified to a standard which it must meet. But in the case of rainwater harvesting we don't have standards for components.

Van Giesen: Very interesting. Why has the development of codes for rainwater harvesting been so arduous and contentious? The practice is still not universally accepted in the United States; isn't there plenty of evidence and overseas data to suggest that, when properly designed, rainwater systems are safe and effective and provide an alternate source of water?

Martin: That's a great question. First of all in the United States, in the 1950s, we moved away from localized to centralized sources of treated water. Prior to 1950 the vast majority of the U.S. population got their water from ground wells and from rainwater, especially in rural areas. Rainwater systems were very common and they were the primary source of water in the United States. It was seen as a progressive move to centralize water treatment systems, to laying down huge pieces of pipe, etc.

Those centralized systems are much easier to manage, so the idea of moving away from that is really hard for the community to fathom. There's a bit of a cultural thing/historical thing. The plumbing industry has not traditionally embraced rainwater. Rainwater came from a different sector (grass roots). The plumbers are not being brought into it, it's been a very slow process.

Water quality has been paramount, especially among public health officials. In addition, we have a lot of disciplines that come into play related to rainwater systems, so getting everyone on board has been hard. You have landscaping implications, excavations, electrical, plumbing, and structural from a standpoint of moving the rainwater from the roof. Getting everyone to sing off the same page has been hard. Generally speaking, I've seen a lot of reluctance from domestic interests accepting data from abroad. They often want data from the U.S. Perhaps the public standards in other countries might not be as strong as ours here. Sometimes these are unfounded, but there's a real desire to see homegrown data and research.

Van Giesen: From our research studying overseas, there is reluctance between France to accept the German results, and British to accept the French results, etc., etc.

Martin: That's just human nature. You never know what might fall next door so you want your own data. I think some of the data is really good, and I think it would be worthwhile to sit down and look at it more carefully. ICC is starting to work on a standard, and we've done a very extensive literature search from around the world to look at, as we develop our standard.

Van Giesen: We know that there are a lot of unsubstantiated fears associated with the indoor use of rainwater, even for non-potable uses. Most of this comes from public health officials; what do you thinks drives these concerns? What are the best ways to separate fact from fiction?

Martin: Well, I think the single biggest issue that we have is lack of a national consensus on the acceptable water quality for various end-uses. Unlike drinking water, which is regulated by the safe drinking water act at the federal level. The federal Environmental Protection Agency (EPA), has no jurisdiction on non-potable water. They have some suggestions, they have a guideline document, but they are not empowered to regulate non-potable water quality. Various states have their own requirements regarding acceptable water quality for various end uses. The lack of a national consensus has held the EPA back, so it has forced individual health officials to address these issues on a locale-by-locale basis. They're reinventing the wheel over and over. I also think there is a fear of the unknown, many of them don't have a very good handle on what the appropriate water quality should be on the end uses. For toilet flushing for example we know we don't need potable water, but we know that flushing with black water is a bad idea; somewhere in between those two represents a threshold for what is acceptable. We need a consensus that the health community can rally around and be able to say, "Yes, this is a credible source of information, and reasonable criteria." That alone would go a long way.

The second thing is the idea of centralized v. decentralized management of water quality. Public officials are charged with maintaining water quality, which is a lot easier in a centralized facility; you can secure it, you can put in place various quality controls, and have trained personnel monitoring, etc. Public health officials like that, they feel that they can wrap their heads around that, and they can keep that under control. Now they still have to deal with the distribution network, but they have learned to do that.

The number one concern I've heard from public health officials is that these rainwater systems are not going to be maintained, and they are going to create a public health hazard, even if they're not used indoors. If you have a big tank of septic water sitting there; unmaintained and undrained, that's a public health hazard. That's the number one thing I hear. There are various well-known methods that show that the systems won't become a health hazard. Examples and case studies go a long way in calming their fears about putting in place systems that ultimately are not going to be maintained.

Van Giesen: Are you aware of any organizations that may be developing minimum criteria water quality?

Martin: There are organizations that looked at it and have walked up to the edge of it. I'll give you an example, NSF 350. Originally it was a standard that supposedly would create minimum water quality criteria for various uses. What they ended up creating was a standard governing the minimal performance of packaged graywater systems. In doing so they created a challenge water which is essentially a concoction that replicates the worst case scenario of graywater going in. It had effluent criteria by which the performance could be validated so that the effluent could meet certain criteria for various end-uses. So their effluent criteria are actually being used as a criteria for minimum standards of water quality for graywater.

I know that the committee is also looking at the possibility of doing something very similar for rainwater harvesting systems where they would develop a challenge water that replicates worst-case scenarios for rainwater and then develop effluent criteria for that. Presumably that effluent criteria would have a similar basis to gray water, but would be tailored to match the challenge water that's presented to it. The basic idea being that all non-potable water systems should be required to have some effluent criteria that are reasonably similar so that one wouldn't have to perform at a higher level than another.

There's similar standard in the Canadian side, it's called CSAB 120, I believe. It does the same thing and also sets the criteria. I know there's a study done in Canada, which I think very highly of, that went into great detail about the risk factors associated with water quality in toilet flushing and urinal applications. It established minimum criteria for specific applications. It was very well done and I recommend that criteria. We need to gather together more studies like that to create a consensus with a credible level.

The EPA has recommendations for various end-uses, whether be indoor or outdoor, but again they are no enforceable. We need a very clear criteria that establishes minimum water qualities for various applications. For example, subsurface irrigation, aboveground spray irrigation, car-washing, toilet flushing, trap-priming, go down through the list, and it is blind to where the water came from, as long as you clean it to a certain level you can utilize the water for this use. We need to get away from the idea that if you have rainwater you don't need to treat it, because we are going to assume that it is good. Regardless where the water comes from, it needs to meet a certain level of purity. If the rainwater collected meets this level without treatment, great, good for them, they can use it in that fashion. Establish the requirements based on risk and public health requirements for the end-use application.

Van Giesen: You were discussing the impacts that rainwater can have from two different angles. One is the minimum water quality standard and the other is how it impacts manufacturers who have fixtures that may utilize that rainwater. Can you elaborate on the impacts that rainwater collection can have not only on public health but also on plumbing equipment?

Martin: When you are looking at setting standards for water quality you need to think about two things. Obviously the major thing is to protect the health and safety of the end user. So you want to have minimum criteria for various indicators to protect public health and safety. So you look at things like fecal coliform levels in the water, BOD (biochemical oxygen demand), TSS (total suspended solids). These are all things that are very important to prevent people from getting sick. You want to take care of their microbiological aspects. However there is another important aspect that is of course subordinate to the first concern, but nonetheless is significant. You need to take into account the reactivity and the quality of the water so as to protect the end use device.

Let me give you an example, if you are supplying treated non-potable water for flushing toilets, usually there is a seal in them, often times a elastomer flapper. Historically the manufacturers have gone to great lengths to get the formulations on those elastomers to stand up to the various disinfectants that are commonly associated with potable water systems. Over the years they have had trouble but they have finally solidified it to the point that they have something that works with the range of disinfectants that are out there in the typical usage dosage. If we introduce a new situation with non-potable water where the disinfectants are uncontrolled, there is a serious potential of corroding not only the elastomers but also the plastic and copper, causing the toilet fixtures to fail prematurely.

If that happens you have defeated the whole purpose of using rainwater and instead of saving water you are wasting water. This can be avoided by setting maximum levels on reactive oxidative materials or disinfectants used in it, whether it be ozone, chlorine, or others. We know that this is a maintenance issue and that some users will say that if a little bit of disinfectant is good than more must be better. The person might say something like, “The manufacturer says one tab of chlorine is good, but I’m really nervous about the whole thing, so I am going to drop in two or three.” That can have some very serious unintended consequences. This can create some serious warranty and liability issues for the manufacturer of the components downstream, i.e., toilets and cooling towers. It’s incumbent on us to get it right. Get the minimal to protect people, get the maximal to protect the end use device and avoid unintended consequences.

NEAL SHAPIRO

The opinions expressed herein are his own and not necessarily those of the policy makers of the City of Santa Monica.

Figure 6.13 Neal Shapiro

Van Giesen: There's a lot of discussion concerning the widespread use of available rainwater sources. Why do you think this discussion is getting so much traction in both policy circles and the design community? What's all the fuss? Why is there is so much discussion happening these days?

Shapiro: I think there are a couple of different things going on. First, for many years the LEED® certification has pushed people to be more resource efficient. Concern for the environment has obviously been playing a lot in the media. People want to do the right thing and they want to get the credit for being responsible. So LEED's® one thing that has been slowly acting as an undercurrent, and encouraging people to be more sustainable and use other water resources, besides the municipal potable supply. Through the LEED® process, you get more points and a higher certification if you look at alternative water supplies. This demonstrates that you are more water efficient and sustainable.

Obviously, what has been going around many years now is that people have been experiencing shortages of municipal potable water. Certainly in the southeast United States there are some serious water-supply challenges going on. The West has had droughts for five-plus years and that has been a serious problem for western states and Mexico. People are starting to be concerned about where they are going to get water to meet demand; lake and river levels are going down and are getting near the red lines.

Australia had a huge "Millennium Drought," and afterward they had the opposite. So people need to know that there are going to be ongoing cycles of drought and flooding. There are also national disasters. If there are earthquakes in California, the breaking of levees will cause water-supply disruption, and will further endanger species. So all this is getting people to think, "Wait a minute, we better find other supplies of water, not just the water that we get from lakes and rivers, and groundwater. We have to start thinking outside the box."

Global warming, as it was called many years ago, has evolved to be called "climate change," since we've had ten-plus years of cooling. It has been played out by the media more than anything else. So people have started thinking, "We've got to look for other supplies of water." The changing climate is affecting the type of precipitation that falls and levels of reliable snowpacks. The runoff is coming all at once, instead of coming over many months. Or there is less snowpack if precipitation doesn't fall as snow. So how do you store it? All these challenges that are being seen, certainly in California, make people reevaluate how they traditionally manage their water.

Van Giesen: You mention the snowpack, and that segues into the next question, which is the introduction of California AB1750. The Rainwater Capture Act of 2012 was signed into law by Governor Brown this past fall. Do you see that as a positive step forward for the State of California?

Shapiro: I see it as very small step now. I was discouraged at the final version of the bill, because it was pretty much gutted to satisfy some political concerns. So a lot of the teeth that would have made it a lot stronger were removed. Instead of the law authorizing indoor/outdoor use, it doesn't say much more other than it's okay to use rainwater. The law lacks any specifics, which I guess that's a silver lining in that you can interpret it widely to mean almost anything.

Van Giesen: And we also know, it settles some long-simmering issues with water rights in the State of California.

Shapiro: Yes, water rights are a big deal and the Capture Act kind of addresses that. It preserves existing water rights for those entities that sell water derived from surface water bodies, mostly the interior of the state, where watersheds drain to rivers. Along the coast, runoff drains to the ocean so there are no or few water rights that could be jeopardized. I am not sure how much it will be affected, because it just gives people permission for water harvesting. I think it wasn't strong enough. The fallback is that the Building Standards Commission is working to finalize specific plumbing guidelines so that if people want to use rainwater, they can.

Obviously, you have been involved and I have been a little bit involved in developing the new standards for the Plumbing Code and the Green Supplement. When the new standards are released on January 1, 2014, it will be a big boost to promote the specifics to help people in California, and I suppose the readers of your book. These standards will help people know how to do rainwater harvesting. It is not enough to say, "Yes you can do it," because people look at it and want to know, "How am I going to do it?" The Rainwater Standards are important. On the other hand, if we come out with too many different standards, it muddies the field and people don't know which one to use and it gets a little bit more complicated.

Van Giesen: Why has the development of codes and policies been so arduous and contentious, and still not universally accepted in the United States? Isn't there plenty of data overseas from which we can draw here in the United

States to demonstrate that when designed properly, a rainwater harvesting system can provide a safe source of water, especially for nonpotable uses?

Shapiro: That's hitting the nail on the head. We have all these studies, a decade of information from Australia, vast experiences from Europe and the Caribbean. We have all these examples where rainwater has been used safely and people are not generally getting sick or dying. The incidences where people will get sick are perhaps due to not maintaining their systems properly. But when you design a safe system, install a system properly, and you maintain it properly there is very little danger to it and the risk is acceptable. Yes, I am kind of flabbergasted why this is so controversial. What I learned in California is that there is a lot of infighting between labor and plumbing unions. They (plumbing unions) want to make sure that if a system goes in a landscape outside, that they will also get the work that goes on in the inside. If you collect rainwater and you store it outside, and you use it for irrigation and for inside uses, you cross the boundaries for different unions. So then, what do you do? Do both contractors get the work? That can be a big problem.

Van Giesen: That's a very good point. I know at least in three very different locations, one in Illinois, two in Massachusetts, and of course, the situation you mentioned in California. I believe that what you are referring to has a lot to do with which trade is allowed to work on which part of the system. The only way that these obstacles will be overcome is when bridges are built between these entities.

Shapiro: In California, the law allows the local authority to decide which guideline they want to use. They can choose between guidelines by the International Association of Plumbing and Mechanical Officials (IAPMO) or the International Code Council (ICC).

These guidelines help plumbers do the work, but then we need to look at government officials on all levels. In many areas, they are not promoting rainwater collection. Locally, here in Southern California, as an example, a building official would not allow any alternative water source unless he got specific examples of cases in the area. He didn't want to see cases in Northern California or from another state that might have a different climate or rainfall pattern. What do you do then, when you don't have any local examples? It's a catch 22.

Officials are also used to dealing with municipal potable water as the sole supply for a building. That's how the code is written. This is the traditional system that they know how to regulate and it's hard for them to change. When you propose an alternative water supply on the premises, officials start to think about cross-contamination and people getting sick. If something goes wrong, the contamination may even leave the property and go to the municipal supply. These are valid concerns but not enough to prevent more sustainable solutions. Despite the fact that there are safety precautions designed into these systems, officials begin to start imagining all these possible doomsday scenarios. They do not even look at the data, certainly not from Australia and the actual percentages of these occurrences. Try putting in a water-free urinal in a building when the code says the building has to have water to flush. The inspector's reaction usually is: "No water to flush? Can't be. Just say no." Instead of, "That's an interesting option, let's see if we can make it work, what the challenges are, and what are the solutions."

Van Giesen: Have you seen any strides toward the installation of commercial systems in Southern California?

Shapiro: In Santa Monica we have a 200,000-gallon cistern in our main library that collects roof and parking lot runoff to use for landscape low-volume drip irrigation. We recently completed a multifamily residential building with a 13,000-gallon cistern to collect roof runoff and that's used for drip irrigation. And now we are in the middle of construction of a new library that has a 13,000-gallon cistern for collection of runoff. It will be the first project in our city using rainwater for indoor flushing.

So the main issue with collecting rainwater is that it makes no sense using it only in the landscape during wet periods. We need to be able to use it indoors, so we can use it for flushing, and use up the water before the next storm. There has been a disconnect in Southern California: Everyone is okay with using it for irrigation. We've been trying to get officials to give permission to use rainwater indoors, so it can be used to flush urinals and toilets and really make a difference there. The cities of Los Angeles and Santa Monica are working on a joint project to collect stormwater from a large storm drain and into a large cistern, almost 3 million gallons, under a baseball field, for park irrigation. There have been some problems with some earlier larger projects like the Alta Vista Park project, in Redondo Beach, California, in which the cistern has leaks, delaying operation.

Van Giesen: You highlight an interesting point, the fact that early pioneer projects are going through growing pains. This is hard for the public to understand. The project in the City of Redondo Beach was designed to catch water off of a number of city blocks. There were a number of setbacks with the materials and construction.

Shapiro: We had to work with the LA County Department of Public Health. We are doing something different, not part of the norm, and the county public health officials were basically fine with these kinds of projects, as long as we were testing water and collecting data and analysis. These exciting projects can lead to improvements in the guidelines, regulations, codes, and standards, so that people doing it in the future will have an easier time with it, especially in the design and the permitting of it.

Van Giesen: How do you respond to the comment that it doesn't rain enough to harvest water in Southern California?

Shapiro: I would say that you are correct, that you cannot harvest rainwater year-round in Southern California. We only get harvestable rain twenty to thirty days over a couple of months of the year, on average. But the amount of water that comes off the roof can be pretty substantial in a short amount of time. So we have to plant climate-appropriate landscapes and make sure that all the devices in the house are the most water-efficient devices possible. Then you can collect a large portion of the wate, needed for your indoor personal use. If everybody does that, it's going to make a difference. Everybody doesn't have to cut back 80 percent, but if we all do 30 to 50 percent with all the many demand and supply efficiency strategies, it will make a difference.

Van Giesen: What is your opinion on sourcing water locally as opposed to the current practice of seeking water from distant sources?

Shapiro: Right now we are living beyond our means, beyond a sustainable rate. The main culprit, I believe, is a turf or other water-thirsty planted yard with spray irrigation. We should not be taking water resources from distant watersheds and should really live with what we have locally, and this includes having landscapes that are climate appropriate. Each watershed has a certain amount of water. Whatever plants and animals are in that watershed are surviving overtime within the means of that system. If a natural system can live within its means, then I think we need to do that as well because we are part of that watershed. Why should we function any differently? We should live within the limits of our local water supply. We have the technology to do this. We just don't have the will and do not want to change our wasteful behaviors.

There are a lot of people (here in Southern California) who want to have green lawns year-round, and they are transplanted or used to climates and landscapes from the Midwest, East Coast, or other wetter environs where they can have a green lawn most of the year because it rains year-round. They come to Southern California, where they can grow things year-round, and they are used to seeing green all the time. That doesn't work here; you can't transplant East Coast watershed mentality to Southern California, which has a Mediterranean climate. That's not how nature works. Nature won't change for one or two species. All the species have to adapt to survive within the means created locally. We just need the will to apply our technical genius and innovation.

People get caught up in everyday activities. They are used to turning on their spigots and having unlimited freshwater come out all the time. That's how they've grown up and I'm concerned that our grandchildren will not be able to have the same amenities that we have and the high quality of life. We will have to do something to adapt to a changing situation.

DAVID STOOKSBURY

David Stooksbury, former State of Georgia Climatologist, is an Associate Professor at Driftmier Engineering Center at University of Georgia, and he specializes in wind and solar resources.

Figure 6.14 David Stooksbury

Van Giesen: You served as the Georgia State Climatologist during the historic drought of 2007 through 2009. You have observed extreme fluctuations in temperature and precipitations over the last ten years, and perhaps beyond. How do these fluctuations in climate affect the design of stormwater infrastructure?

Stooksbury: I think the most important thing for us to realize is that the definition of climate that we learned in middle school, which is, climate is the average weather, is a virtually useless definition. A climatologist wouldn't use this definition because climate is more than just the average; it involves variability and extremes, so it's more than just the average.

When the nightly news gives the average, high, and low temperatures, they almost never hit the average, particularly on both the highs and lows. It's normally close but not exactly at it.

A climate is variable. Any engineering design has to take that into account. Some designers will be more concerned about the extreme events at the high end. Some will be more concerned about the events at the low end. Proper design needs to take into account both high-end and low-end extreme events. One thing that we do know is that the climate is changing and the question is: How long of a time period of data do I need to use? When gathering data, we need to use real data and not rely on our perceptions, because if anything, our perceptions are normally wrong about the data and about what happens. People can't even remember what happened last spring or last summer, much less what has been the normal pattern over the last several years.

The climate is changing and we are the primary cause of that change. It's a slow process. We need to have a long enough period of time to pick up the actual variability and to get outside of just random data. Thirty years is the standard. Climatologists update the thirty-year average routinely, so we are not stuck using the thirty-year average from 1941 to 1970. We are constantly updating the data, so if you're using the past thirty years you should be in relatively good shape. You are still picking up that climate change, but you have a long enough record to have a good sample of the extreme events that you can expect in that time period.

Van Giesen: How does a designer, an engineer, a planner, an architect go about trying to understand what is the average rainfall that he or she might be able to anticipate?

Stooksbury: In the design of handling water coming off a roof, you're looking at both the issue of duration and intensity. So a 1-inch rain over twenty-four-hour period is very different from a 1-inch rain over fifteen minutes. NOAA and the National Weather Service have been updating what has been around for decades, called Technical Paper 40. Quite often just the term "TP 40" is used. Unfortunately, it was done in the early 1960s with minimal data and was designed to give large swaths of guidance of various rainfall intensity duration events. Now they have a large part of the United States updated with much more recent data and statistically much more powerful. Thanks to computers, they can model these much better than in the '60s with slide rules and hand calculations.

Van Giesen: If someone in small-town USA wants to find out the average precipitation, what should be his or her first step?

Stooksbury: A good place to start would actually be their state-climate office in both getting the averages and also getting the return intervals of interest. You want to design this to handle the average storms for a year, the average storm every two years, or the average storm over a ten-year period, and they would be able to assist you in finding that information for your location.

Van Giesen: If a rainwater system designer is trying to figure out the size of a rainwater cistern, not having enough information about precipitation can be a handicap. There are a number of different methodologies to size cisterns. One particular methodology that I've used is the average number of days between rain events. So how would someone find the average number of days between rain events in a specific location?

Stooksbury: First of all, a rain event is not universally defined. A term often used in the construction industry is "barring abnormal rain" and abnormal rain was never defined. The question is that there's a difference between a trace of rain which is less than one hundredth of an inch or let's say two hundredths of an inch of rain.

Does that count as a rain event? Or does it need to have a magical threshold like a tenth of an inch to qualify as a rain event? The definition of a rain event needs to be tested and shown to work over a large geographical region. Does it work in the Pacific Northwest in Seattle where you're going to have many days with very little rainfall? Will it work in Tucson, Arizona, where there is a monsoon type of climatology? By the way, monsoon does not actually refer to heavy rain but refers to the seasonal change in wind direction. When it is said, "the monsoon is occurring in the desert southwest," what is actually meant is that the wind is coming off the Pacific and out the Gulf of California. Monsoon has nothing to do with how heavy the rain is; it's just the seasonal change in wind direction. So, monsoon does not actually mean heavy rain, as it is quite often used by the news media.

Van Giesen: So that gets into the "perception." You talked earlier about how weather is perceived versus how weather really is. Do you find that also true in the world of policy makers and elected officials and how they approach weather and drought?

Stooksbury: Definitely, in part, because policy makers are not driven necessarily by science; as a matter of fact, for some policy makers, science is immaterial. Policy makers are thinking "what can we get through, what people will allow us to do." Science is quite often the least of their concerns.

Several years back, when I was at the undergraduate program in policy, and I puzzled over how the University could offer an undergraduate program on policy, if the students didn't know anything about the subject on which they were writing the policies. When I asked them this question, they said, "You don't need to know anything about the subject in order to write the policy, because it is a process." This attitude probably explains the disconnect that public policy is not science nor is it information driven. A lot of policy is written by those who have a vested interest, whether it is noble or not. Unfortunately, science quite often is not the driving force in policy.

Van Giesen: In the Southeastern United States, the public generally thinks of this region as receiving 40 to 50 inches of rain a year. Is that an accurate statement?

Stooksbury: The driest places in most of the Southeastern United States receive about 45 to 55 inches of rain. Once you get up in the mountains, it goes up. For example, Toxaway, South Carolina, which is not far from where Georgia, South Carolina, and North Carolina meet, has over 100 inches of rain a year on average. Dell Enterprise, which is in the Northern Shenandoah Valley, Virginia, averages about 34 inches a year. It is in the rain shadow from the East and from the West.

Van Giesen: How is it that a city like Atlanta could be having such difficulties with water supply, when they are in such a water-abundant part of North America?

Stooksbury: Part of it is that the average American uses a tremendous amount of water. Atlanta is at the top of the catchment. The drainage basin for Lake Lanier (the Corps of Engineers' lake that supplies nearly all of the drinking water for Atlanta) is just barely over 1,000 square miles, which is not big at all.

Another part of it also has to do with the way we use water. To a large extent, we changed the way we use water. Growing up in the South, we didn't used to water our lawn. Once the plants were established, there was no more watering. The idea was that if you had to water your grass, you had the wrong type of grass. Everybody knew that in July and August the lawn was going to go dormant. Everybody knew that it was because it was dry and hot. Now, there is a kind of "adult peer pressure" to keep up with the neighbors and have the greenest lawn. There are actually covenants for neighborhoods specifying what kind of grass they can have, and they have to keep it a certain way and so forth.

DAVE VIOLA

Senior Director of Technical Services, Dave is a twenty-four-year veteran of model construction code development. He is responsible for IAPMO's sustainability activities, training, education, personnel certification, and custom code development activities.

Figure 6.15 Dave Viola

Van Giesen: Dave, IAPMO has been involved in the development of rainwater harvesting codification for a number of years. Can you elaborate a little on how the codes have impacted the rainwater industry?

Viola: For the first time in the history of model codes, IAPMO, through the development of the Green Plumbing and Mechanical Code Supplement, has standardized code language for the design, installation, maintenance, and inspection of rainwater harvesting systems. These provisions are now being used by designers and installers as the basis for their designs in order to obtain approval from building departments across the country. These professionals rely upon the standardized code provision in order to obtain approval. Up until recently, the codes have been silent or prohibitive on rainwater systems, for potable or nonpotable applications.

The IAPMO Green Technical Committee (GTC) developed the Rainwater Harvesting provisions for use in the Green Supplement with the understanding that they would be evaluated, scrutinized, and enhanced so that they can be submitted for inclusion in the IAPMO Uniform Plumbing Code.

The Green Technical Committee succeeded in getting rainwater harvesting (RWH) provisions in the UPC within two years after completion. The RWH language that first appeared in the 2010 edition of the GPMCS was adopted into the 2012 edition of the UPC. The inclusion of RWH in the UPC had an immediate impact as the State of California incorporated the language as soon as it became available. The speed in which RWH provisions were drafted, incorporated into a model plumbing code, and adopted in jurisdictions such as California is unprecedented. In two short years, the normally slow and deliberate code-development process produced comprehensive requirements that are now allowing the broad use of rainwater harvesting.

Van Giesen: Was California the first state to go through that whole process (from Green Plumbing Supplement to state code)?

Viola: Yes, California was the very first state. They were actually so anxious to use the language that they couldn't wait for it to be published in the 2012 Codes. The State agencies actually asked us to give them draft versions of it while it was still under development, so that they could include it when they initiated their process.

You may be aware that IAPMO publishes the California Plumbing Codes (which is based on the UPC), and the new California Codes have been available for a month now (July 2013) and will become effective in January 2014.

Van Giesen: We know that there are a lot of unsubstantiated fears associated with indoor applications for rainwater harvesting for nonpotable uses. A lot of these concerns come from public health officials. What do you think drives these concerns and, more importantly, what are the best ways to counter these fears?

Viola: You have to understand that public health officials and plumbing inspectors are stewards for protection of public health. They have a different perspective than the industry does when it comes to protecting the citizens they represent. They are obligated to enforce stringent standards to ensure health, safety, and welfare. When in doubt, they err on the side of safety. There is a famous motto that guides these professionals: "Prevention, not cure."

This motto is very helpful in providing insight as to what to expect from a public health official as they are always working to prevent bad things from happening, rather than fixing a problem after one has occurred.

Without proper code language regulating RWH systems, the public health official had to err on the side of safety and was unable to permit their use. The availability of comprehensive RWH code provisions ensures that strong, consistent, and safe codes and design practices are in place, and gives public health officials the confidence they need to approve them.

Van Giesen: Dave, I think you hit the nail right on the head. That, my friend, was very well articulated. Do you think these codes have helped push the rainwater industry forward?

Viola: Absolutely, California is an example of that.

Van Giesen: Yes, we have seen a lot of work in California. What remains to be done? What is on your wish list in terms of further code development?

Viola: In the area of rainwater harvesting we've only just begun to scratch the surface. Initially, the main goal was to ease the minds of folks that were resistant to use rainwater harvesting systems and enable these systems to be used through the creation of code provisions. The goal also was to create a mechanism for RWH to be installed by contractors and sold by manufacturers. These goals were accomplished.

Moving forward, we need to continue working on water quality standards and expand the applications for harvested rainwater as well as the types of collection surfaces.

ENDNOTE

1. Green Infrastructure http://water.epa.gov/infrastructure/greeninfrastructure/index.cfm

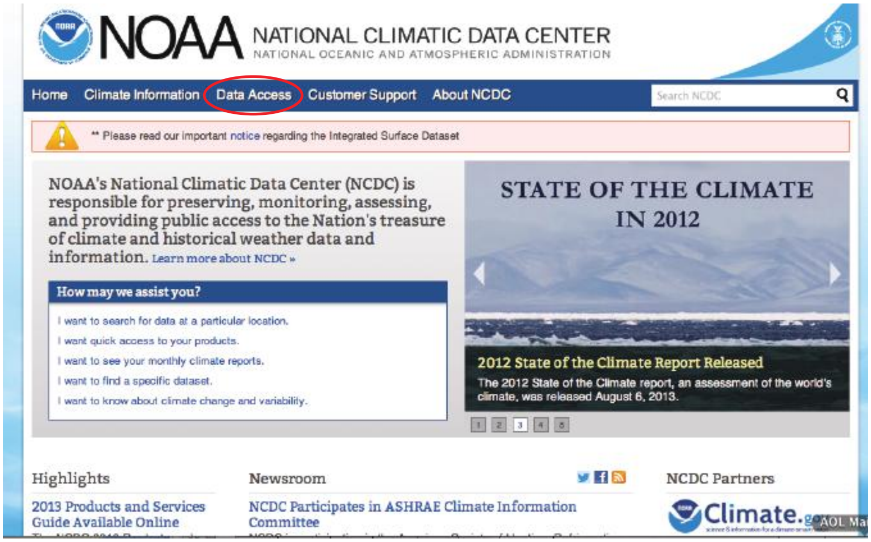
Appendix A

1. NOAA: FINDING ANNUAL AND MONTHLY DATA

The following is the step-by-step process to find detailed weather information on the NOAA website. There is a wealth of data on the NOAA site providing information to the design professional about precipitation and rainfall events. The designer may wish to use annual rainfall data for rough design estimates and monthly data to accurately size a cistern. If there are problems with the NOAA site, contact the Customer Service Representative at the number posted on the site to receive assistance. Following are the steps to follow to obtain current rainfall data.

Step 1: www.ncdc.noaa.gov/

- Select Data Access on the main task bar.



** Please read our important notice regarding the Integrated Surface Dataset

NOAA's National Climatic Data Center (NCDC) is responsible for preserving, monitoring, assessing, and providing public access to the Nation's treasure of climate and historical weather data and information. Learn more about NCDC »

How may we assist you?

I want to search for data at a particular location.
I want quick access to your products.
I want to see your monthly climate reports.
I want to find a specific dataset.
I want to know about climate change and variability.

STATE OF THE CLIMATE IN 2012

2012 State of the Climate Report Released

The 2012 State of the Climate report, an assessment of the world's climate, was released August 6, 2013.

2013 Products and Services Guide Available Online

NCDC Participates in ASHRAE Climate Information Committee

Figure 3A.1 Screen shot of Step 1: NOAA Data Access.

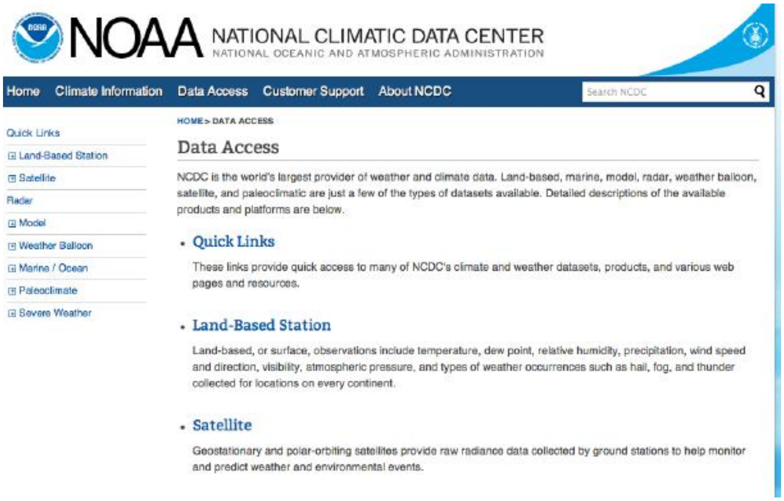
Step 2: www.ncdc.noaa.gov/data-access

- Select Quick Links in the main column in the body of the webpage.

These links provide quick access to many of NCDC's climate and weather datasets, products, and various web pages and resources.

Step 3: www.ncdc.noaa.gov/data-access/quicklinks

- Select Option #1. U.S. Climatological Data



HOME > DATA ACCESS

Data Access

NCDC is the world's largest provider of weather and climate data. Land-based, marine, model, radar, weather balloon, satellite, and paleoclimatic are just a few of the types of datasets available. Detailed descriptions of the available products and platforms are below.

- Quick Links

  These links provide quick access to many of NCDC's climate and weather datasets, products, and various web pages and resources.

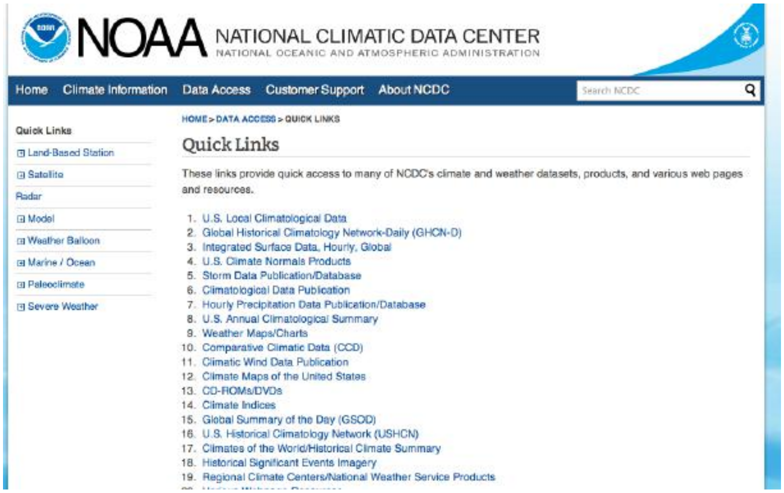
- Land-Based Station

  Land-based, or surface, observations include temperature, dew point, relative humidity, precipitation, wind speed and direction, visibility, atmospheric pressure, and types of weather occurrences such as hail, fog, and thunder collected for locations on every continent.

- Satellite

  Geostationary and polar-orbiting satellites provide raw radiance data collected by ground stations to help monitor and predict weather and environmental events.

Figure 3A.2 Screen shot of Step 2: NOAA Data Access.



HOME > DATA ACCESS > QUICK LINKS

Quick Links

These links provide quick access to many of NCDC's climate and weather datasets, products, and various web pages and resources.

1. U.S. Local Climatological Data
2. Global Historical Climatology Network-Daily (GHCN-D)
3. Integrated Surface Data, Hourly, Global
4. U.S. Climate Normals Products
5. Storm Data Publication/Database
6. Climatological Data Publication
7. Hourly Precipitation Data Publication/Database
8. U.S. Annual Climatological Summary
9. Weather Maps/Charts
10. Comparative Climatic Data (CCD)
11. Climatic Wind Data Publication
12. Climate Maps of the United States
13. CD-ROMs/DVDs
14. Climate Indices
15. Global Summary of the Day (GSOD)
16. U.S. Historical Climatology Network (USHCN)
17. Climates of the World/Historical Climate Summary
18. Historical Significant Events Imagery
19. Regional Climate Centers/National Weather Service Products

Figure 3A.3 Screen shot of Step 3: Quick Links.

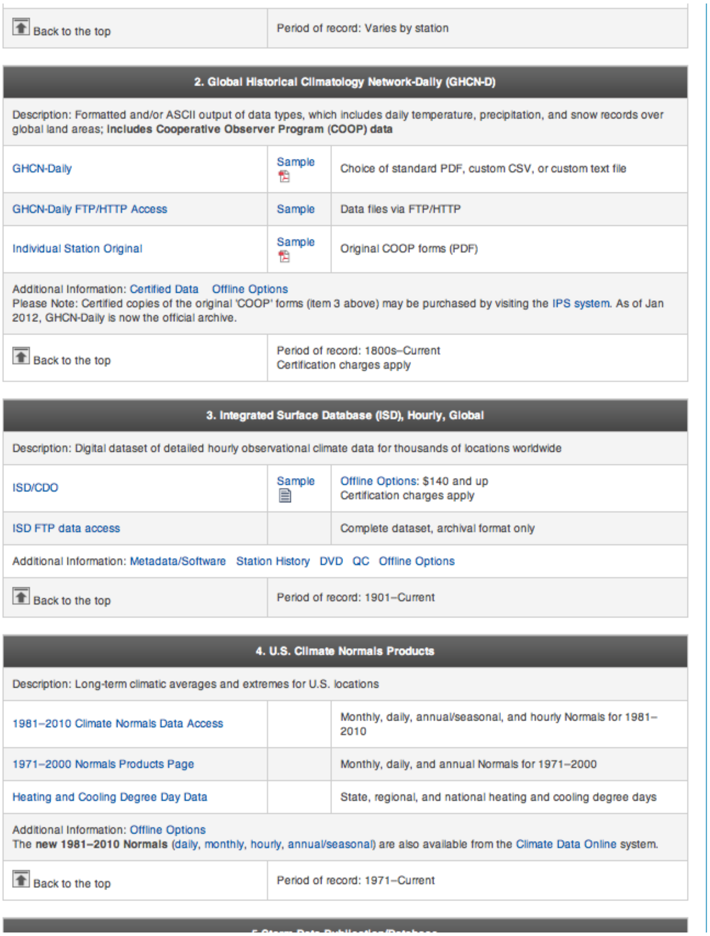
Step 4: www.ncdc.noaa.gov/data-access/quick-links#loc-clim

- Scroll down to Quick Link #4
- Select: 1981-2010 Climate Normals Data Access

Step 5: www.ncdc.noaa.gov/data-access/land-based-station-data/land-based-datasets/climate-normals/1981-2010-normals-data

- On the first pull-down menu choose the state.
- On the second pull-down menu choose the closest city.
- The data will show below, including precipitation, temperature, and climatological variables.
- Use the first column for your rainwater calculations. It shows average precipitation monthly from 1981 to 2010 in inches.

Step 6: Review of Monthly Normals from Berkeley, California



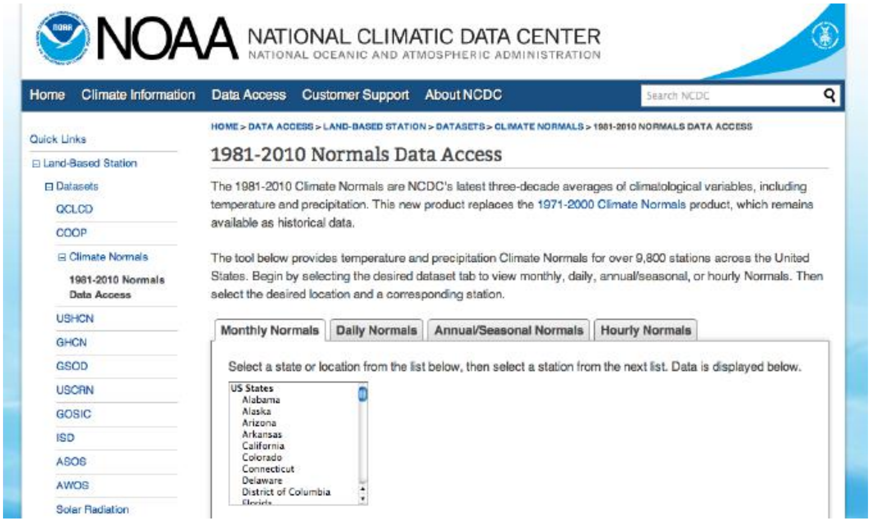
Back to the top	Period of record: Varies by station

2. Global Historical Climatology Network-Daily (GHCN-D)		
Description: Formatted and/or ASCII output of data types, which includes daily temperature, precipitation, and snow records over global land areas; **Includes Cooperative Observer Program (COOP) data**		
GHCN-Daily	Sample	Choice of standard PDF, custom CSV, or custom text file
GHCN-Daily FTP/HTTP Access	Sample	Data files via FTP/HTTP
Individual Station Original	Sample	Original COOP forms (PDF)
Additional Information: Certified Data Offline Options Please Note: Certified copies of the original 'COOP' forms (item 3 above) may be purchased by visiting the IPS system. As of Jan 2012, GHCN-Daily is now the official archive.		
Back to the top	Period of record: 1800s–Current Certification charges apply	

3. Integrated Surface Database (ISD), Hourly, Global		
Description: Digital dataset of detailed hourly observational climate data for thousands of locations worldwide		
ISD/CDO	Sample	Offline Options: $140 and up Certification charges apply
ISD FTP data access		Complete dataset, archival format only
Additional Information: Metadata/Software Station History DVD QC Offline Options		
Back to the top	Period of record: 1901–Current	

4. U.S. Climate Normals Products		
Description: Long-term climatic averages and extremes for U.S. locations		
1981–2010 Climate Normals Data Access		Monthly, daily, annual/seasonal, and hourly Normals for 1981–2010
1971–2000 Normals Products Page		Monthly, daily, and annual Normals for 1971–2000
Heating and Cooling Degree Day Data		State, regional, and national heating and cooling degree days
Additional Information: Offline Options The **new 1981–2010 Normals** (daily, monthly, hourly, annual/seasonal) are also available from the Climate Data Online system.		
Back to the top	Period of record: 1971–Current	

Figure 3A.4 Screen shot of Step 4: Climate Normals.



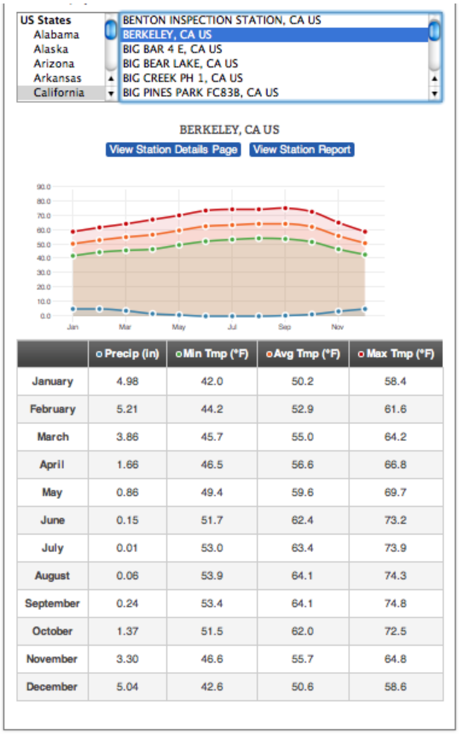
1981-2010 Normals Data Access

The 1981-2010 Climate Normals are NCDC's latest three-decade averages of climatological variables, including temperature and precipitation. This new product replaces the 1971-2000 Climate Normals product, which remains available as historical data.

The tool below provides temperature and precipitation Climate Normals for over 9,800 stations across the United States. Begin by selecting the desired dataset tab to view monthly, daily, annual/seasonal, or hourly Normals. Then select the desired location and a corresponding station.

Select a state or location from the list below, then select a station from the next list. Data is displayed below.

Figure 3A.5 Screen shot of Step 5: 1981–2010 Normals Data Access.



BERKELEY, CA US

	○ Precip (in)	○ Min Tmp (°F)	○ Avg Tmp (°F)	○ Max Tmp (°F)
January	4.98	42.0	50.2	58.4
February	5.21	44.2	52.9	61.6
March	3.86	45.7	55.0	64.2
April	1.66	46.5	56.6	66.8
May	0.86	49.4	59.6	69.7
June	0.15	51.7	62.4	73.2
July	0.01	53.0	63.4	73.9
August	0.06	53.9	64.1	74.3
September	0.24	53.4	64.1	74.8
October	1.37	51.5	62.0	72.5
November	3.30	46.6	55.7	64.8
December	5.04	42.6	50.6	58.6

Figure 3A.6 Screen shot of Step 6: Monthly Normals from Berkeley, California.

2. HYPOTHETICAL EXAMPLES: CALCULATIONS OF SCHOOLS IN DIFFERENT CLIMATE ZONES

1—School in Ann Arbor, Michigan

DATA COLLECTION

- Total collection area: 109,000 square feet
- Runoff coefficient value (membrane): 0.90
- Average number of instructional days during school year: 180
- Specific months school is in session: August through May
- Average number of instructional days per month: 20
- Number of students: 650
- Annual rainfall in Ann Arbor: 32.81 inches

(Note: Using the figures on the NOAA website, the months school is in session, the months for demand, have fairly even rainfall.)

These figures are derived using the NOAA website. Other local contributing factors may cause variation. Review any local specific information available from other sources.

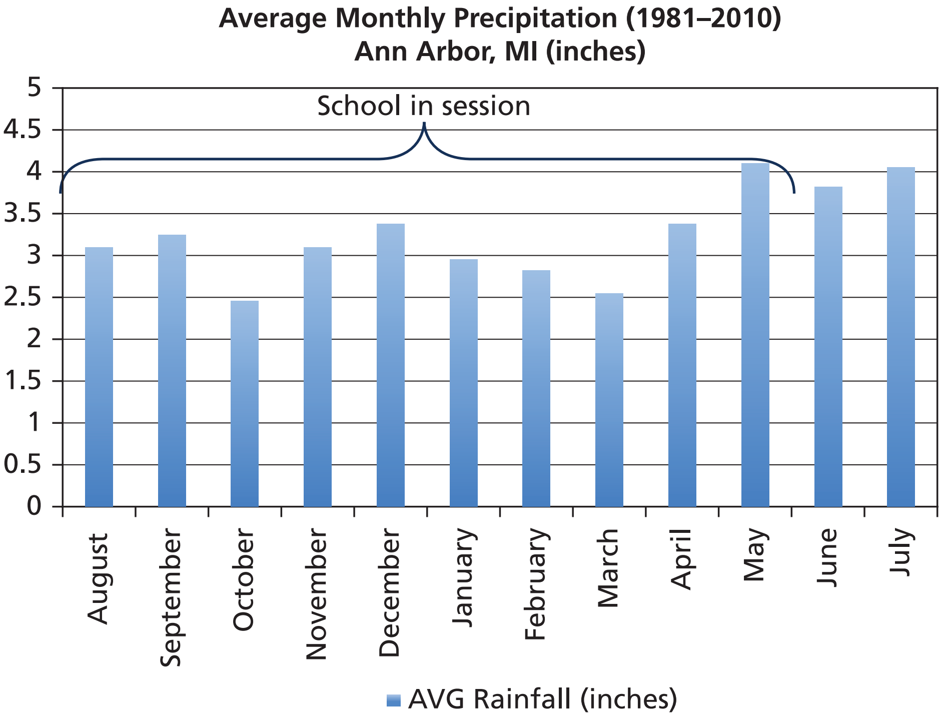


Figure 3B.3 Ann Arbor monthly rainfall.

DEMAND:

Demand for nonpotable water for flushing toilets and urinals is based on data in Table 3.5 Model Water Use by Students

2.11 toilet flushes @ 1.68 gpf = 3.54 g

1.1 urinal flushes @ 1.0 gpf = 1.01 g

4.55 g/student/day

650 students × 4.55 gpd = 2,958 gpd

Monthly demand = 2,958 per day × 20 days
= 59,000 g/month

SUPPLY

Rainwater supply = Collection area (square feet) × Rainfall (inches) × .623 (Conversion factor) × Runoff coefficient

Supply = 109,000 sq. ft. × average monthly amount of precipitations in inches × .623 × .90 = Gallons per Month (see Table 3B.2)

Table 3B.2 Ann Arbor Rainwater supply calculation

Ann Arbor Avg. Monthly Precipitation (1981–2010)	A Collection Area (sf)	B Monthly avg Rainfall (inches)	C Conversion Factor	D Runoff Coefficient	Rainwater Supply (Multiply Columns A×B×C×D)
January	109,000	1.49	.623	.90	91,063.287
February	109,000	1.75	.623	.90	106,953.525
March	109,000	2.14	.623	.90	130,788.882
April	109,000	2.95	.623	.90	180,293.085
May	109,000	3.36	.623	.90	205,350.768
June	109,000	3.51	.623	.90	214,518.213
July	109,000	3.55	.623	.90	216,962.865
August	109,000	3.16	.623	.90	193,127.508
September	109,000	3.46	.623	.90	211,462.398
October	109,000	2.64	.623	.90	161,347.032
November	109,000	2.76	.623	.90	168,680.988
December	109,000	2.04	.623	.90	124,677.252
Annual	109,000	32.81	.623	.90	2,005,225.803

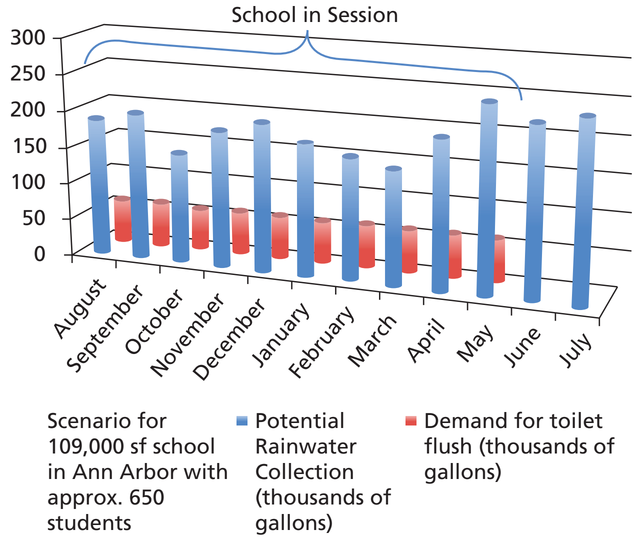


Figure 3B.4 Ann Arbor demand–supply analysis.

2—School in New York City

DATA COLLECTION

- Total collection area: 109,000 square feet
- Runoff coefficient value (membrane): 0.90
- Average number of instructional days during school year: 180
- Specific months school is in session: August through May
- Average number of instructional days per month: 20
- Number of students: 650
- Annual rainfall in New York City: 47 inches

(Note: Using the figures on the NOAA website, the months school is in session, the months for demand, have fairly even rainfall.)

These figures are derived using the NOAA website. Other local contributing factors may cause variation. Review any local specific information available from other sources.

DEMAND

Demand for nonpotable water for flushing toilets and urinals is based on data in Table 3.5 Model Water Use by Students.

2.11 toilet flushes @ 1.68 gpf = 3.54 g

1.1 urinal flushes @ 1.0 gpf = 1.01 g

4.55 g/student/day

650 students × 4.55 gpd = 2,958 gpd

Monthly demand = 2,958 per day × 20 days
= gallons per month

SUPPLY

Rainwater supply = Collection area (sq. ft.) × Rainfall (inches) × .623 (Conversion factor) × Runoff coefficient

Supply = 109,000 sq. ft. × average monthly amount of precipitations in inches × .623 × .90 = Gallons per Month (see Table 3B.3)

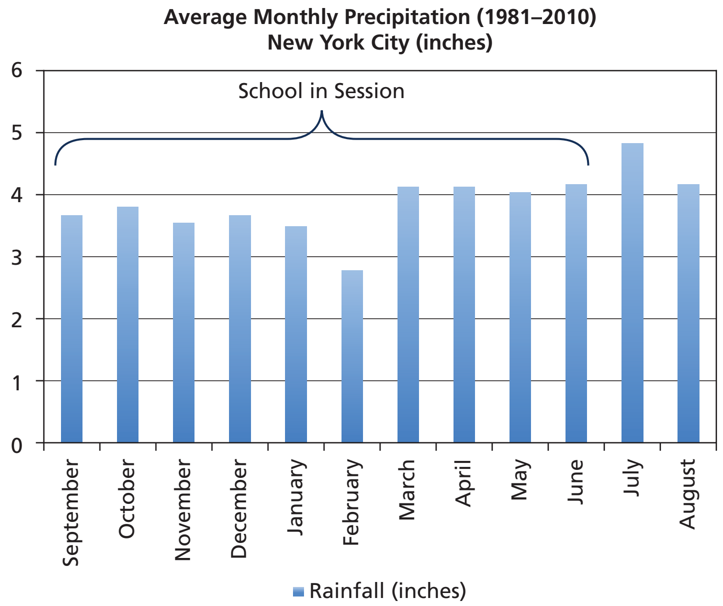


Figure 3B.5 New York City monthly rainfall.

Table 3B.3 NY Rainwater Supply Calculation

New York Ave. Monthly Precipitation (1981–2010)	A Collection Area (sf)	B Montly avg Rainfall (inches)	C Conversion Factor	D Runoff Coefficient	Rainwater Supply (Multiply Columns A × B × C × D)
January	109,000	3.5	.623	.90	213,907.05
February	109,000	2.81	.623	.90	171,736,80
March	109,000	4.15	.623	.90	253,632.65
April	109,000	4.14	.623	.90	253,021.48
May	109,000	4.05	.623	.90	247,521.02
June	109,000	4.16	.623	.90	254,243.81
July	109,000	4.85	.623	.90	296,414.06
August	109,000	4.18	.623	.90	255,466.13
September	109,000	3.71	.623	.90	226,741.47
October	109,000	3.81	.623	.90	232,853.10
November	109,000	3.56	.623	.90	217,574.03
December	109,000	3.68	.623	.90	224,907.98
Annual	109,000	47	.623	.90	2,872,466.10

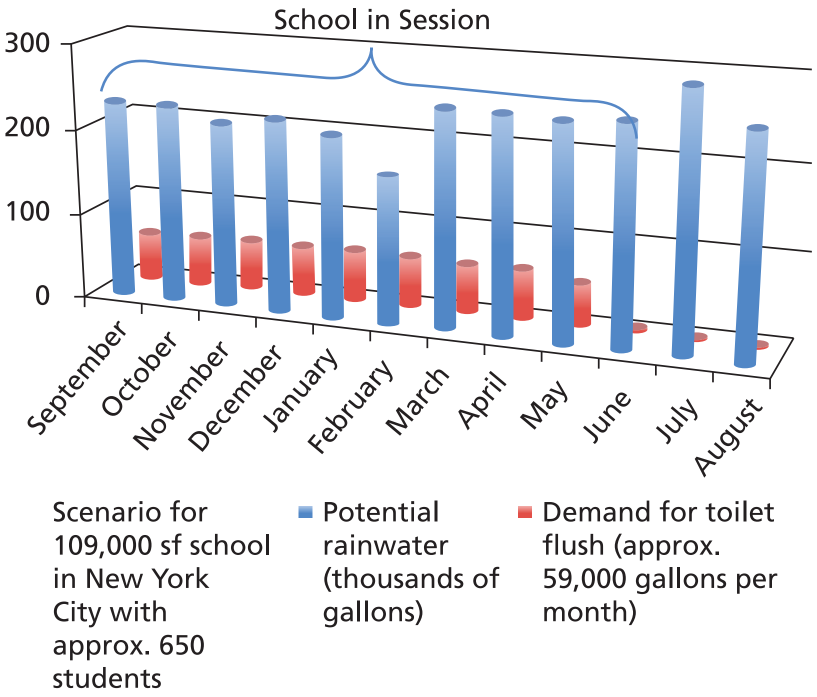


Figure 3B.6 New York City demand–supply scenario.

3—School in Phoenix, Arizona

DATA COLLECTION

The average annual rainfall in Phoenix, Arizona, is 8 inches per year. The designer should be aware of the patterns of rain events in Phoenix. There are relatively large rainfalls that occur in March, during which time the City receives 1.06 inches of rain. The largest rainfalls occur in the months of July and August. The designer will need to carefully target the most effective use of this less plentiful resource. However, even in this desert environment there is still a sizable amount of rain that can be collected from a 109,000-square-foot roof.

- Total collection area: 109,000 square feet
- Runoff coefficient value (membrane): 0.90
- Average number of instructional days during school year: 180
- Specific months school is in session: August through May
- Average number of instructional days per month: 20
- Number of students: 650
- Annual rainfall in Phoenix: 8.22 inches

(Note: Using the figures on the NOAA website, the months school is in session, the months for demand, have fairly even rainfall.)

These figures are derived using the NOAA website. Other local contributing factors may cause variation. Review any local specific information available from other sources.

DEMAND

Demand for nonpotable water for flushing toilets and urinals is based on data in Table 3.5 Model Water Use by Students.

2.11 toilet flushes @ 1.68 gpf = 3.54 g

1.1 urinal flushes @ 1.0 gpf = 1.01 g

4.55 g/student/day

650 students × 4.55 gpd = 2,958 gpd

Monthly demand = 2,958 per day × 20 days
= 59,000 g/month

SUPPLY

Rainwater supply = Collection area (sq. ft.) × Rainfall (inches) × .623 (Conversion factor) × Runoff coefficient

Supply = 109,000 sq. ft. × average monthly amount of precipitations in inches × .623 × .90 = Gallons per Month (see Table 3b.4)

Note: If this facility were in Flagstaff, Arizona, only 150 miles north, the annual rainfall would be twice as much. Flagstaff has an annual rainfall of 23 inches and can supply as much as 544,500 gallons of water, half of what is required for toilet and urinal flushing.

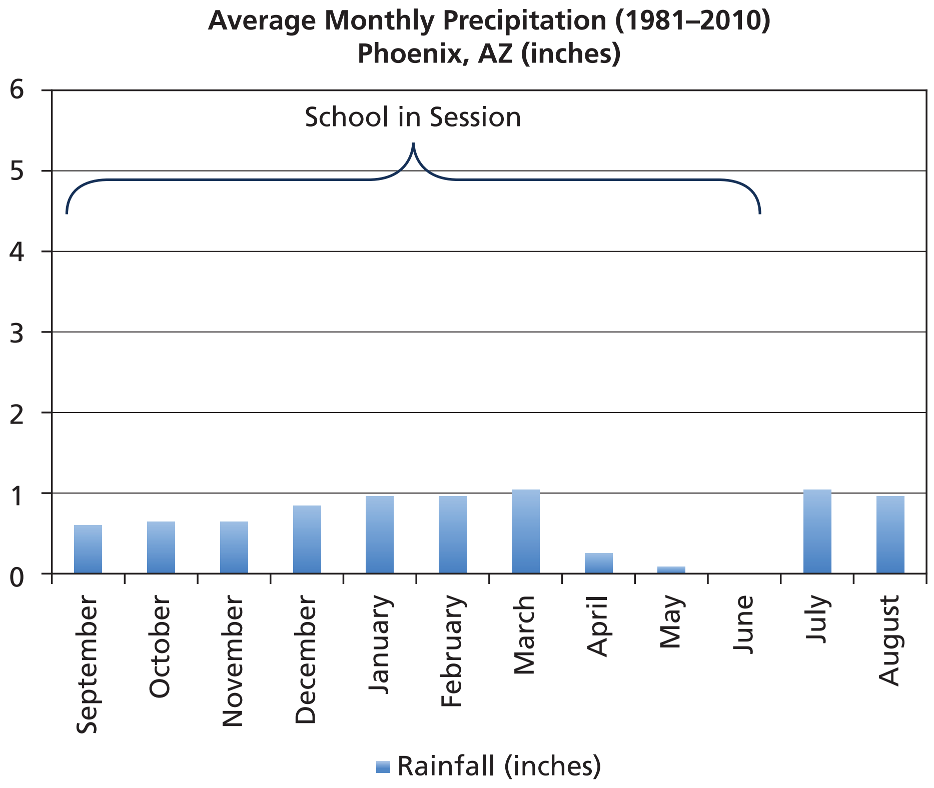


Figure 3B.7 Phoenix, Arizona monthly rainfall.

Table 3B.4 Phoenix Rainwater Supply Calculation

Phoenix Avg. Monthly Precipitation (1981-2010)	A Collection Area (sf)	B Monthly avg Rainfall (inches)	C Conversion Factor	D Runoff Coefficient	Rainwater Supply (Multiply Columns A×B×C×D)
January	109,000	.98	.623	.90	59,893.97
February	109,000	.97	.623	.90	59,282.81
March	109,000	1.06	.623	.90	64,783.28
April	109,000	.26	.623	.90	15,890.24
May	109,000	.08	.623	.90	4,889.30
June	109,000	.02	.623	.90	1,222.33
July	109,000	1.07	.623	.90	65,394.44
August	109,000	.97	.623	.90	59,282.81
September	109,000	.61	.623	.90	37,280.94
October	109,000	.65	.623	.90	39,725.60
November	109,000	.66	.623	.90	40,336.76
December	109,000	.85	.623	.90	51,948.86
Annual	109,000	8.22	.623	.90	502,375.99

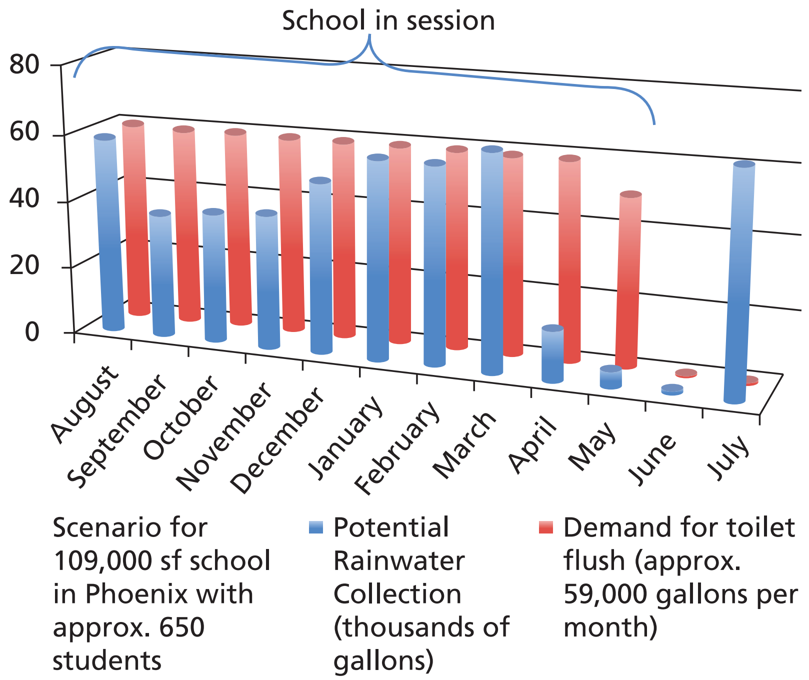


Figure 3B.8 Phoenix demand–supply analysis.

4—School in San Francisco, California

DATA COLLECTION

San Francisco, California's average rainfall is approximately 21 inches per year. However, San Francisco receives almost no rain from April until October. The Mediterranean climate yields dry summers and relatively wet winters. In San Francisco, the school year parallels the exact months when it rains the most, making the use of rainwater collection feasible for use in toilet and urinal flushing in schools.

- Total collection area: 109,000 sq. ft.
- Runoff coefficient value (membrane): 0.90
- Average number of instructional days during school year: 180
- Specific months school is in session: August through May
- Average number of instructional days per month: 20
- Number of students: 650
- Annual rainfall in San Francisco: 20.69 inches

(Note: Using the figures on the NOAA website, the months school is in session, the months for demand, have fairly even rainfall.)

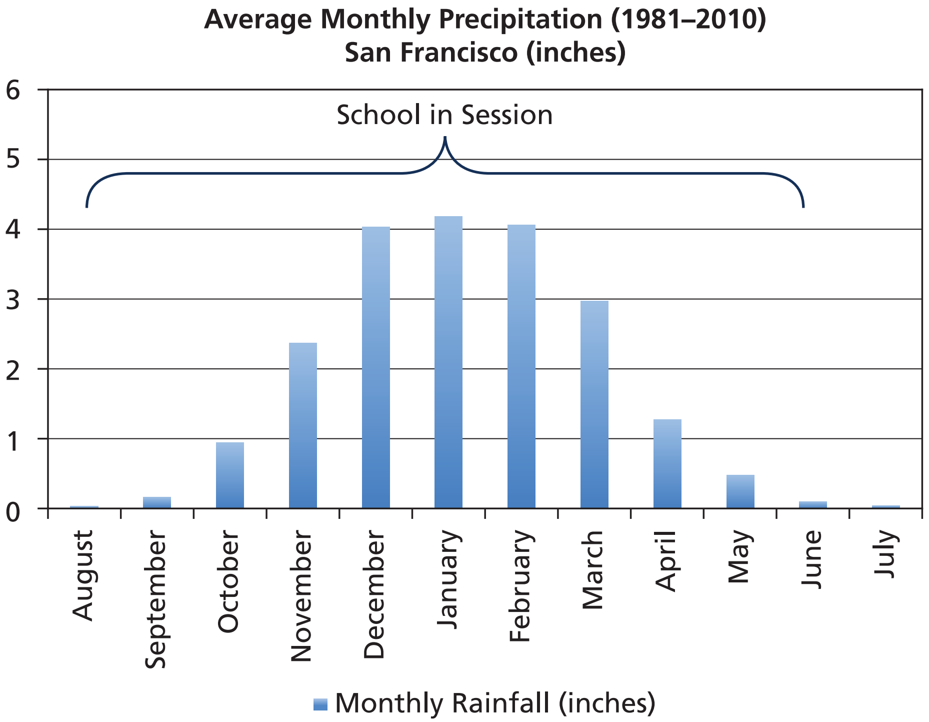


Figure 3B.9 San Francisco monthly rainfall.

These figures are derived using the NOAA website. Other local contributing factors may cause variation. Review any local specific information available from other sources.

DEMAND

Demand for nonpotable water for flushing toilets and urinals is based on data in Table 3.5 Model Water Use by Students

2.11 toilet flushes @ 1.68 gpf = 3.54 g

1.1 urinal flushes @ 1.0 gpf = 1.01 g

4.55 g/student/day

650 students × 4.55 gpd = 2,958 gpd

Monthly demand = 2,958 per day × 20 days
= 59,000 g/month

SUPPLY

Rainwater supply = Collection area (sq. ft.) × Rainfall (inches) × .623 (Conversion factor) × Runoff coefficient

Supply = 109,000 sq. ft. × average monthly amount of precipitations in inches × .623 × .90 = Gallons per Month (see Table 3b.5)

Table 3B.5 San Francisco Rainwater Supply Calculation

San Francisco Avg. Monthly Precipitation (1981-2010)	A Collection Area (sf)	B Monthly avg Rainfall (inches)	C Conversion Factor	D Runoff Coefficient	Rainwater Supply (Multiply Columns A × B × C × D)
January	109,000	4.19	.623	.90	256,077.30
February	109,000	4.06	.623	.90	248,132.18
March	109,000	2.96	.623	.90	180,904.25
April	109,000	1.29	.623	.90	78,840.03
May	109,000	0.47	.623	.90	28,724.66
June	109,000	.11	.623	.90	6,722.79
July	109,000	.04	.623	.90	2,444.65
August	109,000	.04	.623	.90	2,444.65
September	109,000	.17	.623	.90	10,389.77
October	109,000	.95	.623	.90	58,060.49
November	109,000	2.38	.623	.90	145,456.79
December	109,000	4.03	.623	.90	246,298.69
Annual	109,000	20.69	.623	.90	1,264,496.25

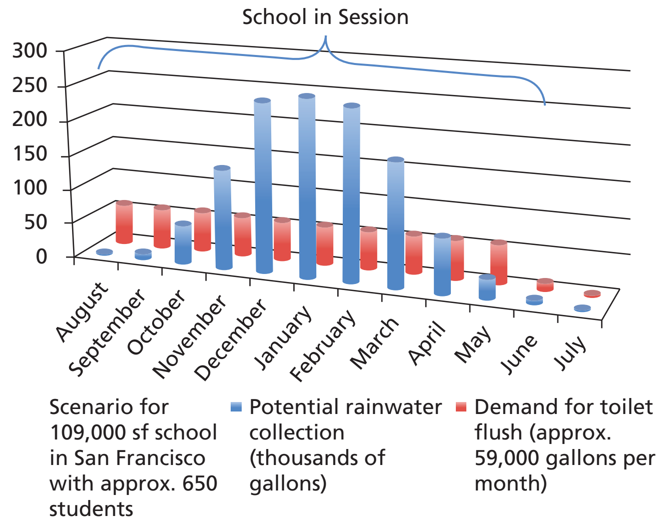


Figure 3B.10 San Francisco demand–supply analysis.

COMPARING THE RESULTS—NORTH, SOUTH, EAST, WEST, AND SOUTHWEST SCHOOL RAINWATER COLLECTION SYSTEMS

The following table summarizes and compares the results of the previous examples.

As shown above, in some communities, the public school can become a major water resource for the neighborhood or a small community. By understanding the relationship between supply and demand and the basic formulas for rainwater collection, the next step is to plan for an integrative system for any building type in any community.

Table 3B.6 Cities Comparison

City	Average Annual Rainfall (inches)	Potential Annual Collection of Rainwater from 109,000-square-foot Roof (gallons)	Annual Water Demand for Toilet Flushing (gallons) in Typical Middle School (average of 10-month school year)	Potential Annual Surplus (gallons)
Atlanta*	49.71	3,038,091.27	590,000	2,448,091.27
Ann Arbor	32.81	2,005,225.803	590,000	1,415,225.80
New York	47	2,872,466.10	590,000	2,282,466.1
Phoenix	8.22	502,375.99	590,000	−87,624.01
San Francisco	20.69	1,264,496.25	590,000	674,496.25

*Data for Atlanta found in Chapter 3

Appendix B

KEY FINDINGS

Table A4.1 Key Findings from Numerous Studies on the Effect of Roofing Materials on Rooftop Runoff Quality from *Rainwater Harvesting—A Comprehensive Review of Literature*, contains a compilation of case studies from different locales and climates available from the North Carolina Water Resources Research Institute.

References	Study Location	Roof Type	Sampling	Key Findings
Yaziz et al., 1989	Selangor, Malaysia	Galvanized iron (GI) & concrete tile	2 roof types, 24 samples each; Sept. 1987 thru Jan. 1988	• Relatively better water quality for galvanized iron roofs (compared to concrete tile) due to smoother surface (with respect to TSS, turbidity, conductivity) - Coarse surfaces allow better deposition and entrapment of atmospheric pollutants • Some dissolution of Zn likely for galvanized iron roof due to acid rain, but Zn concentrations within WHO guidelines for drinking water (5 mg/l)

*Studies that did not present raw data are not included in Table 4, but are summarized herein.

(*Continued*)

Table A4.1 (*Continued*)

References	Study Location	Roof Type	Sampling	Key Findings
Zobrist et al., 2000	Switzerland	Clay tile, Polyester, Gravel	3 roof types, 14 storm events; 2 year study period, 1994/1995	• Pb and Fe present predominantly in particulate form for tile and polyester roofs • Cu, Zn, Cd, Mn and Cr occurred predominantly in dissolved form for tile and polyester roofs; particulate/dissolved partitioning did not change significantly with runoff depth for tile roof, but this ratio decreased with runoff depth for the tile roof. • In gravel roof, all heavy metals predominantly in dissolved fractions • Most total Zn existed in labile (i.e. reactive) form • Cu, Pb, and Cd occurred predominantly in the moderately reactive form, representing the continuum of reactivity between labile and inert (labile and inert forms very small). • When pH in runoff decreased from about 7 to 5, labile species of Zn, Cu, Pb, and Cd slightly increased. • In general, constituents in dissolved form showed a lower initial concentration and a faster decrease than those in particulate form (indicates that particles were being washed off roof and drain surfaces). • Data indicate that roof and drains acted as source for Cu. • Tile roof acted as slight source for alkalinity, TSS, total Mn, total Pb, and total Fe. • Polyester roof contributed TOC, DOC, and total Mn via erosion; otherwise just conveyed compounds present in rainwater. • Weathering of gravel on gravel roof produced significant amounts of Ca and alkalinity (considered a beneficial water quality change); gravel roof retained most heavy metals and phosphorus and supported nitrification (indicated by transformation from NH_4 to NO_3).

*Studies that did not present raw data are not included in Table 4, but are summarized herein.

References	Study Location	Roof Type	Sampling	Key Findings
Clark et al., 2008	Alabama, USA	Individual Building Materials, as listed	pilot scale roofs, 2 years of monitoring	• Traditional galvanized metal roofing contributed the greatest concentrations of cations, metals (especially Zn), and nutrients. • Pressure treated and water-proofed wood contributed substantial Cu loads. • There is the potential for galvanized metal and wood products to release nutrients due to natural degradation. • Pollutant release may continue for extended period of time after roof construction; low-level, long-term release of many pollutants noted.
Coombes et al., 2007*	Australia	Not specified	40 rain events in July & August 1998	• For first flush (the first 2mm) samples, pH values and ammonia concentrations exceeded Australian guidelines in 24% and 68% samples, respectively. Iron and lead concentration guidelines were exceeded in one sample, each. • Roof samples collected after the first flush exceeded guidelines for ammonia (29% of samples), pH (17% of samples) and lead (two samples). • Significant water quality improvement occured within the storage tank; samples collected from the storage tank did not exceed metal and chemical standards. • Water collected from the hot water tap did not exceed metal and chemical guidelines either.
Davis et al., 2001	Maryland, USA	Varied (first flush samples only)	38 samples	• Roof samples • High Zn concentrations for all types (residential, commercial, industrial) • All other metals relatively low for residential roofs • All metal levels from commercial and industrial buildings significantly higher than residential by approximately 1 order of magnitude for Pb and Zn, and by >2 orders of magnitude for Cu

*Studies that did not present raw data are not included in Table 4, but are summarized herein.

(*Continued*)

Table A4.1 (*Continued*)

References	Study Location	Roof Type	Sampling	Key Findings
				• All metal levels from commercial and institutional buildings were significantly larger than those from residences. • For Pb and Cu: fiberglass and asphalt roof catchments demonstrated better runoff quality than slate tile, rubber, and galvanized metal. • Highest Zn concentration - galvanized metal roof
Despins et al., 2009*	Canada	Asphalt shingles, steel shingles	7 sites, October 2006 thru October 2007, 30 sampling occasions (360 samples total)	• pH, turbidity, TOC, TN and color found to vary significantly with catchment materials. - poorer quality = asphalt shingles (compared to steel roofs); higher turbidity, TOC, and color - may be attributable to textured surface and corresponding adsorption of atmospheric particulates between rain events • Zn concentrations from steel roofs much higher than from asphalt shingle roofs (but still below Health Canada's 5 mg/l aesthetic level) • Temperature, rainfall, and antecedent dry period found to have little effect on majority of WQ parameters • Physicochemical properties of rainwater most influenced by the catchment surface, storage materials, and site environment • Absence of metal contamination other than Zn; asphalt shingle and steel acceptable for rainwater harvesting with respect to metals

*Studies that did not present raw data are not included in Table 4, but are summarized herein.

References	Study Location	Roof Type	Sampling	Key Findings
Quek & Förster, 1993	Germany	Tar felt, pantile, asbestos cement, zinc sheet, gravel	5 roofs, 2 storm events; April & May 1988	• Samples were only collected during first 3mm of runoff. • Increase in concentration of zinc from zinc sheet roof due to dissolution • Dissolution of $CaCO_3$ on asbestos cement and gravel roofs cause pH to increase. • Maximum TSS concentration produced by zinc sheet roof due to smooth surface and greater inclination • Flat gravel roof acted as a sink for particles and heavy metals due to hydraulic properties that facilitate sedimentation and immobilization. • Asbestos cement roof showed high degree of weathering, which caused TSS concentrations to increase (concentrations were greater than for tar or pantile roofs). • Pb concentrations doubled during high-intensity rain event on sloped roofs. • Zinc sheet roof runoff was most heavily polluted with heavy metals. - Zn concentrations originate from roofing materials; other metals originate from dry deposition or minor constituents in roofing materials. • Tar felt roof released least polluted runoff of all inclined roofs due to high pH of roofing material (shifts most heavy metals to adsorbed phase) and rough surfaces (retain particles on roof except during high-intensity rains). • Pantile roof exhibited Cu contamination due to copper sheets fitted onto roof sides. • Flat gravel released least polluted runoff—due to high pH, runoff retention, and filtering effects of gravel.
Schriewer et al., 2008	Germany	14 year old zinc	1 site, 38 storm events; May 2004 thru May 2005	• Significant amount of zinc in runoff could be observed, mostly in dissolved form. • Negative correlation between rain intensity and zinc concentrations; lower rain intensities = increases in amount of Zn in runoff; high intensities dilute concentrations. - Exclusion of runoff due to extreme flows is recommended. • 93% of events exhibited first flush characteristics.
Simmons et al., 2001	Auckland, New Zealand	Varied	125 houses, sampled once	• High lead levels likely result of corrosion of galvanized iron, lead, and lead-based paint on catchment surface

*Studies that did not present raw data are not included in Table 4, but are summarized herein.

(*Continued*)

Table A4.1 (*Continued*)

References	Study Location	Roof Type	Sampling	Key Findings
Thomas & Greene	Australia	Galvanized iron, concrete tile	2 roofs, 8 samples each	• High Zn concentrations likely due to leaching of Zn from galvanized iron roof • Galvanized iron roofs produce best runoff quality when compared to concrete tile.
Van Metre & Mahler, 2003	Austin, Texas, USA	Metal (nearest road), Metal (furthest from road), Asphalt shingle (nearest road), Asphalt shingle (furthest from road)	2 roof types, 2 locations, 3 sampling events	• There were no observed differences between the concentrations of TSS or PAHs from each type of roof. • Concentrations of all major elements, except Ca and Mg, were higher in runoff from metal roofs than asphalt shingle roofs, most likely due to increase particle trapping and dilution of particles by Ca and Mg on asphalt roofs. • Lead and mercury concentrations were significantly higher in runoff from asphalt shingle roofs. • The metal roof was a source of particle-bound Cd and Zn. • Concentrations of some parameters (Cd, Cr, Cu) were higher at roof sites closer to a major highway, while other parameters (As, Ni, PAHs) had higher concentrations at sites further from the highway. The latter phenomenon could be due to the deposition of larger amounts of uncontaminated sediment closer to the highway, which results in a dilution factor. • Each roof was a source of a contaminant of concern: Zn from metal roofs, Pb from asphalt shingle roofs and PAHs from both. Therefore, the roof runoff should be treated to remove particles prior to it being used.

*Studies that did not present raw data are not included in Table 4, but are summarized herein.

Index

Note: Index entries followed by an f or a t refer to figures and tables respectively.

Figure C.1 Designed by HOK, the NOAA Center for Weahter & Climate Protection in College Park, Maryland, achieved LEED NC Gold Certification uses rainwater collected in an underground cistern for many uses. (*Alan Karchmer/HOK*)

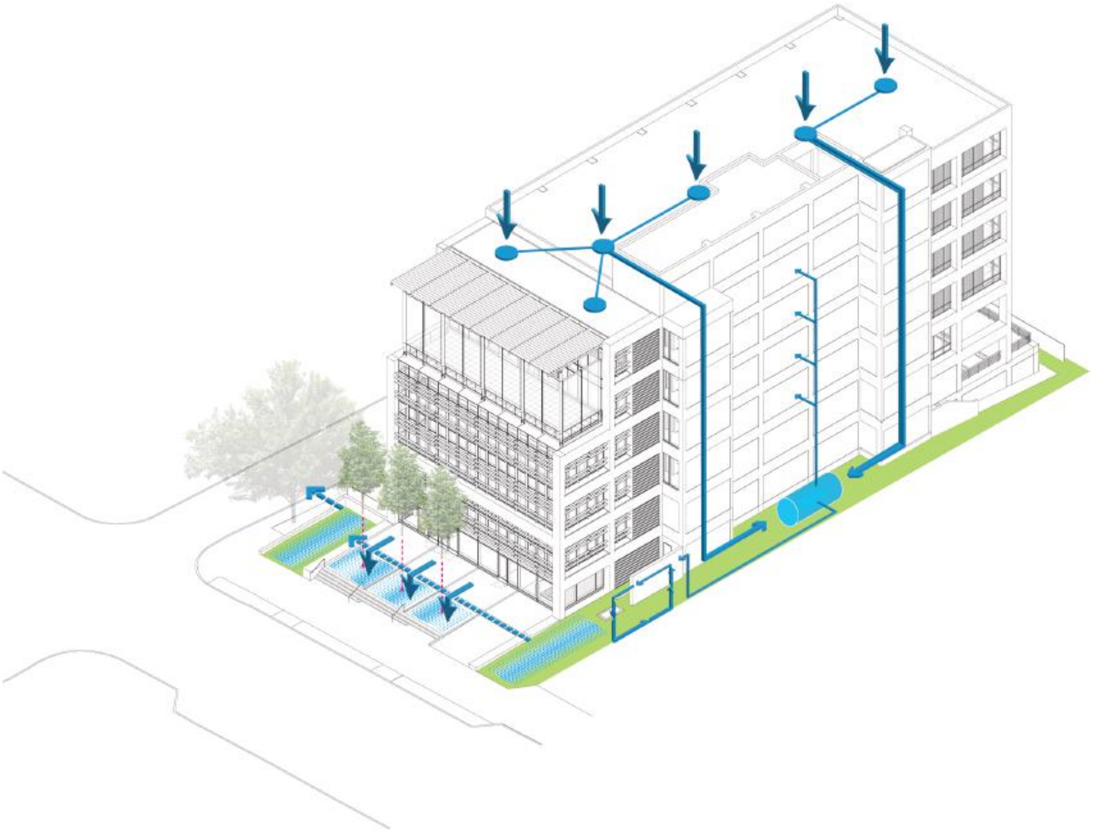


Figure C.2 Rainwater system diagram for the renovated Atlanta offices of Perkins+Will. (*Diagram: Courtesy: Perkins+Will*)

Figure C.3 The Paul Coverdell Research Center at the University of Georgia in Athens, Georgia, uses rainwater for toilet flushing and cooling tower makeup water. (*Viviane Van Giesen*)

Figure C.4 The West Virginia Regional Jail designed by AECOM uses rainwater for toilet flushing, washing, and irrigation. (*Richard Boyd Photography*)

Figure C.5 Three aboveground rainwater collection tanks are sized to meet both the monthly demand for toilet flushing and for irrigation. (*KMD ARCHITECTS & PFAU LONG ARCHITECTURE, a Joint Venture*)

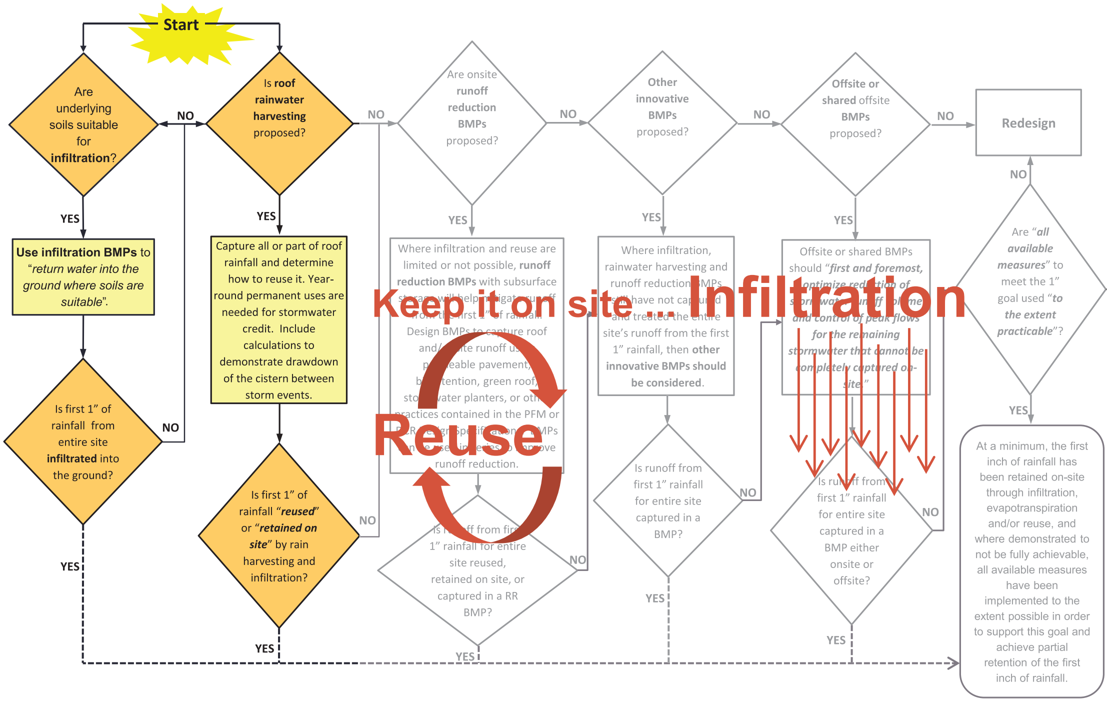
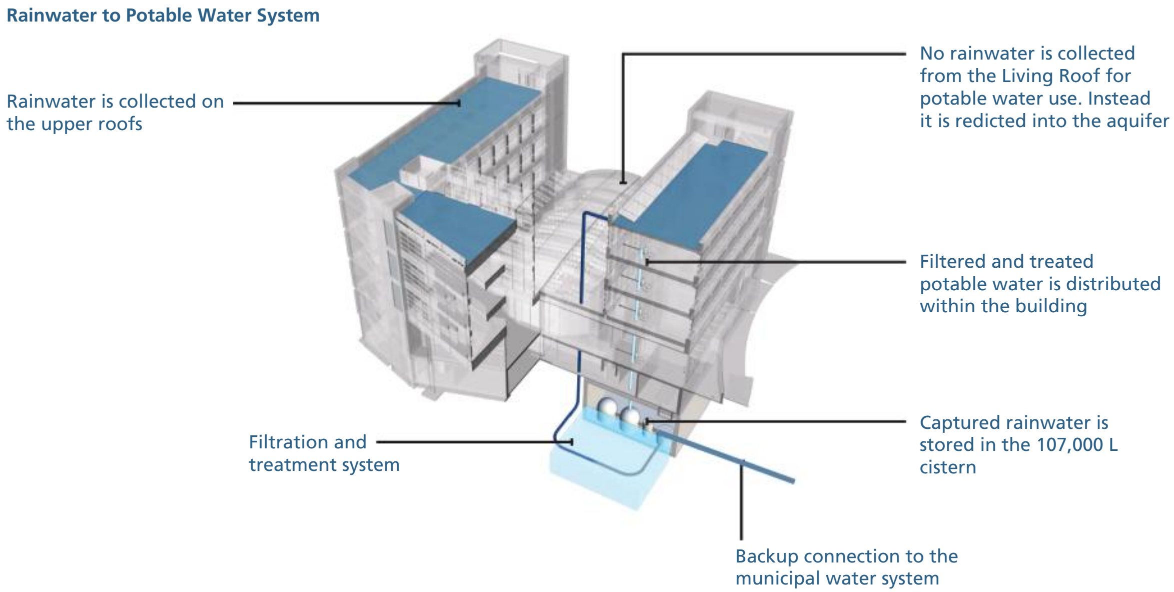


Figure C.6 Tysons Corner flowchart showing stormwater concepts and the decision tree for the use of rainwater harvesting in Fairfax County. (*Bruce McGranahan, County of Fairfax Virginia, Land Development Services*)

Figure C.7 Center for Interactive Research on Sustainability, designed by Perkins+Will Architects, has an extensive rainwater harvesting system. (*Martin Tessler/Courtesy: Perkins+Will*)



Rainwater to Potable Water System

Rainwater is collected on the upper roofs

No rainwater is collected from the Living Roof for potable water use. Instead it is redicted into the aquifer

Filtered and treated potable water is distributed within the building

Filtration and treatment system

Captured rainwater is stored in the 107,000 L cistern

Backup connection to the municipal water system

Figure C.8 Rainwater to potable water system. (*Perkins+Will Architects*)

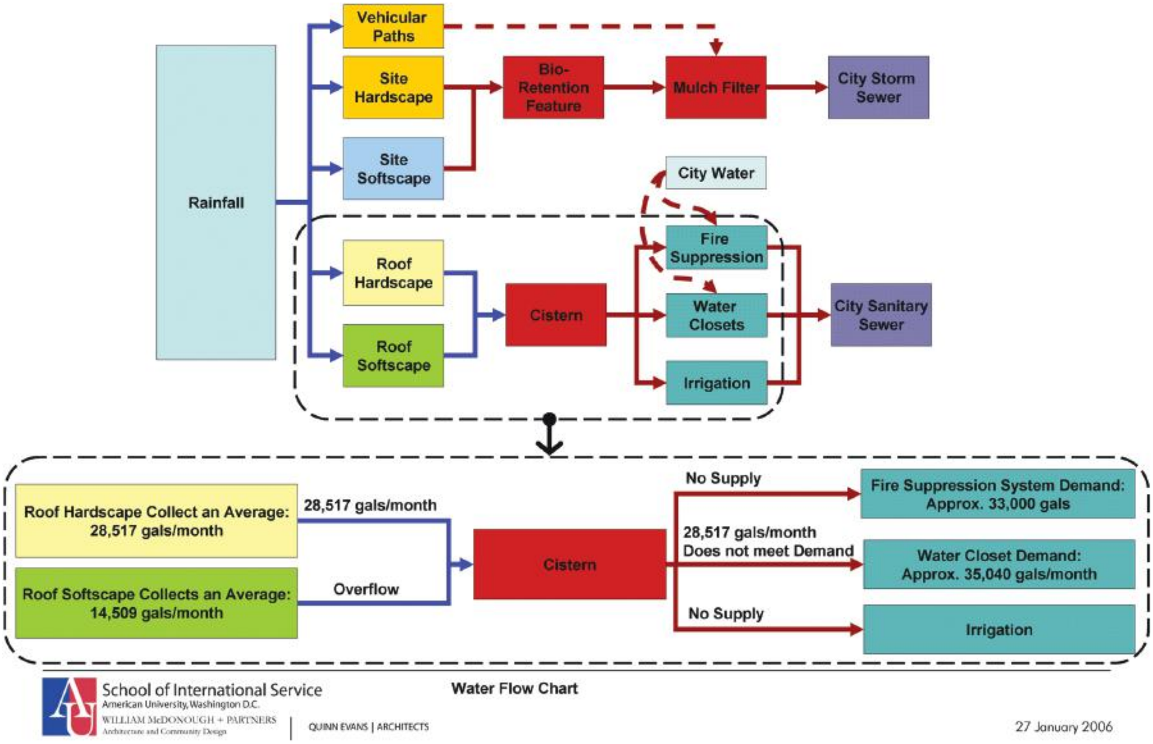


Figure C.9 Water balance chart and analysis of the rainwater system for American University School of International Service designed by Quinn Evans Architects with William McDonough Partners. (*Courtesy of Quinn Evans Architects*)

Figure C.10 Great Neck Middle School in Virginia Beach is one of several Virginia schools that collects rainwater for toilet flushing and irrigation. (*Photographed by Steve Budman Photography, Courtesy of Waller, Todd & Sadler Architects, Inc*)

Figure C.11 An integrated system provides water for toilet flushing and cooling towers at the University of Georgia Visual Arts Building. (*Viviane Van Giesen*)

Figure C.12 Rainwater harvesting equipment area in mechanical room at the College of Environment and Design at the University of Georgia, Athens. (*Celeste Allen Novak*)

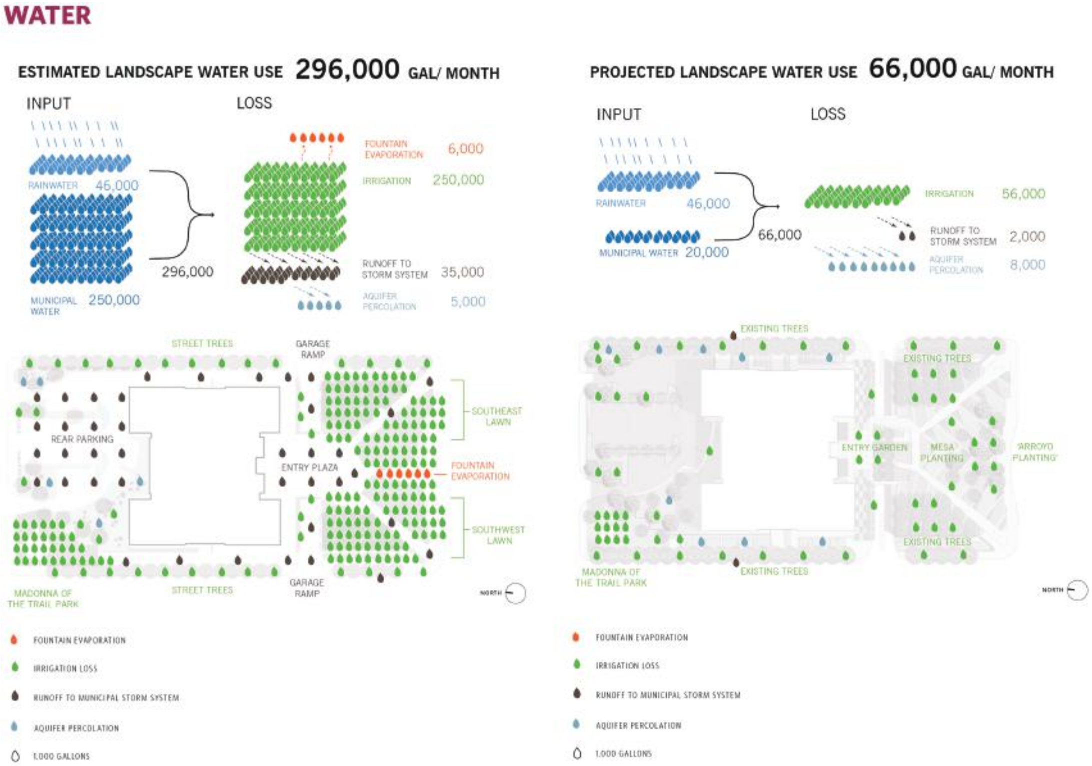


Figure C.13 Diagram showing the estimated amount of landscape water for the Pete V. Domenici Federal Courthouse in Albuquerque, New Mexico with and without the rainwater system; demonstrating an approach to using rainwater to meet stormwater management regulations. (*Rios Clementi Hale Studios/Biohabitats*)

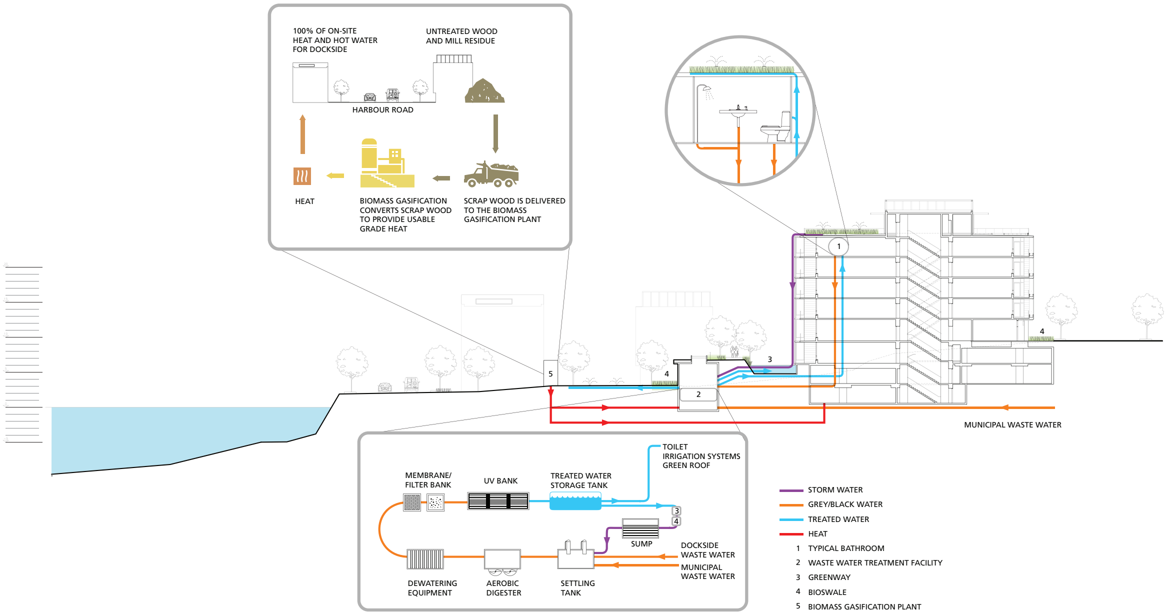


Figure C.14 Complete rainwater harvesting system at Dockside Green in Vancouver, BC. (*Perkins + Will*)

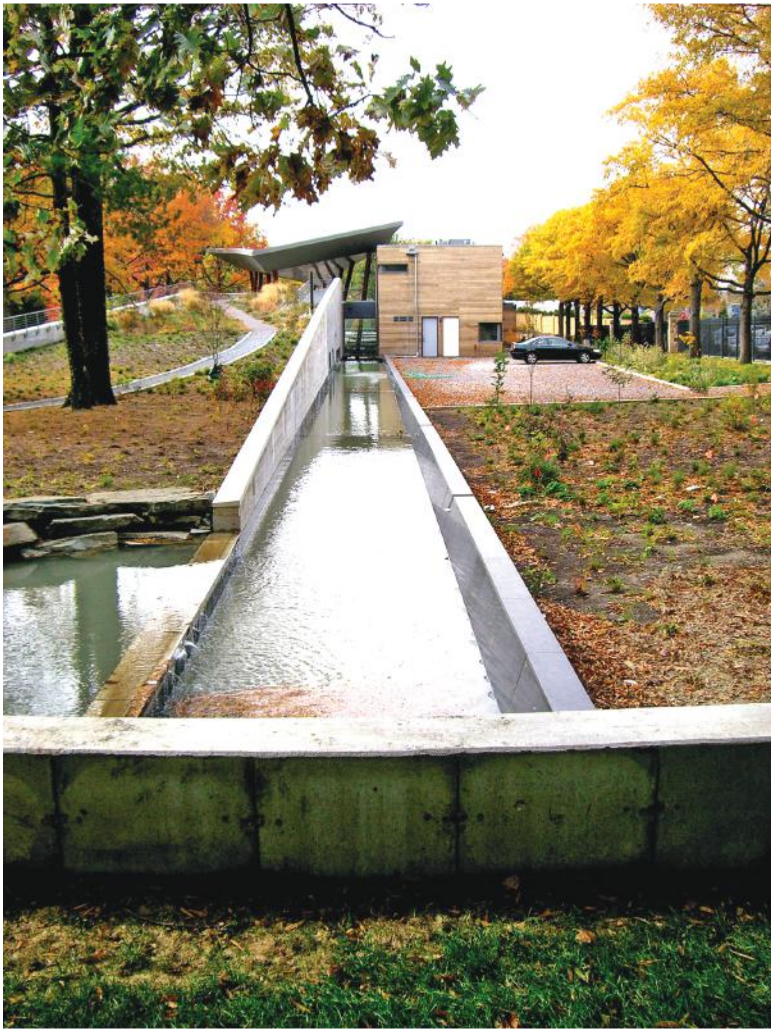


Figure C.15 Rainwater harvesting is an integration of place, water, and the environment as seen in the Queen's Botanical Garden Visitor and Administration Center designed by architects BKSK of New York with Atelier Dreiseitl, who were responsible for the landscape architecture, master plan and the stormwater system. (*Atelier Dreiseitl*)

Figure C.16 Queens Botanical Gardens design plan. (*Atelier Dreiseitl*)