Determining if onsite water reuse systems make sense for your project

by

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Abstract

Water is one of the most important natural resources to sustaining life on this planet. Fresh water quality and supplies are in decline throughout the world due to overuse, aging infrastructure, rapidly expanding communities, and changing climate and weather patterns. Recently several communities in the United States have been left without access to fresh potable water for extended periods of time due to these issues. To protect our water systems and make them more resilient, the adoption of onsite water reuse systems is becoming more prevalent.

This report looks at the current state of water supplies and policy that dictate how we interact with the water cycle in the built environment. Several municipalities already require or incentivize the installation of onsite water reuse systems for new construction. It is a growing trend throughout the world, which plumbing designers and building owners will need to adapt to. This report discusses several concepts that will help with the design, installation, maintenance, and operation of these systems.

The report also explores the relatively new concept of Net Zero Water; which both public and private organizations, such as the Living Building Challenge, have created framework for. An engineer working on these types of projects must know how to design for onsite water reuse systems. The design, calculations, components, and applications of several onsite water reuse systems are presented in this report.

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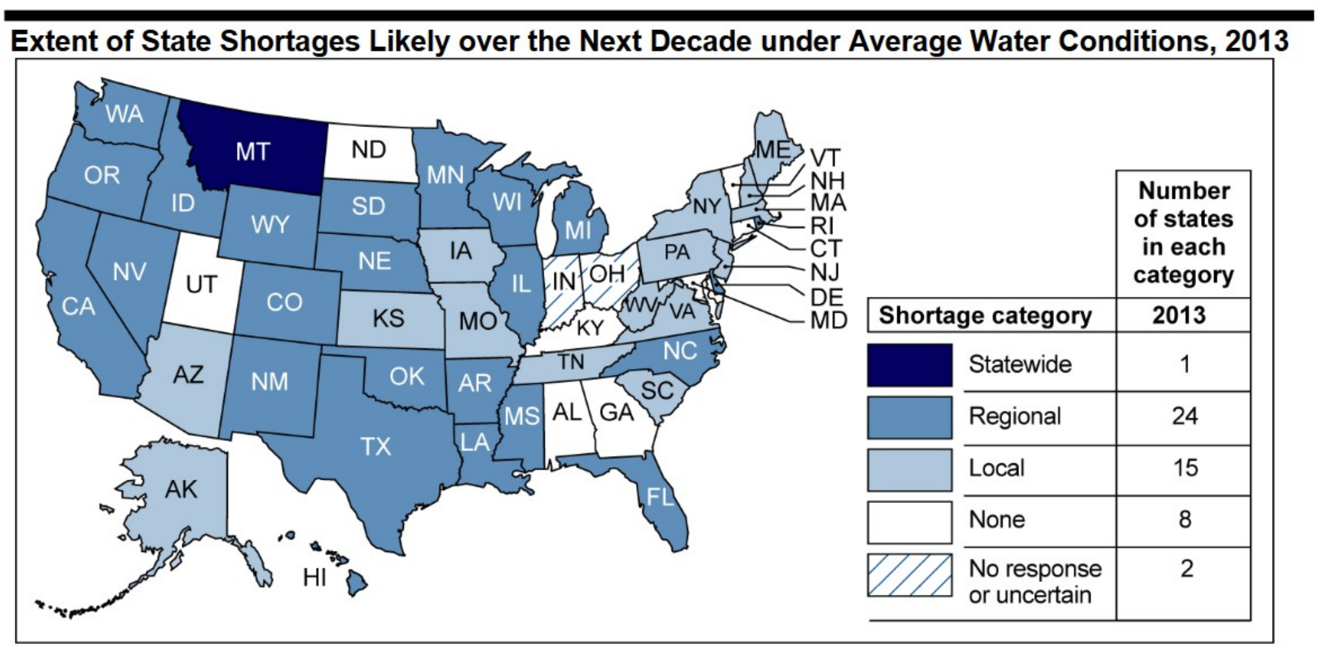
Chapter 1 - Introduction

Humans have benefited from the ability to manipulate the Earth's water cycle for thousands of years. The improvement of systems that provide clean water supplies and the removal of waste has allowed the human population to grow to nearly 8 billion. With the explosion in world population over the past two centuries, freshwater supplies are stretched to their limit due to overuse and mistreatment. Strategies for reducing water usage and waste treatment are needed to sustain the quantity and quality of the planet's remaining freshwater supplies and reduce a buildings carbon footprint. The United States Government Accountability Office (GAO) surveyed state water managers in 2013 and found that 40 of 50 states expected water shortages in some portion of their state under average conditions in the next 10 years.

Figure 1-1. GAO Analysis of State Water Managers' Survey Responses[1]



[1] GAO. Freshwater Supply Concerns Continue, and Uncertainties Complicate Planning

As urban populations grow, so does the demand for fresh water and the amount of waste water generated, causing an increase in energy consumption for the treatment and pumping of these systems. Reducing a building's carbon footprint to the maximum extent possible requires limiting this energy usage. In addition to the problems caused by increased freshwater demand and wastewater discharge, there are significant concerns about the aging infrastructure of these systems throughout the country.

The American Society of Civil Engineers (ASCE) estimates that over 2.2-million miles of underground potable water supply pipes in the United States (U.S.) are aging and underfunded. Water main breaks are estimated to lose 6-billion gallons of treated water each day, which is essentially lost energy[2]. Pipe breaks and equipment malfunctions causing loss of pressure have at times left tens of thousands of people without access to freshwater supplies for extended periods of time. A 2015 U.S. Environmental Protection Agency (EPA) national assessment of public water infrastructure shows a 20-year capital improvement need of $472.6 billion[3]. Reducing freshwater usage and wastewater treatment alleviates stress on existing systems, allowing utilities to focus already limited resources on infrastructure repair and improvements.

Dwindling freshwater supply is another serious concern in various parts of the country due to a combination of factors such as rapid population growth and changing weather patterns causing draught and flood conditions. Water scarce cities such as Las Vegas, NV and San Antonio, TX have municipal scale recycled water programs already in place. Treating wastewater to non-potable levels and redistributing it for use in irrigation and process use. Even with some of the strictest water conservation efforts in the country, the Las Vegas water supply

[2] SFWPO, Onsite Water Recycling
[3] US EPA, Drinking Infrastructure Needs Survey and Assessment

from the Colorado River is declining at a rapid rate. As the city considers paying southern California large sums of money to supply potable water from wastewater treatment facilities they already operate[4], it is clear that further reduction of demand on municipal potable water systems is beneficial. Reducing demand on these supplies provide opportunity for lakes, rivers, and groundwater aquifers to recharge and last into the future.

On the opposite end of the spectrum, heavy rainfall and flooding has a huge impact on many wastewater management systems throughout the U.S. due to outdated combined sewer systems still in use today. These systems carry both stormwater and wastewater to facilities for treatment before being releasing to the water source. During heavy rain these systems become overwhelmed and the combined untreated raw sewage is released directly to the water source. It is estimated that 850 billion gallons of untreated waste water per year is released to freshwater sources.

The purpose of this report is not to highlight the myriad of water system issues we face as a society. It is intended to provide a simple method to analyze a buildings potential for onsite water reuse (OSWR) systems and the resources necessary to implement them.

Reducing demand on treated freshwater supplies from a municipal source is a growing strategy to combat dwindling supplies and aging infrastructure. Cities such as San Francisco, CA and Austin, TX now require the installation of OSWR systems for large developments. While some municipalities require OSWR systems, others may not allow them due to a lack of framework for regulation and knowledge on the systems. Chapter 2 of this report explores the current state of governmental regulation and policy on OSWR systems in the U.S.

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[4] Hager, Amid Climate change

Going beyond reduced water demand, several organizations are implementing guidance and certification programs for a building or property to achieve Net Zero Water (NZW). Essentially NZW means a building returns an equal or greater amount of treated wastewater back to the water supply source than it takes from the source. Chapter 3 focuses on the concept of NZW and the organizations that are implementing it.

Several types of OSWR systems, such as rainwater, condensate, and graywater collection, are available today. Chapter 4 and 5 provide a better understanding of these systems; including supply and demand calculations, components, treatment, and applications. Tools and resources to perform a water budget on a building to estimate OSWR system potential are provided.

Protection of water supplies for future generations is not a responsibility for any one group. As a precious resource that every living being depends on, it will take work from all of us to protect these systems for future generations. For most of us the cost of water has always been cheap due to its availability, but the day may soon come when the tap runs dry. As Benjamin Franklin famously said "When the well is dry, we know the worth of water."

Chapter 2 – Regulation and Policy

Typically, local municipalities and governmental agencies manage water supplies and wastewater treatment. Improperly funded and aging infrastructure throughout the U.S. is an ever-growing problem requiring attention in the near future. Existing freshwater and wastewater treatment systems may also be inadequate for areas with rapid population growth, requiring investment in new treatment facilities and infrastructure construction. Reducing the demand on freshwater supplies and the amount of wastewater treatment reduces stress on these systems and allows utilities to focus resources on existing infrastructure concerns. On-site water reuse (OSWR) systems can significantly reduce the amount of water used by a building. If a large number of buildings incorporate these systems, the combined impact will be a significant reduction on utility demand.

Implementation of OSWR systems require regulations for proper installation and management to ensure the systems meet water quality standards and are not a health risk to the building occupants. Since widespread use of these systems is a fairly new concept, many local municipalities have not adopted a framework for their regulation. In locations where water supply levels don't appear concerning, adoption of OSWR system requirements and regulations will be more difficult to implement due to cheap water rates, added construction costs, and perceived health risks.

While some jurisdictions are slow to accept OSWR systems, there are a growing number of municipalities throughout the U.S. that recognize the concern of future water availability and are adopting policies requiring installation. San Francisco now requires development projects larger than 100,000 square feet to install and operate an OSWR system. Austin, TX currently provides incentives up to $500,000 to developers for voluntary installation of OSWR systems.

Beginning December 1, 2023, Austin will require OSWR system installation on large development projects.

As popularity began to grow, there was recognition that national standards and regulatory guidance for decentralized OSWR systems were lacking. In 2014, The San Francisco Public Utilities Commission (SFPUC), Water Research Foundation (WRF) and Water Environment and Research Foundation (WE&RF), convened a meeting of public health agencies, water agencies, and research institutions from across North America titled the Innovation in Urban Water Systems conference. The conference identified a need for guidance to local municipalities in developing OSWR system oversight and management programs and to establish water quality standards that are protective of public health.

Research to develop recommendations for appropriate water quality criteria and monitoring for treating alternative onsite water sources led to the 2017 report titled "Risk-Based Framework for the Development of Public Health Guidance for Decentralized Non-potable Water Systems". This report is intended to provide information and guidance through risk-based framework to help state and local health departments develop oversite of the design, permitting, construction, monitoring, and reporting of OSWR systems. It is intended for technical staff at public health agencies and is not the focus of this report.

The National Blue Ribbon Commission (NBRC) for Onsite Non-potable Water Systems was established in 2016 to create model policy for adoption by local water authorities. The commission also develops resources for the safe, practical, and sustainable implementation of onsite non-potable water systems. The commission is comprised of representatives from municipalities, water utilities and public health agencies from 14 states, the District of Columbia, U.S. Environmental Protection Agency (EPA), U.S. Army Engineering Research and

Development Center, the cities of Vancouver and Toronto. Additional partners include the US Water Alliance, the WE&RF, and the WRF. The goals of the commission are to:

- Serve as a forum for collaboration and knowledge exchange on the policies, best management practices, procedures, and standards for onsite non-potable water systems.
- Craft model policy guidance and frameworks for the management and oversight of onsite non-potable water systems (e.g. water quality criteria, monitoring and reporting requirements, and operational and permitting strategies).
- Develop case making resources for water utilities based on best practices and lessons learned in the design, development, integration, and operation of onsite non-potable water systems.
- Identify additional research needs in the field.

The NBRC has developed documents for local municipalities wishing to implement OSWR systems titled A Guidebook for Developing and Implementing Regulations for Onsite Non-potable Water Systems. The intent is to help states and local jurisdictions develop and implement regulations and oversight programs that are based on science and are protective of public health. Section 4 of the guidebook provides recommendations on owner responsibility to operation and maintenance of OSWR systems based on risk categories and scale the system. Figure 2-1, Figure 2-2, and Figure 2-3 provide information to assign owner responsibilities based on risk categories. Where no current OSWR system regulation exists, this information may be useful to anticipate an owner's responsibilities if planning for future use of these systems.

Figure 2-1 Risk Control and Accountability Matrix for the Risk-Based Management Categories[5]

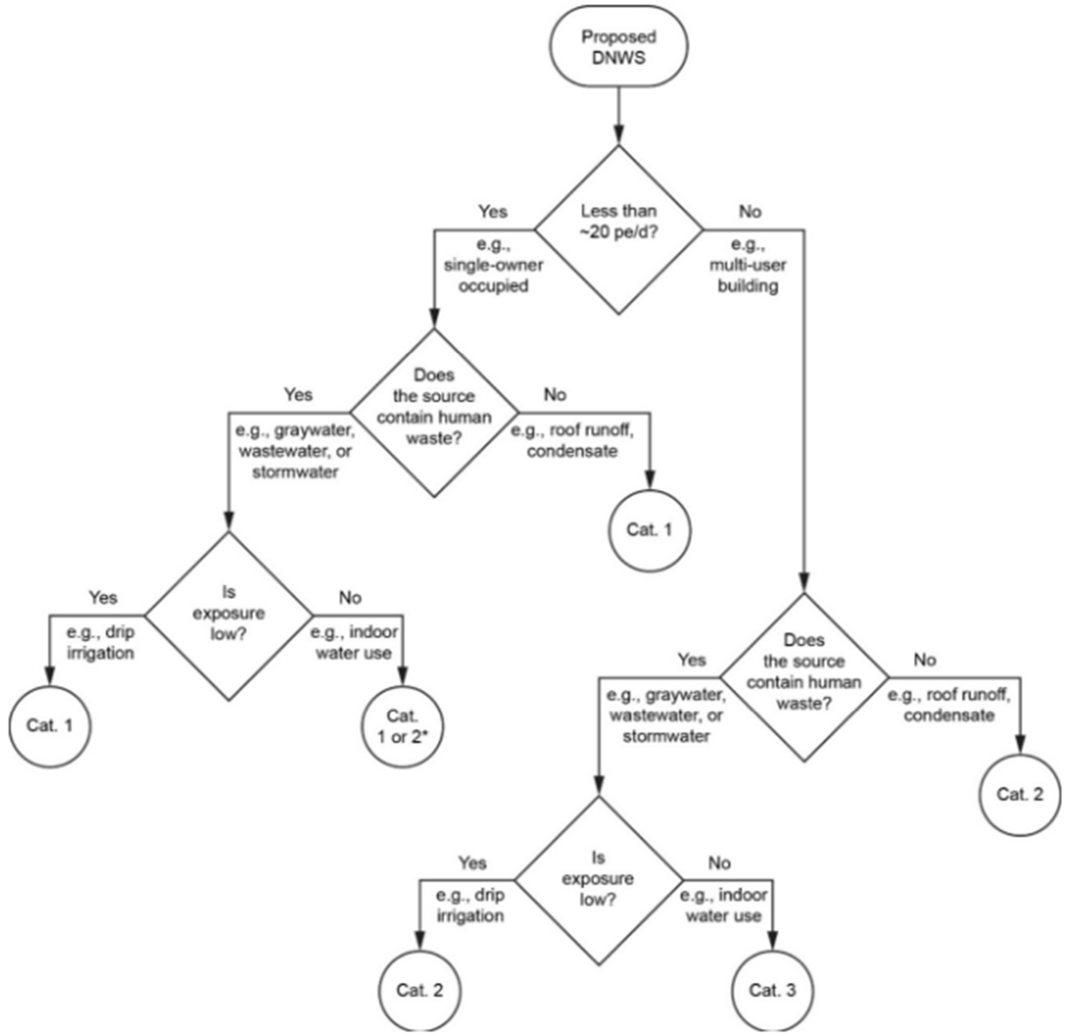
Management Category		
1	2	3
Low	← **Risk characterization** →	High
Few users, no public access	← **Pathogen risk** →	Many users, public access
Simple devices and/or processes	← **Process malfunction risk** →	Complex devices and/or processes
	Regulatory oversight	
System owner is fully responsible and accepts all liability for system performance. Local regulatory authority may provide owner education and registration of system as per their specific regulations.	System owner retains system responsibility and complies with local regulatory authority's additional quality control via a combination of manufacturer approval/certification, O&M manual, installation inspection, system permit, and some degree of performance monitoring.	Prequalified RME accepts all performance responsibility. Regulator qualifies the RME, issues permit, reviews performance report and certifications, performs periodic inspections, and enforces permit compliance.
	RME requirements	
Private owner serves as RME and complies with regulatory authority's requirements.	Private owner as RME fully complies with local regulatory authority's requirements.	RME provides financial security, assumes full performance accountability, responsibility for permit compliance, routine reporting, and certification.

Figure 2-2 Examples of Risk-Based Considerations for Identifying the Management Category of the Onsite Water Reuse System (OSWR)[5]

Example	Number of Persons Exposed	Likelihood of Malfunction	Management Category and Considerations	Health Agency Role
Single-owner occupied system using roof runoff for irrigation	Small user base (<~20 pe/d[1])	Low—low pathogen content—simple process	Low Risk—Building owner serves as the Responsible Management Entity (RME) with full responsibility	Provides educational information to building owners and issues permit
Single-owner occupied system using graywater for toilet flushing and irrigation	Small user base (<~20 pe/d[1])	Moderate—equipment maintenance required	Low Risk—Building owner serves as RME with full responsibility	Requires manufacturer certification of equipment, operation and maintenance (O&M) manual and issues permit
Single-owner occupied system using roof runoff and treated wastewater for toilet flushing, laundry, and subsurface irrigation	Small user base (<~20 pe/d[1])	Considerable—complex equipment requires routine O&M by trained staff	Moderate Risk—Independent registered service agent provides O&M	Registers/licenses service agent, defines reporting of data and issues permit
Multi-user building with roof runoff system for irrigation	Moderate user base (20–100 pe/d[1])	Low—low pathogen content—simple process	Low Risk—Building owner or HOA serves as RME with full responsibility	Registers/licenses service agent, defines performance reporting and issues permit
Multi-user system using treated graywater for toilet flushing and irrigation	Large user base (100–1,000 pe/d[1])	Moderate—equipment and distribution system requires trained O&M staff oversight	High Risk—Qualified full service RME with financial security and routine reporting	Establishes RME qualifications, ensures financial guaranty, requires data reporting, and issues permit
District/multi-user system serving mixed uses, collecting roof runoff and treated wastewater sources for toilet flushing, laundry, cooling, and irrigation	Large user base (100–5,000 pe/d[1])	Significant—Complex process and distribution system requiring skilled O&M	High Risk—Qualified full service RME with financial security and routine reporting	Establishes RME qualifications, ensures financial guaranty, requires data reporting, and issues permit

[5] NBRC, Guidebook for Developing and Implementing Regulations

Figure 2-3 Guidance to Specify Management Category[6]



Whether it is to reduce demand on dwindling supplies, allow repair and replacement of aging infrastructure, or to reduce the release of untreated wastewater; implementing OSWR systems is a strategy that will grow in the future. While OSWR systems are not currently required in many locations, many valuable resources exist to aid local water authorities and health agencies to implement them if they desire.

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[6] NBRC, Guidebook for Developing and Implementing Regulations

Chapter 3 – Net Zero Water

Typical public freshwater supply systems draw from either ground water or surface water sources such as lakes and rivers, treat the water to potable levels, and then supply it through a large system of distribution pipes and pumps to its end use. A majority of that water is used for non-potable purposes. Treating water to higher levels than needed for most applications requires significantly more energy than would be required to treat only the amount needed for potable end uses.

Similar to freshwater supplies, wastewater from a property is typically sent back to a different facility for treatment before returning to the original freshwater source to complete the cycle. This process also uses a large amount of energy to treat and pump the waste. Areas where combined sewers still exist are significantly worse because they must also treat stormwater mixed with wastewater.

Creating a Net Zero Water (NZW) property reduces the demand on both freshwater supply and wastewater treatment, making our current sources more sustainable and our buildings more water resilient in the event of emergencies. This chapter describes current definitions and applications of NZW.

3.1 – Defining Net Zero Water

Compared to net zero energy and the focus to reduce carbon emissions, net zero water is a relatively new goal for buildings to achieve. The Federal Energy Management Program (FEMP) states that a net zero building has been achieved when the amount of alternative water consumption and the water returned to the original source is equivalent to the building's water consumption. This definition applies to federal buildings and is outlined in the Federal New Buildings Handbook for Net Zero Energy, Water, and Waste.

For the commercial and residential building sectors, the handbook refers to the International Living Future Institute's net zero building certification system called the Living Building Challenge (LBC) as a guide for achieving NZW.

While different definitions are applied to federal and private sector buildings, the overall goal of net zero water is the same; a building must use less water from a fresh supply than it returns to the source.

3.2 – Federal Energy Management Program

The Federal Energy Management Program developed three handbooks with strategies for federal buildings to achieve net zero energy, water, and waste. The handbooks cover new buildings, existing buildings, and campuses. The new construction handbook contains elements for design (WA.D.x), construction (WA.C.x), and operations and maintenance (WA.O.x) that are required for a federal building to achieve NZW. Each of the water elements are described below.

Design Elements

WA.D.1 provides guidance on specifying indoor water consuming equipment and outdoor water use. Plumbing fixtures and commercial kitchen equipment must be WaterSense and ENERGY STAR-labeled. Landscaping must incorporate low-water using principles such as xeriscape, native plants, and plants that do not require supplemental irrigation.

Figure 3-1 Water Net Zero Design Elements for New Buildings[7]

WA.D.1	Design for a high performance, water efficient building
WA.D.2	Estimate annual water use and develop water balance by end-use
WA.D.3	Maximize alternative water sources
WA.D.4	Treat wastewater on-site and return to the original water source
WA.D.5	Design green infrastructure features to return water to its original water source
WA.D.6	Minimize the impact of design reviews or value engineering on the net zero target

WA.D.2 requires the creation of a water balance budget to estimate the buildings annual water consumption by end use. This helps identify the proposed building's high-water uses and focus water efficiency and conservation efforts to the areas of highest impact.

WA.D.3 requires the building to maximize alternative water sources. A net zero water building minimizes the use of potable freshwater and maximizes the supply of alternative water supplies. Alternative water comes from a source that is not derived from freshwater, such as lakes, rivers, or aquafers, and include harvested rainwater and stormwater, sump pump water, air cooling condensate, and reclaimed gray and black wastewater. Graywater is wastewater from such fixtures as lavatories, drinking fountains, and showers that don't contain a high organic loading. Blackwater is wastewater that contains high organic loading such as from toilets, urinals, and kitchen sinks. The ideal use for captured alternative water sources is toilet and urinal

[7] Fowler et al. Federal New Building Handbook for Net Zero Energy, Water, and Waste

flushing, irrigation, and cooling tower make-up water. Chapter 4 covers alternative water source systems in greater detail. Figure 3-2 provides examples alternative water sources and applications to consider.

Figure 3-2 Alternative Water Source Examples[8]

Alternative Water Source	Potential Applications	Considerations
Rainwater	Irrigation, toilet and urinal flushing	Minimal treatment is needed for irrigation
Stormwater	Irrigation, cooling tower make-up, industrial uses	Foundation drain water can be reused similarly to stormwater
On-site Reclaimed Wastewater	Irrigation, cooling tower make-up, industrial uses	Substantial filtration and disinfection is required
Graywater	Toilet and urinal flushing, irrigation	Design building with dual plumbing system for toilet and urinal flushing; subsurface irrigation is most appropriate unless water is disinfected
Air Handling Condensate	Cooling tower make-up, industrial uses	Condensate water can be corrosive to metals because condensate can be slightly acidic; water may absorb copper from cooling coils

WA.D.4 requires the treatment of wastewater onsite and returning it to the original water source. The original water source is considered fresh surface water and groundwater sources that are within the same watershed or aquifer as the building's supply water. Treating of wastewater prior to returning to the source may be accomplished through an onsite septic system or a wastewater treatment system that discharges wastewater to the original water source. Treatment of wastewater both for returning to the source and reuse on site must meet local and federal health requirements.

WA.D.5 provides another option to return water to the original source through green site infrastructure. This includes site features that retain stormwater onsite and return it to

[8] Fowler et al. Federal New Building Handbook for Net Zero Energy, Water, and Waste

groundwater such as through bioswales, raingardens, and permeable pavement. Where the building is not located within the same watershed that the supply water is received from it is not possible to return water to the original source and alternate water sources must be maximized.

WA.D.6 recommends to define and incorporate net zero water goals early in the design process to ensure they are incorporated. Water savings design concepts is often times one of the first items looked at for removal from scope during a value engineering phase. It is important to bring stakeholders, including the future occupants and operators, into the process early to confirm the net zero water goals. Having a person that advocates for the net zero water goals of the project through the design process is important to ensure the systems are applied.

Construction Elements

During the construction phase, the following practices are recommended to ensure that the systems are properly constructed. The construction phase requirements indicate to include language in the construction contract that ensures equipment specified is installed and meets the intended performance requirements. The contract should also include commissioning during the construction phase of all net zero water equipment and features.

Operation and Maintenance Elements

Lastly, several elements are defined for proper operation and maintenance (O&M) of a net zero water building.

WA.O.1 calls for the development of a building operation plan to address O&M of water efficient design features, alternative water systems, and wastewater treatment systems. A plan to perform leak detection and water quality assessment should be included. The plan should include a description of the measure, action items that should be performed, the frequency of occurrence, and the personnel that are responsible for the action.

Figure 3-3 Example O&M Measures for Water Equipment[9]

End-Use	O&M Measure	Frequency	Responsible Party
Plumbing	Inspect for leaks, long toilet/urinal flush cycles, and broken or missing aerators	Bi-annually	Plumber/building manager
Commercial Kitchen	Ensure that manufacturer specified use and care instructions are being followed, inspect for broken components, loose connections, and leaks	Bi-annually	Commercial kitchen maintenance staff
Landscape/ Irrigation	Aerate turf, alternate turf mowing height, add mulch to landscaped areas, and keep landscaped areas weed free Review irrigation schedule, inspect emitter components for broken heads and leaks, verify system pressure	At the beginning and mid-point of growing season	Grounds maintenance personnel
Rainwater Harvesting System	Inspect the system for leaks and loose connections, test for water quality, change or clean the filter and screens, inspect motors and pumps to ensure they are fully operational	Bi-annually (or per the manufacturers' recommendations)	Building engineer

WA.O.2 addresses metering and indicates that a building should be metered as a whole to monitor total water use as well as sub-metering for water-intensive applications such as irrigation and cooling towers. Metering helps to identify unnecessary water use and leaks in a system. Minimizing leaks ensures that a system operates as efficiently as possible.

WA.O.3 requires the implementation of training programs to encourage water conservation by building occupants. Lastly, WA.O.4 states the water systems must be measured and verified to operate at net zero water levels over a one-year performance period.

The framework is in place for federal buildings to achieve NZW; however, it is unclear if any buildings have done so. At the very least, a water budget analysis to determine the feasibility

[9] Fowler et al. Federal New Building Handbook for Net Zero Energy, Water, and Waste

of all water reuse systems could be required. Facility managers may need help deciding if NZW is achievable at their site.

3.3 – Living Building Challenge

For the private sector, The International Living Future Institute (ILFI) is a non-profit organization that created a certification program called the Living Building Challenge (LBC). The LBC defines some of the most advanced measurements of sustainability in the built environment today. To achieve LBC certification, a building must meet seven core imperatives, each focusing on a different function of the building. The different functions are categorized under petals, with each petal containing several imperatives. The water petal contains Core Imperative 05 – Responsible Water Use and optional Imperative 06 – Net Positive Water, which is similar to the federal definition of a net zero water building described above.

The responsible water use imperative requires a building to use no potable water for irrigation and reduce potable water use to all other demands by 50% for new construction and 30% for existing building plus interior as compared to a baseline annual water consumption rate. For comparison, the minimum reduction in potable water consumption required by LEED v4.1 is 20% with an additional six points credit possible for reducing consumption by 50% from the baseline. Baselines are also established differently. The LEED v4.1 baseline is based on fixture consumption rates established by the Energy Policy Act of 1992, such as 1.6gpf for a water closet. The ILFI baseline is established using measured data from various occupancy types from multiple sources.

The ILFI provides average gallon per day data for several common building types that are used to create a baseline value (Table 3-1). The data comes from a variety of sources and is intended to represent the typical use of a building by occupancy type. Values are provided as either gallons per square foot or per person, depending on the type of occupancy. Irrigation demand is not included in provided values. A second table includes a breakdown of typical water end use for each occupancy type (Table 3-2).

Table 3-1 Baseline potable water use by occupancy type

Occupancy Type	Gallons per Day (Minus Irrigation)	Per Unit
Education	8.50	Student
Entertainment/Public Assembly	1.84	Seat
Food Sales + Service	0.35	Square Foot
Healthcare	154.38	Bed
Hotel	33.18	Guest
Warehouse/Manufacturing/Industrial	10.27	Employee
Office	10.61	Employee
Parking	0.001	Square Foot
Retail/Public Service/Religious	0.03	Square Foot
Single-family/Multi-family	52.56	Person

Note. Adapted from Living Building Challenge Petal Handbooks, pg.119, Copyright International Living Future Institute

Table 3-2 Water end uses assumed in baseline

Building Type	Percent Allocation by End Use					
Residential	Dishwasher (2%)	Faucets (2%)	Shower/Bath (23%)	Toilet (24%)	Laundry (16%)	Other (16%)
Schools	Kitchen/Dishwashing (10%)	Clg/Htg (15%)	Domestic/Restroom (63%)	Pools (1%)	Laundry (4%)	Other (7%)
Healthcare	Kitchen/Dishwashing (8%)	Clg/Htg (22%)	Domestic/Restroom (36%)	Medical Equip (16%)	Laundry (10%)	Other (6%)
Food Service	Kitchen/Dishwashing (54%)	Clg/Htg (1%)	Domestic/Restroom (32%)	Other (13%)	-	-
Office	Kitchen/Dishwashing (17%)	Clg/Htg (36%)	Domestic/Restroom (47%)	-	-	-
Hotel	Kitchen/Dishwashing (17%)	Clg/Htg (14%)	Domestic/Restroom (36%)	Pools (1%)	Laundry (19%)	Other (13%)

Note. Adapted from Living Building Challenge Petal Handbooks, pg.122, Copyright International Living Future Institute

As an example, the baseline for an office building with 100 employees is 100 x 10.61 gallons per day, equaling 1,061 gallons per day. If the building does not include water use for heating and or cooling, the baseline is reduced by 36%, leaving 679 gallons per day. If the building is occupied 270 days out of the year, the annual baseline is 183,330 gallons per year. If the building in this example is new, it must reduce its annual use of potable water by 50% and is allowed to use 91,665 gallons per year to meet this required imperative. An example water use demand calculation is presented later in the report for comparison to these baseline values.

In addition to water use reduction, a property is also required to treat and manage all stormwater on site using green stormwater infrastructure with minimal impact to the existing site hydrology. This report does not focus on stormwater management strategies and only focuses on rainwater harvesting.

An owner may choose to go further than the core imperative water reduction levels described above and seek to achieve the imperative for Net Positive Water (NPW). NPW requires that one hundred percent of a project's water be supplied through captured precipitation, other natural closed-loop water systems, and/or through recycling used project water. All re-used water must be treated as needed without the use of chemicals. Additionally, no potable water may be used for non-potable uses. Supplemental supply from a municipal potable water source is allowed if it is shown that the project water demand cannot be met by maximizing all available alternate water sources. There is an exception for the use of municipal potable water supply when it is required by regulatory agencies; however, it must only be used for potable water required end uses. To qualify for the exception there are advocacy steps the designer must take to present information on the safety and benefits of these systems to the AHJ.

The NPW imperative also requires that all gray and black wastewater be treated onsite and either reused or returned to the site via infiltration. Treatment methods are discussed in Chapter 4. Connection to a municipal waste system is allowed if the treatment facility uses a biologically based treatment process with no Red List chemicals, is located within the same watershed, captures nutrients from the treated water, and treats water to tertiary levels before returning it to the same watershed, completing the cycle. Additionally, the project must show that it won't overload the existing municipal system and generate enough on-site power to offset the treatment and pumping energy equivalent to the amount of waste leaving the site.

To achieve LBC certification for either imperative, not only are calculations required to show compliance with water reduction targets, actual monthly water use and alternate water supply captured must be documented over a 12-month performance period once the building reaches 85% of the maximum occupancy. If a project achieves compliance with imperative 06 it is assumed to also comply with core imperative 05 without additional documentation.

The Living Building Challenge water petal provides framework to significantly reduce a building's water use. Even if an owner is not seeking LBC certification, the baseline data provided can be utilized to compare a building's water use reduction to a typical building of similar occupancy. To reduce water use by the maximum extent possible, OSWR systems such as rainwater harvesting and graywater reuse are necessary. These systems are discussed in greater detail in the following chapter.

Chapter 4 – On-Site Water Reuse Systems

To determine the feasibility of an OSWR system, a water budget for the building must be performed. This includes a number of calculations to determine the demand of fixtures and equipment that utilize recycled water and the available supply from alternate water sources. Methods for calculating demand and alternate water supply from multiple sources are described below.

The alternate water systems require storage tanks, sized based on the estimated supply from the source and the demand for the non-potable water. Consideration must be given to the availability of the sources throughout the year as they can vary significantly. The amount of space available for storage tanks and treatment systems is another consideration on system design.

In addition to storage tanks and treatment systems, separate piping systems for graywater waste and non-potable water supplies are required. Typical sizing practices, components, and the level of treatment for several OSWR systems are described below.

4.1 – Non-potable Water Demand

Non-potable water is water not intended for human consumption or interaction. It has many uses within a typical building such as for flushing toilets and urinals, cooling tower make-up, and irrigation. One of the most important steps in selecting the size of a storage tank or tanks on a project is determining the demand for non-potable water. While it is possible for alternative water sources to reach potable levels through treatment, this report focuses on non-potable reuse.

Water Closet and Urinal Flushing

Estimating the amount of non-potable water used daily for flushing is based on the number of occupants expected in the building, amount of times each occupant will use the fixtures, and the flush rate of each fixture type. Communicating with the owner for an accurate occupant load is a must to estimate flushing demand. The demand for each fixture type, such as female water closets, male water closets, and urinals, are calculated by multiplying the number of uses per occupant by the number of occupants by the flush rate of the fixture. Determining the flow rate is straight forward, as it will be specific to the fixture types specified. The most difficult assumption is the quantity of people and the amount of times each will use the restroom. An example demand calculation for water closet and urinal flushing is presented in Chapter 5.

Specifying low water consumption flushing plumbing fixtures, such as those that are WaterSense labeled, reduces non-potable water supply demand on a project and is crucial to maximizing water savings potential. The current baseline requirements for flushing fixtures set by the Energy Policy Act of 1992 is 1.6-gallon per flush (gpf) for water closets and 1-gpf for urinals. WaterSense labeled products are certified to be 20% more efficient than the baseline for the product without sacrificing performance. To achieve a WaterSense label, a water closet must consume a maximum of 1.28-gpf and a urinal no more than 0.5-gpf. For urinals, manufacturers have gone beyond this requirement to develop fixtures that go as low as 0.125-gpf. Waterless urinals are also available, though they require additional maintenance and should be coordinated with a building owner before being specified on a project.

Cooling Tower Make-up

Cooling tower make-up water is another opportunity for non-potable water use. Cooling towers are used to reject heat generated from interior air conditioning systems to the exterior by the evaporation of water. Early cooling tower systems utilized a continuous stream of water from either a utility supply or body of water, heating it as it passed through the process, then discharging it directly to the building sewer or returning it to the body of water. Eventually continuous make-up water from a utility supply became too expensive and a supply from a local body of water proved detrimental ecologically due to increasing the temperature of water. This led to systems that circulate water and make-up water is predominantly required for the amount lost through evaporation.

Heat pumps are becoming more popular for building heating and cooling systems to help with building decarbonization. Where ground source heat pumps are not feasible, a cooling tower is necessary for heat rejection. As such, an increase in cooling tower use is likely and a good application for the reuse of non-potable water. The amount of make-up water required to supply a cooling tower system is based on several factors and not constant throughout the year. The size of the cooling tower, the cooling requirements, and outdoor air conditions all play a factor in the amount of water lost due to evaporation and blow down, which requires approximately 0.03gpm of make-up water per cooling tower ton at peak conditions. A study of cooling tower operation is not the focus of this report and its demand is not included in the example office building presented in Chapter 5; however, considerations for such systems are discussed.

Irrigation

Landscape irrigation is a significant user of water and ideal for non-potable sources. A property owner looking to minimize overall water use should explore landscape options that require no irrigation such as native landscaping that survive on the amount of naturally occurring rain in the area. If irrigation is required, it should be kept to the minimum amount possible. This load will be more intensive during warmer times of the year. This report will focus on water use within the building footprint and will not focus on estimating irrigation demand, but rather estimating the amount of collected water remaining for irrigation.

4.2 – Alternate Water Sources

Rainwater/Stormwater Harvesting

Civilizations have captured and stored rainwater for thousands of years. As our water systems became centralized, the practice has mostly gone away in certain parts of the world where fresh water supplies seem abundant. Rainwater is defined as precipitation that falls on a roof surface, while stormwater is precipitation falling elsewhere on the site. The collection and reuse of rainwater requires less treatment than stormwater because it comes in contact with less contaminants. Both types require minimal treatment compared to other alternate water sources as it falls from the sky in a pure form and doesn’t collect contaminants until striking a surface.

Today, most urban systems in the U.S. remove rainwater and stormwater from a site through a series of inlets and drainage pipes, returning the water to a source such as a river or lake. Ideally a centralized stormwater drainage system is kept separate from the municipal wastewater drainage system; however, many combined sewer systems still remain today. With separate systems, wastewater is sent to a facility for treatment before returning to a water source, while stormwater is sent to the source untreated. With a combined sewer system, stormwater and wastewater are transported through a shared piping system to a single facility for treatment. This causes a significant increase in energy use and the risk of overloading the treatment facility during a heavy rainfall event. When a system becomes overloaded, raw untreated wastewater and stormwater mixture are returned directly to the source. A 2004 EPA report estimated that 850 billion gallons of untreated wastewater and stormwater are released from combined systems each year. The release of untreated wastewater into the same source freshwater is drawn from often times lead to boil water orders and loss of potable water supply for local residents. While work is ongoing to separate combined systems, there is still a heavy need for funding.

The Kansas City wastewater system serves about 320 square miles. Approximately 58 square miles are served by a combined sewer system, primarily in heavy urban areas. It is estimated that this system releases 9 billion gallons of untreated wastewater per year into freshwater sources when the system is overburdened during heavy rain events. In 2010 the EPA forced the city to pay a fine and commit $2.5 billion over 25 years to eliminating unauthorized overflows of untreated raw sewage. The city does not plan to eliminate the combined sewer system, instead focusing efforts on the installation of green site infrastructure, limiting stormwater entering the system by retaining it on-site. In addition to green landscaping, rainwater harvesting systems would also prove beneficial to the sewer system. Currently there do not appear to be any incentive programs encouraging the installation of rainwater harvesting systems in the Kansas City area.

To assist in the safe design, installation and maintenance of rainwater harvesting systems, the American Rainwater Catchment Systems Association (ARCSA) and the American Society of Plumbing Engineers (ASPE) jointly developed standard ARCSA/ASPE/ANSI 63:

Rainwater Catchment Systems. Since the standard provides minimum level requirements for a safe installation, the local authority having jurisdiction must also be consulted for any additional requirements.

To determine the available rainwater harvesting supply, historical monthly rainfall rates for the project area must be researched. Multiple sources of historical rainfall data are available. Once such source is Appendix F in ARCSA Standard 63. It provides average monthly rainfall rates over 30 years for select U.S. cities. Once monthly rainfall rates have been determined the available supply can be estimated based on the collection area and efficiency of collection coefficient. Additionally, a Rainwater Harvesting Calculator spreadsheet developed by the Federal Energy Management Program (FEMP) is available for free to estimate monthly rainwater potential at a specific site. It was developed to aid federal agencies in determining the potential and implementation of rainwater harvesting systems at their facilities. The calculation method presented in the ARCSA Standard 63 to determine monthly rainfall available for reuse is the same as the FEMP calculator. The equation used in both to determine the monthly rainwater supply in gallons is 0.623 x Precipitation Density (in) x Catchment Area (sf) x System Collection Efficiency. The system collection efficiency coefficient typically ranges from 0.8 to 0.85, accounting for loss due to leakage, evaporation, and roof composition. 0.623 is a conversion factor to convert inches of rain to total monthly gallons of harvesting potential. An example calculation is presented in Chapter 5.

When sizing a rainwater storage tank, often referred to as a cistern, the estimated available monthly rainwater, catchment area, and anticipated demand by the reuse system are all factors. Ideally a cistern is sized to store enough water to meet the demand through dry periods with little to no rain. In areas that experience exceptionally long droughts, it may not be practical to install tanks large enough to store the amount water needed to meet the demand through the entire dry period. A balance must be struck between the desired length of time with no rain the system will operate versus the size of tank that is practical to install due to cost and space limitations. An example exploring how several factors play a role in sizing is presented in Chapter 5.

Rainwater harvesting drainage piping, gutters, and downspouts are sized based on the local plumbing code. The piping system connects the drainage of all roof surfaces to a cistern, which may be located above or below grade and either interior or exterior to the building. The cistern must contain an overflow pipe connection to the site stormwater drainage system in the event the tank becomes full. The overflow pipe must be large enough to carry the full flow available from the roof catchment area at peak rain conditions. The overflow system must also contain screen protection and a readily accessible backwater valve to prevent rodents and site stormwater from entering the cistern.

A properly maintained system can store rainwater indefinitely. The first stage of treatment for all rainwater collection is a pre-filtration system occurring before the water enters the cistern. The pre-filter should contain a screen with openings no larger than $1/16^{th}$ inch to remove large objects such as leaves, needles, sticks, and other debris from entering the cistern. Where multiple cisterns are used, each shall have its own pre-filtration screen unless connected in series. The pre-filtration screens must be readily accessible for regular maintenance per the manufacturer's specifications. A first-flush device is an additional option to consider. They divert a set amount of rainwater away from the cistern when rain first begins to fall as this is when the most debris is collected. The diverted rainwater should drain in a manner consistent with the site stormwater system. The first-flush device should be placed before to the pre-filtration screen and must also be readily accessible for regular maintenance. First-flush devices with integral pre-screen filters are available.

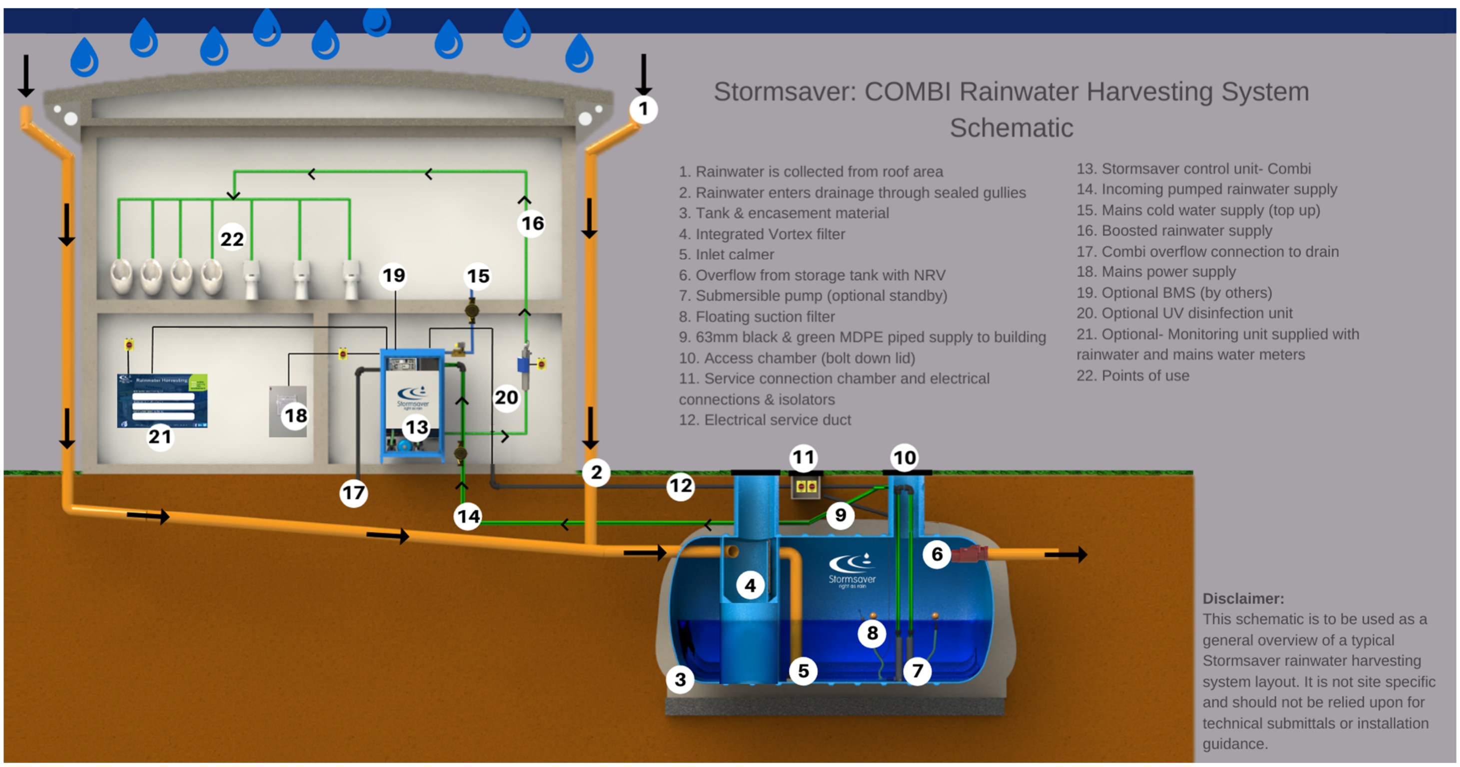
Depending on the location of the cistern, a pump may be necessary to adequately pressurize the system. The pump must be capable of providing the minimum required residual pressure to the most demanding connected fixture outlet.

The level of treatment required for rainwater stored in a cistern before it is used is dependent on the final purpose. For exterior non-potable uses such as for irrigation, maintenance, and cleaning, additional treatment may not be required. Interior non-potable uses such as fixture flushing, laundry, and process make-up water typically requires additional filtration to remove sediments that are harmful to fixtures, equipment, and valves. The piping distribution system must be separate and identifiable from the potable water distribution system. Typically, a nonhazardous food coloring dye injection to the non-potable water system is required to warn occupants of the type of water.

For systems with consistent, low flow end use applications, a direct system is appropriate to eliminate the need for an additional treated water storage tank. An additional storage tank is useful when a system may experience high instantaneous flow, because the treatment system and pump must be sized based on the peak flow rate. A treated water storage tank allows for a smaller treatment system, sized to refill the smaller tank at a set flow rate. Typically, this tank is sized to meet the demand for a day. A dual tank system allows the pump and filtration system to operate at a lower flowrate and during off hours. If expected peak flow conditions are low and consistent, a smaller interior tank is not necessary. A tank sizing procedure is presented with the example in Chapter 5.

Figure 4-1 below indicates the typical components required for a non-potable rainwater harvesting system. If an interior tank is desired, it would typically be installed after the filter. The smaller interior tank also requires a pump to pressurize the distribution piping system and typically connects to a municipal water supply to for make-up water when the supply of rainwater is low.

Figure 4-1 Typical Rainwater Collection Detail[10]



[10] Stormsaver Ltd., Rainwater Harvesting for Supermarkets

Condensate Collection

Cooling coils in HVAC equipment and other types of refrigeration equipment creates waste water by cooling air as it passes over the coils. Condensation is typically drained to the sanitary drainage system with all other building waste and is a good opportunity to collect for reuse. Condensate supply is only available when the cooling equipment operates. As such, the supply will be much greater during warmer months of the year when air conditioning equipment is operating. Greater condensate supply in warm months may work well with a higher cooling tower make-up and/or irrigation demand. Water collected from condensate may utilize the same storage tank as rainwater harvesting since they have similar properties and require similar levels of treatment for reuse. Condensate supply is also dependent on humidity of the location. The EPA provides a useful tool for free online called the Non-potable Environmental and Economic Water Reuse Calculator. The calculator provides economic analysis of various OSWR systems based on region and building type. While this report won't focus on all of the information this calculator provides, the monthly AC condensate harvesting potential it provides is useful for estimating condensate supply. Considerations for implementing condensate collection are discussed in Chapter 5.

Graywater Collection

Graywater is waste discharged from fixtures that do not include human excrement or other high organic loading such as lavatories, drinking fountains, washing machines, showers, and bathtubs. Waste from fixtures such as water closets, urinals, kitchen sinks, and dishwashers are considered blackwater and cannot be mixed with the graywater system. The authority having jurisdiction will dictate the fixtures allowed to connect to the system. Model plumbing codes such as the International Plumbing Code (IPC) indicate approved and prohibited fixtures.

The daily available graywater supply is estimated based on the anticipated number of occupants in a building and the number of times a fixture such as a lavatory is used. For example, a lavatory typically discharges 0.25 gallons of greywater for each use. In a typical office building it is estimated that each occupant discharges one gallon of greywater per day. An office with 100 occupants will generate a supply of 100 gallons per day. The building owner should be consulted to help determine the expected building occupant schedule. The type of building will play a large role in estimating the available supply of graywater. An apartment building or hotel will generate much more graywater per person than a typical commercial building because of the additional use of showers and washing machines.

A graywater collection system requires separate piping, storage tank(s), and treatment systems from the rainwater and condensate collection systems described above as it requires a higher level of treatment. The 2021 IPC allows storage of untreated graywater for up to 24 hours. Treated graywater should be stored no longer than 72 hours. The system design must include a plan to reuse graywater much faster than a rainwater system. The local AHJ must be consulted to determine the required level of treatment based on the end use. Unlike ARCSA standard 63 for rainwater harvesting, no generally accepted standard for the design, installation, and operation of a graywater reuse system exists today.

Graywater systems typically require higher levels of regulation compared to rainwater and may be more difficult to permit. Local water authorities and health agencies are tasked with ensuring water that is safe for public interaction and will set requirements for the treatment of such systems. Graywater treatment systems may include turbidity removal, storage, biological treatment, filtering, or any combination of these items. In addition to filtering, graywater must be disinfected through either the use of ozone, ultraviolet irradiation, chlorine, or iodine addition. UV disinfection is a good choice for systems looking to avoid the use of chemicals. The level of filtration and disinfection is based on the intended use of the water. Subsurface irrigation may require minimal levels of treatment compared to reusing the water for toilet flushing and cooling tower make-up.

Due to the public health concerns described above, local authorities may not have adopted regulation for graywater systems and do not allow them. As described in Chapter 2, there are numerous resources available to help health agencies and water authorities establish regulations for oversite of design, installation, operations, and maintenance of these type of systems.

4.3 – Water Treatment

All onsite water reuse systems require some amount of treatment in the form of filtration and disinfection before storage and use. In theory, any form of waste water a building produces could be treated to potable water; however, the equipment cost and space required to treat the dirtiest water such as blackwater for reuse is prohibitive.

To achieve a NZW building as defined by either FEMA or the LBC, a property must treat all blackwater onsite before returning it to the source. This may be achieved by a Living Machine, composting toilets, membrane bioreactors, constructed wetlands, treatment lagoons, and other forms of biologically based or mechanically based treatment trains. A traditional septic system is another acceptable method of treating and returning wastewater to a ground source. Blackwater treatment systems are not the focus of this report.

The level of treatment required by the other systems is dependent on the alternate water source and the intended final use. Rain is typically one of the purest forms of water available and doesn't pick up contaminants until striking a surface. Since this water is relatively clean it requires minimal treatment to reuse. Condensate from the HVAC system is also relatively pure and can typical combine with collected rainwater. By comparison, graywater requires additional treatment before storage and reuse and is typically kept separate.

Local health agencies and water authorities must be consulted to determine the required level of treatment, testing, and reporting based on the source and the use of OSWR systems.

Chapter 5 – Application

In addition to jurisdictions where OSWR systems are required, owners may desire these systems to help achieve green building certification or reduce the water bill in areas that water rates are high. No matter the reason, if OSWR systems are desired, it is critical to identify and incorporate the systems in the early stages of design. The additional space required for storage and treatment equipment will be difficult to add late in project design. This chapter provides an example calculation for a fictitious 500 occupant office building located in the Kansas City area. The building is assumed to be 3-story with a 25,000-sf footprint. Considerations and implications for adapting systems to other building types are also discussed.

5.1 – Water Budget

To determine the feasibility of OSWR systems on a project, a water budget analysis must be performed. This analysis is necessary to best match alternate source supply with the reuse demand and to properly size storage tanks and treatment systems. The budget will also help quantify the building's water savings potential for economic analysis of the systems. The demand estimate of the budget in this report focuses on urinal and water closet flushing, cooling tower make-up, and irrigation since they are the largest non-potable water demands in typical commercial buildings. Alternate water supply estimates focus on rainwater harvesting, condensate collection, and graywater collection systems. While on-site blackwater treatment systems are available, they require a significant amount of additional space, energy, and monitoring than the previously mentioned systems and are not a focus of this report. Figure 5-1 is an example of a simple spreadsheet that may be utilized to estimate monthly and annual supply and demand for these systems. Estimating per month supply and demand helps with sizing the storage system. Examples of estimating the monthly totals for each category are provided later in this chapter.

Figure 5-1 Water Budget

Demand	Month												Total
	January	February	March	April	May	June	July	August	September	October	November	December	Total
Flushing													
Irrigation													
CT/HVAC													
Total													

Supply	Month												Total
	January	February	March	April	May	June	July	August	September	October	November	December	Total
Rainwater													
Condensate													
Graywater													
Total													

5.2 – Estimating Demand

Urinal and Water Closet Flushing

Several factors dictate the amount of water required for flushing urinals and water closets. Gallons per flush (gpf) is based on the specified fixtures. Utilizing low flow fixtures should be a priority on nearly all projects, but is especially true if planning to incorporate an OSWR system for flushing.

The more difficult variable in estimating the flushing demand is determining the frequency the fixtures will be used. Figure 5-2 is an example spreadsheet for calculating monthly flushing demand for a typical office building. Fixture flushing demand for each month of the year based on the number of occupied days should be estimated for the water budget analysis.

Figure 5-2 Fixture Flushing Demand Estimate

Fixture Flushing Demand						
Occupancy Type:	Office	Day Type:	Weekday			
Fixture Type	gpf	Use per occupant (Full Time)	Full Time Occupants	Use per occupant (Transient)	Transient Occupants	Gallons per day
Toilet (female)	1.28	3	250	0.75	10	970
Toilet (male)	1.28	0.5	250	0.25	10	163
Urinal	0.125	2.5	250	0.5	10	79
					Daily Total	1,212
					No of Days	20
					Monthy Total	24,231

In the example, 1.28 gpf water closets and 0.125 gfp urinals are specified. Next the number of full-time occupants and the average number of times each will use a flushing fixture must be estimated. This will vary greatly depending on who occupies the building. For a typical office building, each full-time occupant uses the restroom three times a day on average. Male occupants are assumed to use a urinal a majority of the time. Transient occupants and their frequency of fixture use must also be estimated and is highly dependent on the type of business. The LEED Reference Guide for Building Design and Construction v4.1 provides data on typical per day fixture use in nonresidential buildings by occupant type (Table 5-1) and may be used for daily and monthly demand estimating purposes for different building types. The building owner should also be consulted to better understand the intended end user schedules, and data modified as necessary.

Table 5-1 Nonresidential default fixture uses

Fixture Type	Duration (sec)	Uses per day			
		Employees (FTE)	Visitors	Retail Customers	Students
Water closet (female)	n/a	3	0.5	0.2	3
Water closet (male)	n/a	1	0.1	0.1	1
Urinal (female)	n/a	0	0	0	0
Urinal (male)	n/a	2	0.4	0.1	2
Public lavatory faucet	30	3	0.5	0.2	3
Shower	300	0.1	0	0	0
Kitchen sink	15	1	0	0	0

Note. Adapted from LEED v4, pg.277, Copyright U.S. Green Building Council

Irrigation Demand

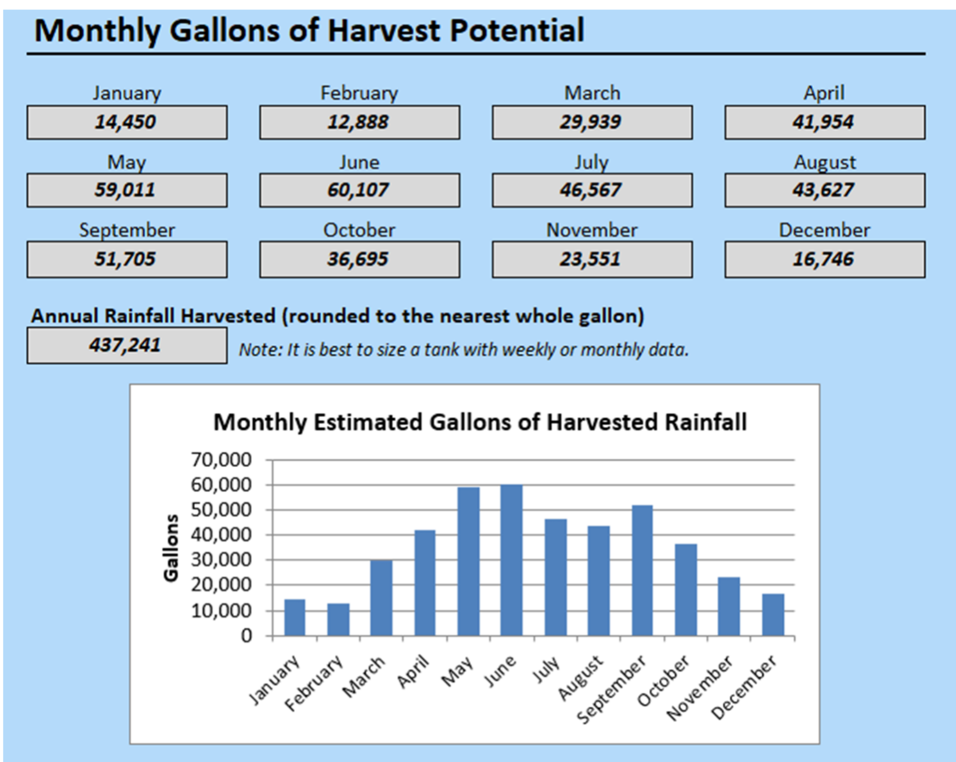
A project looking to minimize water use should first explore native landscaping that requires no supplemental water for irrigation and survives on the natural amount of precipitation typical for the area. If irrigation for landscaping is desired, OSWR systems are a great source as the water requires little to no treatment. Instead of designing landscaping then deciding how much water is needed to irrigate, the landscape design should incorporate the remaining available alternative water supply after flushing demand has been met so that it minimizes the amount of overflow from storage tanks that is lost. The example in this chapter does not attempt to estimate the irrigation water demand based on typical irrigation techniques used today. Instead the amount of water available for irrigation is estimated during the storage tank sizing process. Storage tank sizing is discussed later in this chapter.

5.3 – Calculating Alternate Water Supply

Rainwater Harvesting

The rainwater available for harvesting is dependent on the amount of rainfall, catchment area, and the efficiency of the collection system. The equation to determine monthly rainwater harvesting potential in gallons is 0.623 x Precipitation Density (in) x Catchment Area (sf) x System Collection Efficiency Coefficient. The system collection efficiency coefficient typically ranges from 0.8 to 0.85, accounting for loss due to leakage, evaporation, and roof composition. 0.623 is a conversion factor to convert inches of rain to total monthly gallons of harvesting potential. For this example, the free FEMP Rainwater Harvesting Calculator was utilized to determine monthly rainwater harvest potential in gallons for a building located in the Kansas City area with a 25,000 square foot catchment area (Figure 5-3).

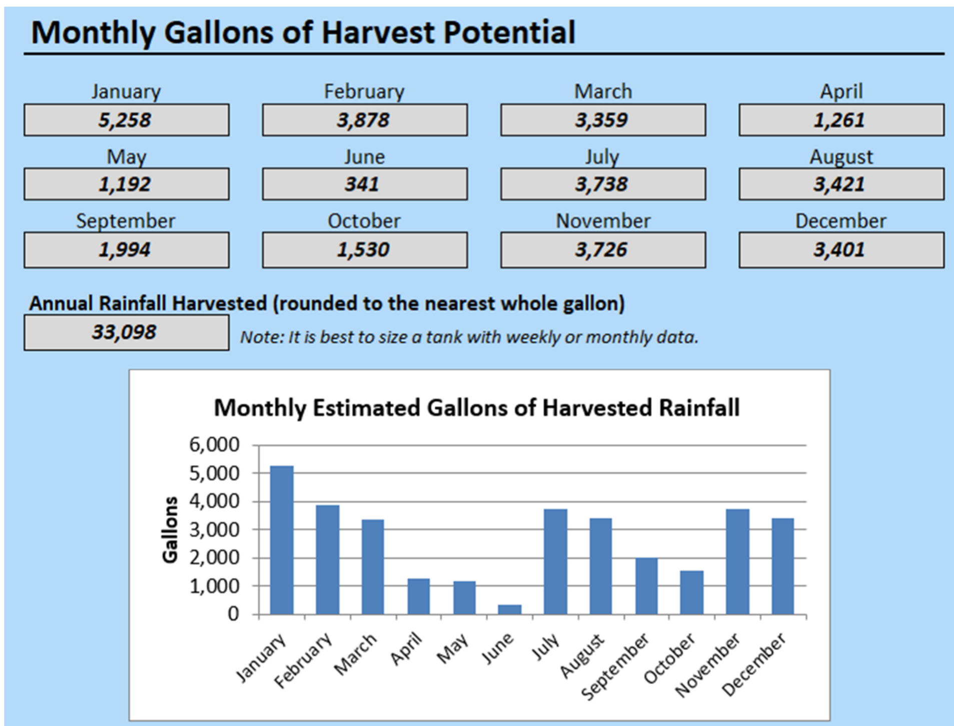
Figure 5-3 Monthly Rainwater Harvesting Potential (Kansas City)[11]



[11] FEMP, Rainwater Harvesting Calculator

For comparison, the rainwater harvest potential for the same building located in Las Vegas, NV is provided in Figure 5-4. The annual rainfall harvest potential in Las Vegas is only 33,098 gallons which would barely meet the demand for a month of flushing for the example building.

Figure 5-4 Monthly Rainwater Harvesting Potential (Las Vegas, NV)



Monthly estimated rainfall potential will be used in sizing the storage tank or tanks later in this chapter.

GRAYWATER COLLECTION

Graywater available for reuse is limited in most commercial applications. Collection will typically be limited to waste from lavatories. Since lavatory use should match the use of flushing fixtures, the net amount of graywater to reuse for flushing will always be negative. Graywater collection is not considered in the example office building discussed in this chapter. With 500 occupants each using a lavatory three times during a day, the monthly available supply would be 8,500 gallons, which is significantly less than the estimated flushing demand. The additional storage and treatment systems necessary for graywater reuse would be difficult to justify since the supply would not come close to meeting the demand. Climates that don't produce much rainfall may be a good candidate for graywater use for irrigation. Landscape irrigation could be designed to match the available graywater supply.

Multi-family residential buildings and hotels present a better opportunity for graywater reuse, as the wastewater from showers and washing machines can also be collected. Similar to the data presented in Table 5-1, the LEED Reference Guide also provides typical water use for residential occupants as shown in Table 5-2.

Table 5-2 Residential default fixture uses

Equipment	Duration (sec)	Uses per day
Water closet (female)	n/a	5
Water closet (male)	n/a	5
Private lavatory faucet	60	5
Shower	480	1
Kitchen sink	60	4

Note. Adapted from LEED v4.1, pg.277, Copyright U.S. Green Building Council

As an example, an 8-minute shower with a WaterSense labeled 2 gpm shower head will produce 16 gallons of graywater per person each day that is available for reuse. This is more than enough water to meet the typical residential flushing demand. Mixed-use occupancies that include residential units are a good opportunity to supply non-potable demand with graywater collection systems.

5.4 – Storage Capacity

Sizing and selecting the location of OSWR storage tanks is an important task to ensure the system operates as efficiently as possible. If a tank is too small, water that could be potentially captured for reuse will be lost by normal stormwater removal methods. Small storage tanks also reduce the length of time a building can operate normally on recycled water during periods of little to no rain. As rainfall rates vary throughout the year, properly sizing a tank for rainwater storage can be a challenge. An example sizing method for a rainwater harvesting storage system is described below. Graywater system storage is simpler to estimate due to consistent fixture use throughout the year.

ARCSA standard 63 provides recommendations for sizing rainwater harvesting system storage. It is recommended to select a rainwater harvesting storage system that is capable of meeting the demand of intended water use over a period of little to no rainfall. As mentioned previously, in certain climates it may not be practical to provide enough storage capacity for the entire length of a dry period. The required storage capacity would be too large and cost prohibitive. An owner must be consulted to determine their desires for water resiliency. One month of storage is a good estimate to begin with. In the example we established a flushing demand of 24,231 gallons per month (Figure 5-2). Comparing an estimated storage capacity to the monthly demand indicates which months may not have enough supply and in which months overflows may occur (Figure 5-5).

The storage capacity estimate should begin at the end of the dry season and assume an empty tank to start. The water stored at the end of each month is equal to: (Storage at end of previous month) + (Month Rainfall Collection Potential) – (Month Total Demand). The water in storage at the end of each month is limited by the size of the tank. Rain in excess of the storage capacity is lost to the overflow system. The example shown in Figure 5-5 begins with the month of March.

Figure 5-5 Storage Tank Capacity Estimate

Tank size =	25,000							
Tank fill at start =	0							
Month	Flushing Demand	Irrigation Demand	Cooling Tower Demand	Total Demand	Rainfall collection potential (gal)	End of month storage (net)	End of month storage	Overflow
March	24,231			24,231	29,939	5,708	5,708	
April	24,231			24,231	41,954	23,431	23,431	0
May	24,231			24,231	59,011	58,211	25,000	33,211
June	24,231			24,231	60,107	60,876	25,000	35,876
July	24,231			24,231	46,567	47,336	25,000	22,336
August	24,231			24,231	43,627	44,396	25,000	19,396
September	24,231			24,231	51,705	52,474	25,000	27,474
October	24,231			24,231	36,695	37,464	25,000	12,464
November	24,231			24,231	23,551	24,320	24,320	0
December	24,231			24,231	16,746	16,835	16,835	0
January	24,231			24,231	14,450	7,054	7,054	0
February	24,231			24,231	12,888	-4,289	0	0
Totals:	290,772			290,772	437,240		227,348	150,757

Initially a 25,000-gallon storage tank is selected for the example based on the monthly demand. Where the end of month net storage is negative, the tank is empty and collected water is unable to meet the demand for that month. Municipal water would be needed to make up the difference. On the opposite end, when net end of month storage is greater than the storage capacity, the excess water is lost through the overflow system. This example shows a 286,483-gallon per year reduction of potable water the water utility would normally supply. Negative net storage is subtracted from the total demand. Increasing the tank size reduces overflow and ability to meet the demand year-round, but will add cost and placement limitations. Calculations for a 20,000-gallon (Figure 5-6) and 30,000-gallon (Figure 5-7) sized tanks are shown below for comparison.

Figure 5-6 20,000-gallon Storage Tank Estimate

Tank size =	20,000							
Tank fill at start =	0							
Month	Flushing Demand	Irrigation Demand	Cooling Tower Demand	Total Demand	Rainfall collection potential (gal)	End of month storage (net)	End of month storage	Overflow
March	24,231			24,231	29,939	5,708	5,708	
April	24,231			24,231	41,954	23,431	20,000	3,431
May	24,231			24,231	59,011	54,780	20,000	34,780
June	24,231			24,231	60,107	55,876	20,000	35,876
July	24,231			24,231	46,567	42,336	20,000	22,336
August	24,231			24,231	43,627	39,396	20,000	19,396
September	24,231			24,231	51,705	47,474	20,000	27,474
October	24,231			24,231	36,695	32,464	20,000	12,464
November	24,231			24,231	23,551	19,320	19,320	0
December	24,231			24,231	16,746	11,835	11,835	0
January	24,231			24,231	14,450	2,054	2,054	0
February	24,231			24,231	12,888	-9,289	0	0
Totals:	290,772			290,772	437,240			155,757

Figure 5-7 30,000-gallon Storage Tank Estimate

Tank size =	30,000							
Tank fill at start =	0							
Month	Flushing Demand	Irrigation Demand	Cooling Tower Demand	Total Demand	Rainfall collection potential (gal)	End of month storage (net)	End of month storage	Overflow
March	24,231			24,231	29,939	5,708	5,708	
April	24,231			24,231	41,954	23,431	23,431	0
May	24,231			24,231	59,011	58,211	30,000	28,211
June	24,231			24,231	60,107	65,876	30,000	35,876
July	24,231			24,231	46,567	52,336	30,000	22,336
August	24,231			24,231	43,627	49,396	30,000	19,396
September	24,231			24,231	51,705	57,474	30,000	27,474
October	24,231			24,231	36,695	42,464	30,000	12,464
November	24,231			24,231	23,551	29,320	29,320	0
December	24,231			24,231	16,746	21,835	21,835	0
January	24,231			24,231	14,450	12,054	12,054	0
February	24,231			24,231	12,888	711	711	0
Totals:	290,772			290,772	437,240			145,757

A 20,000-gallon tank is unable to meet the demand for the month of February by 9,289-gallons. A 30,000-gallon tank is able to meet the demand year-round. The annual overflow ranges from 145,757 to 155,757-gallons per year.

Knowing the potential for monthly overflow allows for us to design other systems around its availability. While it is ideal to have no irrigation demand, designing low irrigation landscape systems around the available overflow is a way to limit the amount lost to the regular stormwater drainage system. Cooling tower make-up is another potential use of overflow.

Tank size analysis must be specific to each project as there are several variables such as demand and rainfall to consider. Working closely with the building owner to understand their desires for water savings and capacity for withstanding periods of no rain are important to the design process.

For the example, installation options for both 25,000 and 30,000-gallon exterior tanks should be considered. An additional interior tank sized to meet the daily demand would limit the size of the treatment system since it could be sized for a lower and consistent flow rate.

There are many options to choose from when designing a system that impact the cost and present major considerations for an owner. Ultimately the decision will be between if they want a system or not. Economic considerations for OSWR systems are discussed in the next section.

5.5 – Economic Considerations

One of the biggest concerns an owner will have about potential use of OSWR systems is the cost versus how much money it will save. Installation of OSWR systems are difficult to show payback from utility savings alone. Water prices typically don’t reflect the true cost of utility service and is one of the world’s most undervalued resources. A recent survey found that only one-third of water utilities are operating under rate structures that provide adequate revenue to fully cover the costs[12]. The current cost of water makes it difficult to show a payback of system installation in a reasonable timeframe. An estimated system installation price of $100,000 for the example building would take 19 years (Figure 5-8) for payback based on a current approximate utility rate of $8 per 1,000-gallons of water, assuming the cost increases by 10% each year. This analysis is for a system that uses rainwater for flushing fixtures only. If there are additional needs such as irrigation or cooling tower make-up that allow the building to utilize all of the rainwater available for collection, the payback time is reduced to 15 years based on the same rate structure (Figure 5-8). The assumed installation cost for a system using additional rainwater is slightly higher at $110,000 due to additional piping and components. No additional storage is assumed for the system utilizing the full amount of rainwater.

[12] USWA, One Water Roadmap

Figure 5-8 Simple payback analysis

Year	Annual Water Reduction (gal) w/ overflow use	Utility Rate ($/1000gal)	Total Annual Savings
1	437,240	$7.00	$3,061
2	437,240	$7.70	$3,367
3	437,240	$8.47	$3,703
4	437,240	$9.32	$4,074
5	437,240	$10.25	$4,481
6	437,240	$11.27	$4,929
7	437,240	$12.40	$5,422
8	437,240	$13.64	$5,964
9	437,240	$15.01	$6,561
10	437,240	$16.51	$7,217
11	437,240	$18.16	$7,939
12	437,240	$19.97	$8,732
13	437,240	$21.97	$9,606
14	437,240	$24.17	$10,566
15	437,240	$26.58	$11,623
16	437,240	$29.24	$12,785

Total Savings	$110,031

Year	Annual Water Reduction (gal)	Utility Rate ($/1000gal)	Total Annual Savings
1	290,772	$7.00	$2,035
2	290,772	$7.70	$2,239
3	290,772	$8.47	$2,463
4	290,772	$9.32	$2,709
5	290,772	$10.25	$2,980
6	290,772	$11.27	$3,278
7	290,772	$12.40	$3,606
8	290,772	$13.64	$3,966
9	290,772	$15.01	$4,363
10	290,772	$16.51	$4,799
11	290,772	$18.16	$5,279
12	290,772	$19.97	$5,807
13	290,772	$21.97	$6,388
14	290,772	$24.17	$7,027
15	290,772	$26.58	$7,729
16	290,772	$29.24	$8,502
17	290,773	$32.16	$9,353
18	290,774	$35.38	$10,288
19	290,775	$38.92	$11,317

Total Savings	$104,130

Annual maintenance and operations costs are not considered and would further increase the payback time. This way of thinking will probably not encourage an owner to install an OSWR system. A better approach is to compare the installation cost to the total project construction cost as it is often a very small portion. If the fictitious 3-story, 75,000-sf office building cost $400/sf to build for a total construction cost of $30 million, the $100,000 price to install a rainwater harvesting system is pretty small at 0.3%.

If an owner desires a building that reduces its water usage and has an overall positive impact on the environment, the cost to install an OSWR system in comparison to the total building construction cost is a good way to encourage them to do so. If they are looking for cost reduction from utility savings alone it will be difficult to show a reasonable payback period. Though it could be anticipated that water rates will continue to rise, saving additional money.

Government incentives for OSWR system installation are not currently widespread. Several cities throughout the U.S. will cover some of the installation cost of a rainwater harvesting system or other OSWR systems. Additional incentive programs would go a long way towards encouraging owners to consider OSWR systems. Reduced demand benefits water utilities by allowing them to use less energy to treat water and maintain the distribution system[13]. As the benefits become clearer to local water authorities and communities, hopefully incentives become more common practice.

[13] NBRC, Making the Utility Case

Conclusion

It may not be readily apparent to most of us that our water supply systems are so fragile because of the availability of freshwater and ease with which we remove our wastewater. Most in this country are fortunate not to worry about what happens behind the scenes to treat our freshwater and wastewater because it is always available when we need it. The low cost of water compared to other resources allows us to use it without much consideration to the amount we waste.

Not all are so fortunate. There are often reports of communities without freshwater supply due to equipment failure and pipe breaks that reduce pressure levels to unusable levels. At the very least a boil water order could be issued if water pressure drops low enough that harmful bacteria is allowed into the piping. Improperly funded and aging water treatment and distribution infrastructure is a serious problem that could impact anybody. Reducing potable water demand and wastewater output helps alleviate stress on these systems and allows utilities to focus resources on infrastructure repair and improvements. OSWR systems, especially if implemented by many properties, can make large reductions to these systems.

Draught and population growth are also causing several regions' water supplies to drop significantly. Since these areas don't experience as much rainfall, a graywater collection system may be more beneficial than rainwater harvesting. In extreme circumstances it may become required to treat and reuse blackwater onsite, as the City of San Francisco now requires for developments larger than 100,000 square feet to meet toilet and urinal flushing demands. Water budget calculations are required for all developments over 40,000 square feet, assessing the potential for OSWR systems at the property, but they are not required to be installed at this time.

As more breakdowns of infrastructure occur and water sources shrink, communities may look to requiring OSWR systems as a solution. Plumbing system designers of the future need to understand the additional scope of work the analysis, design, operation, and maintenance these systems will cause. Preparing a water budget for a project to analyze the potential of OSWR systems will become a common design practice in the future.

Unfortunately, with little incentives currently, it is difficult for owners to justify installation of OSWR systems by cost alone because of the cheapness of water. However, there are several sectors that plumbing designers need to be prepared to design OSWR systems for. Owners that desire a green building certification such as the Living Building Challenge will require these systems to meet water demand reduction targets. Additionally, any work on federal projects will require a water budget to determine the feasibility of OSWR systems as part of the design.

There is a growing market for systems improving the way we interact with water. As onsite treatment technologies and regulatory oversight improve, the ability for an owner to supply their own water on site is improving. Engineers and architects must be prepared to work with building owners and water authorities to design systems that both protect the health of occupants and the precious water supply that remains.

There are opportunities to research further on the larger picture impact that reducing demand on water supply and wastewater treatment plays on municipal utilities. Quantifying the amount of energy saved by a large reduction in water treatment and distribution when many buildings incorporate OSWR systems may help municipalities justify providing incentives to building owners for installing them.

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