Public Building Commission of Chicago

Water Reuse Handbook

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Valley Forge Park Fieldhouse

Letter from the Chairman

As Chairman of the Public Building Commission of Chicago, I welcome you to our first publication of the *Water Reuse Handbook*. This handbook outlines strategies for water conservation and water reuse that reflect Chicago's leadership in sustainable development and stewardship of our natural resources in each project we develop.

Chicago's greatest natural resource is Lake Michigan, which provides the City and surrounding areas with freshwater. Although there is ample water supply today, it is of the utmost importance to conserve our water for future generations. Both existing and emerging technologies are important for water conservation and water reuse in and around the city. The City routinely includes cisterns to preserve rainwater and other rainwater harvesting systems in new and renovated public facilities.

Our streamlined project oversight and efficiencies focus on building high-quality, low-maintenance and environmentally sustainable facilities throughout Chicago. With guidance from the PBC Board of Commissioners, client agencies, consultants, and internal staff, the PBC processes evolve and improve. As you read the *Water Reuse Handbook*, please note that we will continue to update and inform you of these new and innovative strategies.

Whether you are a client agency, a professional services consultant, or a citizen, I believe you will find that the PBC's commitment to high standards for water reuse and conservation will provide social, cultural and environmental benefits for generations to come.

Sincerely,

Rahm Emanuel

Rahm Emanuel
Chairman
Public Building Commission of Chicago

Langston Hughes Elementary School

Letter from the Executive Director

The Public Building Commission (PBC) plays a unique role in shaping the environment, building both public facilities and infrastructure. As a public developer and a responsible steward of the public fund, the PBC focuses on both economic and environmental sustainability. The *Water Reuse Handbook* is an important tool in our broad vision for environmental sustainability. This living document addresses the issues of water reuse and conservation for the City of Chicago and will be updated regularly as a resource for professional service providers, builders and other staff working on behalf of the PBC and its clients.

The PBC is responsible for a wide range of projects, from fire houses and police stations to schools and libraries. All PBC projects are designed to achieve a minimum LEED "Silver" certification, but we also aim higher. When integrate sustainable practices into each of our projects, we achieve the long-term results of reduced operating costs and preservation of our natural resources. The PBC already uses many techniques to reduce the amount of potable water demand for the development of sustainable public facilities and we are always looking for new opportunities for conservation as well as water reuse.

This handbook outlines benefits of water reuse, the regulations governing water reuse systems, tools and strategies for implementing and maintaining different types of water reuse systems and a host of examples both on the local and national level. To lead by example, the strategies described herein are applied in all PBC projects – demonstrating and strengthening our commitment to the environment and strong stewardship of our natural resources and the public fund.

Sincerely,

Erin Lavin Cabonargi
Executive Director

Osterman Beach House

Introduction

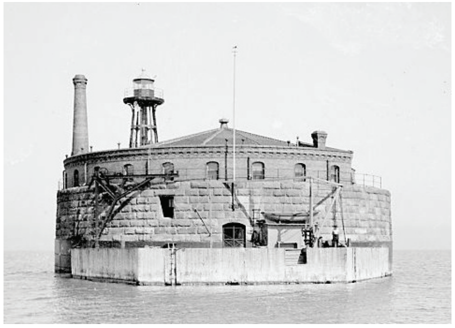
The Public Building Commission of Chicago (PBC) created this Water Reuse Handbook in its mission to serve the people of the City of Chicago and the County of Cook that reflects the highest standards of environmental sustainability. These guidelines offer PBC staff, project architects, engineers, facility managers, maintenance staff, and user agencies both a design reference and an educational tool for water reuse systems. The goals of the Water Reuse Handbook are to:

1. Examine the current regulatory climate surrounding water reuse strategies in the City of Chicago and the County of Cook;
2. Identify case studies on a local, regional, national, and international basis to define best practices in water reuse strategies as well as the types of water reuse systems most applicable for use in the City of Chicago and the County of Cook; and
3. Recommend appropriate water reuse measures, particularly relating to rainwater harvesting and greywater recycling, and to guide the implementation and maintenance of water reuse systems for PBC projects and beyond.

Water reuse systems have and will continue to become more efficient. As such, this Handbook is a living document through which the PBC will continue to evaluate built projects and opportunities for water reuse and conservation. These guidelines will be updated regularly to include lessons learned that reflect changes in both technology and regulations.

Benefits of Water Reuse

Introduction



Carter H. Harrison water intake crib 2 miles from the Lake Michigan shore (1910)
http://en.wikipedia.org/wiki/File:HARRISON-CRIB-1910.jpg

The City of Chicago was founded, in large part, due to its location at the junction of the Chicago River and Lake Michigan, as well as at the convergence of the Mississippi River and Great Lakes watersheds. It promised superior transportation, enhanced trade opportunities, and ease of access for visitors. Nearly 20 percent of the earth's and 95 percent of the nation's fresh water supply is found in the Great Lakes. While the region's fresh water supply may appear endless, there are compelling reasons to initiate comprehensive conservation methods--these efforts are in line with a Supreme Court 1967 ruling that limits Lake water diversion rates to 3,200 cubic feet per second, regardless of the future development or population growth the area has experienced. Policy documents of many major regional planning agencies, such as the Chicago Metropolitan Agency for Planning and the Alliance for the Great Lakes, emphasize potable water use reduction to ensure the region's ongoing water vitality.

Water levels in Lake Michigan have been falling, with only one percent of the water in the Lake renewed each year. Ground water levels have declined between 300 and 800 feet in the region, further lowering Lake water levels. At the same time, demand for water is expected to increase over the next 20 years, with a projected population increase of 20% in the Chicago-Milwaukee region. With both increasing demand and decreasing supply, it is critical for the Chicago area to take prudent and sustainable measures to safeguard against a dwindling fresh water supply.

At the same time, the Chicagoland area is experiencing increased incidences of local flooding each year due to severe storms; flooding within the City alone is largely a result of the City's high water table and combined sewer system (a sewer system in which wastewater and stormwater are combined and treated in the same way). The combined sewer system occasionally overflows (called a combined sewer overflow or CSO) during major storm events, causing sewer contents to discharge into a waterbody, such as Lake Michigan or the Chicago River. Prevention of such flooding is important to minimize the cost of damages as well as to protect water quality. These issues can be at least partially ameliorated by reusing water and reducing the load on the municipal sewer infrastructure.

This document outlines several methods to conserve and reuse water. These strategies are key to reducing fresh water, or potable water, usage in the City of Chicago and provide many key benefits.

Reduced Demand for Potable Water

Reusing rainwater or greywater for toilet flushing or irrigation, as well as using high efficiency and low flow fixtures and appliances, can have a significant impact on the amount of potable water used in a building, particularly for commercial and institutional buildings where toilet flushing comprises a large percentage of water use.

Metered users in Chicago, comprised of mostly non-residential buildings, may also see an added benefit of reduced water bills. Installing meters for small-scale residential buildings (such as single-family homes and two-flats) through such programs as Chicago's voluntary Meter-Save program may provide further impetus for water conservation to previously unmetered accounts.

Reduced Discharge to Sewer

Rainwater harvesting and greywater systems replace potable water; rainwater harvesting systems divert water from the City's combined sewer system, reducing its overall load. This is particularly important in the City of Chicago due to the frequency of combined sewer overflows (CSOs) and basement flooding.

CSOs are harmful because they pollute our fresh water bodies with raw sewage and pollutants such as motor oil, heavy metal trace elements, fertilizers, and other chemicals, leading to degraded water quality and wildlife habitats. CSOs can be limited by reducing, as much as possible, the amount of water input into the sewer system, particularly during periods of high system strain (such as during large rainfall events). This reduction is also a benefit: lake water diversion rules state that diverted stormwater quantities act as a credit toward the amount of water that can be pumped from the Lake.

Utilizing cisterns or rainwater harvesting systems reduces the amount of rainfall hitting the ground and entering the sewers in an area. This diminishes the risk of basement, yard and street flooding, which occurs occasionally during major storm events in the City. Lower sewer loads at peak times reduces flood risk and the resultant property damage and costs associated with such events.

Environmental Stewardship

There are many ancillary environmental benefits to utilizing water reuse systems: reduced overall demand for potable water conserves fresh water sources, which saves energy used in the treatment and conveyance of municipally supplied water, prevents flooding, protects water quality through diminished CSOs, and improves community water assets for recreation and wildlife habitat. This is consistent with the City of Chicago's Climate Action Plan. A commitment to sustainability ensures that present needs are met without compromising the ability of future generations to meet their own needs. Conserving our water resources helps to provide for our own needs as well as those of future generations.

Water Regulations

Introduction

The State of Illinois and City of Chicago both have jurisdiction over plumbing code in the City of Chicago, including regulation of any rainwater harvesting and greywater systems. Federal legislation is more general and ancillary to this discussion.

Existing Regulations

The Illinois Plumbing Code, adopted by the State of Illinois and administered by the Illinois Department of Public Health (IDPH), sets minimum standards that regulate the design and construction of plumbing systems within the State, the City of Chicago, and the County of Cook.

While the City of Chicago Department of Buildings has a separate plumbing code to govern plumbing systems State approval is also needed for rainwater harvesting and greywater systems for reuse interior to a building. The Illinois Plumbing Code and the Chicago Building Code currently do not include standards for water reuse systems, although this may change in the near future given recent activity around Illinois State legislation. Until these standards are fully established, public health and safety is protected through required review by the State DPH and the City of Chicago through the Department of Buildings Green Permit Program and the Committee on Building Standards and Tests (CST). The Green Permit Program provides incentives to sustainable design and gives the City of Chicago a tool to track sustainable features installed in Chicago. CST's purpose is to "ascertain the suitability of. . . systems of construction. . . .not permitted by or varying from, the performance requirements established by the building provisions of this Code but are claimed to be equally as good as or superior to those permitted. . ." under the Chicago Building Code. A growing number of water reuse systems have been approved to date. However, the CST is required to evaluate each project independently, which may add cost and time to the review process, and should be considered in budget and schedule development.

State approval is not necessary for rain barrel exterior rainwater harvesting systems for irrigation, as they are not physically tied to the public water system, and therefore are exempt from the State Plumbing Code. However, cisterns, which store larger quantities of water and have greater maintenance requirements, and may have a connection to City water for supplemental supply, are subject to review under State and City code. Both such systems are widely accepted and approved in the City of Chicago, the County of Cook and the State of Illinois.

Setting Standards to Protect Health and Safetly

At the core of the regulatory discussion is the responsibility to ensure public health and safety. To this end, it is important to have accepted minimum standards for water reuse system operations. Such systems are relatively new in the Midwest region, and water quality and development standards for water reuse systems have yet to be established locally. For such newly emerging systems, it is critical to protect public health and safety while regulatory standards are being drafted.

The water reuse systems that currently exist in Illinois have been approved on a case-by-case basis. Requirements vary, but most include the incorporation of chlorine dosing and/or micron filtration, and/or UV filtration into the treatment process.

In the absence of accepted standards, Section 820.400 (Minimum Sanitary Requirements for Bathing Beaches) of the Illinois Administrative Code (IAC) has been used at times as the standard to which water must be treated within rainwater harvesting or greywater reuse systems. In particular, IDPH has required that rainwater or greywater be treated to the minimum sanitary requirements for bathing beaches before it is reused. This means that water reuse systems must remove suspended solids, viruses, E.Coli bacteria to a level of less than 235 colony-forming units per 100 mL, and fecal coliform bacteria to a level of less than 500 colony-forming units per 100 m L.

The Chicago Building Code (CBC) contains key provisions that CST considers when approving a water reuse system. Specifically, CBC requires that only potable water be supplied to plumbing fixtures that provide water for drinking, bathing, or cooking purposes, or for the processing of food, medical, or pharmaceutical products (CBC 29, Section 18-29-602.2). The definition of potable water is "water used for human consumption that meets the requirements of the Safe Drinking Water Act, including water used for drinking, bathing, and washing dishes" (CBC 29, Section 18-29-202). Potable water also must meet the requirements set forth in the Public Area Sanitary Practice Code, Section 895.20. This provision requires that potable water be supplied to all plumbing fixtures, unless expressly permitted.

The CBC and IAC provisions put the onus on the design team to describe how a nonpotable source can be used where water is not intended for human consumption. The IDPH and CST then have the responsibility to evaluate the proposed system to determine whether it aligns reasonably with safety standards.

The institution of regulations and standards related to water reuse systems will eventually resolve the need for individual projects to be considered independently, and will facilitate water harvest systems reuse.

Recent Regulatory Developments

There has been considerable recent activity at the State of Illinois and City of Chicago levels in regulatory guidance for rainwater harvesting systems. Greywater systems have recently been included in this discussion.

In January 2010, Illinois Department of Public Health (IDPH) issued a Memorandum to serve as an interim guideline for evaluating rainwater harvest systems to be used for toilet and urinal flushing (see Appendix). The memorandum outlines the basic requirements for such systems.

State of Illinois Senate Bill SB 38, introduced in February, 2011, outlined requirements to include rainwater harvesting for non-potable uses in IDPH jurisdiction, and subsequently in State Plumbing Code. This bill would require that IDPH establish minimum standards for rainwater harvest systems by 2012. These new standards would facilitate implementation of rainwater systems in the City of Chicago, County of Cook, and State of Illinois.

While this bill was not successful in the recent legislative session it opened serious discussion around State policy on non-potable water reuse.

Most recently, IDPH and the Chicago Department of Buildings Green Permit Program developed a joint-review strategy to reduce the time and number of steps involved in review of rainwater harvest systems for use in flush fixtures and irrigation.

Tools and Strategies

*Chicago Center for Green Technology - the first rehabilitated municipal building in the nation to receive a LEED Platinum rating

Water reuse systems are an important component of the PBC's environmental sustainability program. This section begins with a review of techniques to reduce overall potable water demand in PBC developed buildings, as reduction of potable water usage is a critical first step in accomplishing the goals of this Handbook. The PBC is already using many of these techniques to lessen its potable water demand. This section also provides design guidelines for rainwater harvesting and greywater systems, and points to ideas for utilizing blackwater systems. These recommendations have been informed by research and local, national, and international case studies, and provide strategies for developing water reuse systems. However, users of this Handbook should keep in mind that different buildings will have different needs depending on the water source(s) being used, project budget, aesthetic and space planning concerns, etc.

Reducing Fresh Water Usage

Introduction

Before considering the reuse of rainwater and greywater, the most basic strategy to reduce potable water consumption is to use low-flow or high efficiency fixtures and appliances wherever possible. These may include shower heads, restroom or kitchen faucets, toilets, urinals, water fountains, dishwashers, washers, cooling systems, and landscape irrigation systems.

Moen sensor-operated lavatory faucet
http://www.moen.com/pressroom/press-release?id=5023

Accepted Toilet/ Urinal Strategies

The PBC typically installs high efficiency fixtures in its buildings. Such fixtures have been implemented in many different buildings across the City and are well accepted by local municipal code and the public. One resource for many of these products is EPA's WaterSense program, which certifies high-efficiency fixtures if they are shown to perform as well or better than their less efficient but code-compliant counterparts, and if they are 20 percent more water efficient than average products in that category (visit http://www.epa.gov/WaterSense/index.html).

High efficiency toilets (HETs): High efficiency toilets have been defined by the EPA as using, on average, 20% less water per flush than the industry-accepted standard of 1.6 gallons per flush-around 1.28 gallons per flush maximum. Utilizing HETs can significantly reduce the amount of potable water demand, particularly if more innovative water-saving toilets are used.

Dual flush toilets: Dual flush toilets are commonly used in Europe and Australia and are gaining popularity in the US as well. A dual flush toilet has two flushing options: a 0.8 gallon flush for urine only or a 1.6 gallon full tank flush for solid waste. The 2 options are typically displayed as two buttons or a variant on a handle. The handle either goes up for one flushing option and down for the other option, or a smaller handle (for the 0.8 gallon flush) is included in addition to the regularly sized handle.

Dual flush buttons
http://www.otismaxwell.com/blog/2009/09/user-interface-design-dual-flush-toilets-look-out-for-number-one/

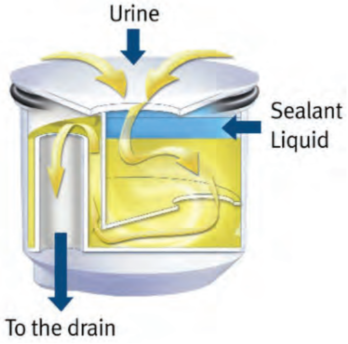
Sloan Dual Flush Handle Diagram
http://greenasathistle.files.wordpress.com/2008/02/dual.jpg

Although many users have reported that using the 0.8 gallon flush for all flushes causes no significant problems, it is necessary to educate building occupants on how to properly use the system. This should include instructional signage, as well as choosing a toilet with buttons or handles that are straightforward and easy to use.

High efficiency urinals (HEUs): High efficiency urinals use on average 0.5 gallons per flush or less, which is at least half the water used to flush a traditional urinal. Several HEUs now on the market, use just a pint of water per flush, and have been found to outperform waterless urinals and perform similarly to traditional urinals.

Other Toilet/Urinal Strategies

Other fixtures exist which are not currently recognized by the State of Illinois Plumbing Code or Chicago building code. Use is conditional upon approval of installation as an IDPH test site.



How a waterless urinal works
http://www.treehugger.com/files/2010/02/stinky-waterless-urinals.php

Waterless urinals: Waterless urinals have been implemented locally over the past several years, as test cases, with mixed results. One cause for failure has been the corrosion of copper piping that drains the urinals. The US Army Corps of Engineers specifically states that drainpipes for waterless urinals should not be made of copper due to corrosion, however, the Chicago Building Code requires copper piping. Another key reason for waterless urinal failures is foreign liquids (such as coffee, juice, and chemicals) being poured down the urinal, which ruins the cartridge in the system. Each time a cartridge is ruined, it must be replaced.

Technology for waterless urinals should continue to be explored (particularly for low-use facilities) as the technology evolves to resolve some of these issues. Alternatively HEUs should be implemented to save water when appropriate.

Composting toilet: A traditional composting toilet consists of an aerobic processing system that treats human waste with little or no water involved. This is either accomplished through composting or managed aerobic decomposition. Thermophilic bacteria break down the waste, reducing its volume and eliminating potential pathogens.

Composted waste is eventually converted to a humus-like material, which may be used as fertilizer, although not suitable for food crops.

Moisture must be managed (50% +/- 10 is desirable) in order to control odor and ensure the effectiveness of the system. Another way to manage odor is to add absorbent material, such as sawdust or peat moss, after each use. This enhances aerobic productivity and absorbs excess liquid. Composting toilets are regulated under IDPH Private Sewage Disposal Licensing Act and Code, 2003, Section 905.130.

Urine-diversion toilet
Flickr Sustainable sanitation's photostream http://www.flickr.com/photos/gtzecosan/3513116536/

Urine-diverting toilet: Urine diverting toilets use 2 separate bowls (1 for solid waste, 1 for urine) to harvest urine. Urine is rich in nitrogen and phosphorus, and may be useful as a fertilizer should appropriate refinement technology become available. Such systems depend on occupants using the system properly and instructional signage should be included to ensure proper use. Their use is not allowed in the State of Illinois or City of Chicago.

Other Fixtures

Public lavatory faucets: Public lavatory faucets have been given a maximum flow rate by ASME of 0.5 gallons per minute. This flow rate is much lower than that of residential or private bathrooms due to the fact that public restroom sinks are used almost exclusively for hand washing. Fixtures should be chosen to meet this maximum flow rate.

Faucet motion sensors may be incorporated to prevent disease transmission. Faucet motion sensors and push-down (metered) lavatories (hand sinks), when properly calibrated, can save additional water. Faucet motion sensors have been shown to reduce water usage by 70% over push-down faucets even when both are properly calibrated.

A low-flow shower at the Chicago District 9 Police Station

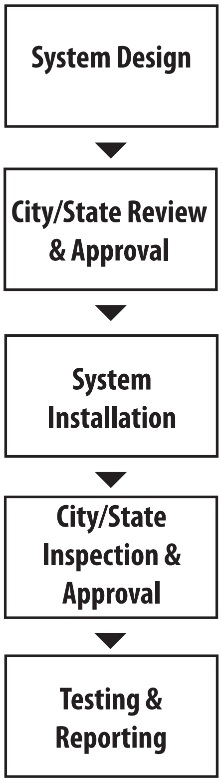
Showers: The PBC has incorporated high efficiency, low flow and metered showers into its buildings with flow rates as low as 1.5 gallons per minute; the Water Sense standard is a maximum flow rate of 2 gallons per minute.

Rainwater Harvesting System Design

Introduction

Rainwater harvesting systems can be utilized at an exterior and/or interior building level for irrigation or toilet or urinal flushing or for other nonpotable uses, as a way to drastically reduce potable water use, help manage stormwater, and enhance the environmental sensitivity of buildings. Since exterior rainwater harvesting systems, such as cisterns or rainbarrels, are already used widely in the City of Chicago, this document will focus primarily on interior reuse systems. The basic strategy for such interior systems is to harvest rain from roof catchment surfaces, filter and purify the water to an acceptable water quality standard, and store it until needed to flush toilets and/or urinals. Utilizing a rainwater harvesting system can make a huge impact in terms of water conservation, particularly for office and institutional buildings where flush fixtures may be a major part of the demand for potable water.

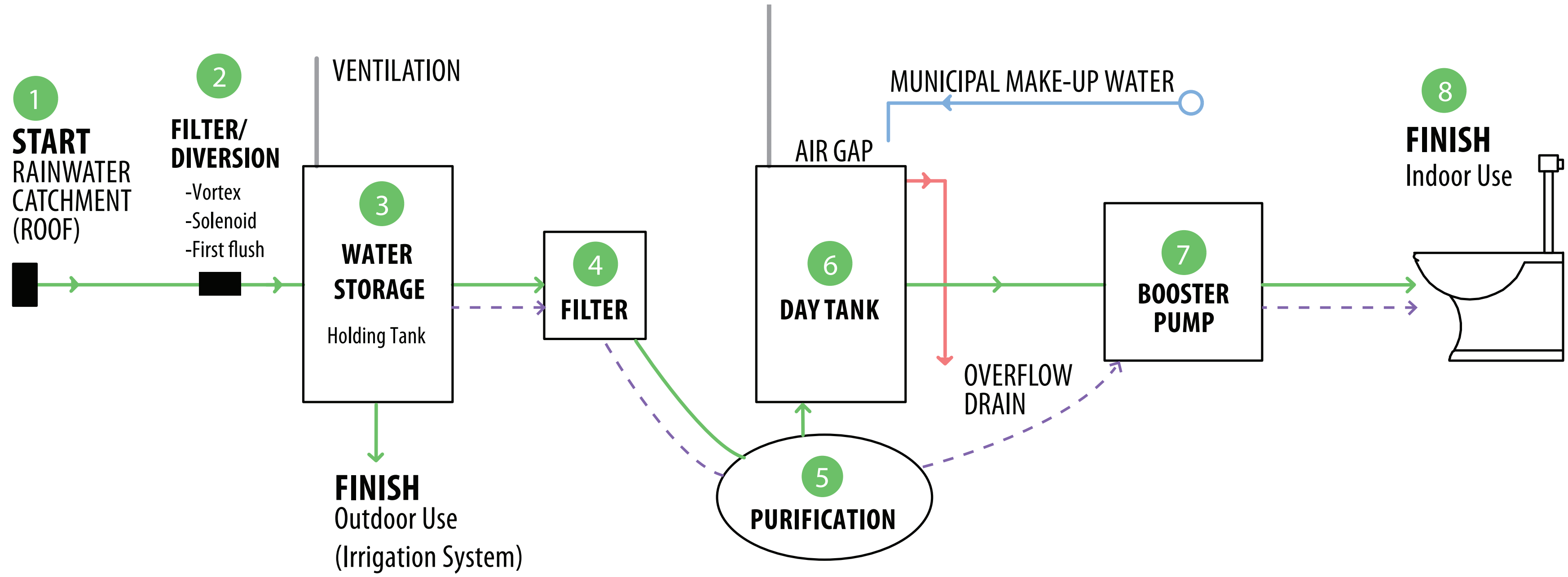
This section provides a series of recommendations as to when such systems are appropriate, as well as the various components needed for a rainwater harvesting system to protect public health and safety and potentially be permitted at the City and State levels. The components included in the Sample Rainwater Harvesting System Diagram, shown on the following page, are explained in greater detail and more options for system components are given in the narrative that follows.



Approval Process

As mentioned in the previous Water Regulations section, standards for rainwater harvesting systems are not established in the Illinois Plumbing Code (the State has jurisdiction over plumbing issues in Chicago). Therefore, the approval process should roughly follow the flowchart above until coordinated regulations are enacted to approve rainwater harvesting systems.

Currently, rainwater only systems submitted to the City of Chicago for permit approval are reviewed in coordination with IDPH and do not require separate submission to the State. IDPH must provide approval to the City of Chicago before a building permit is issued.



Sample Rainwater Harvesting System Diagram.

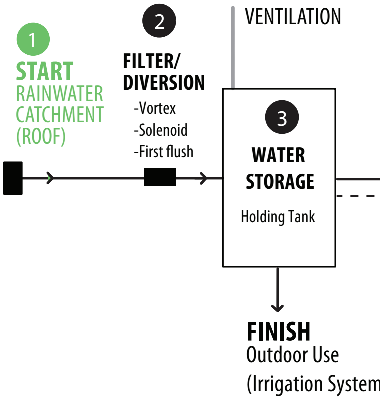
Following the recommendations of this section does not guarantee system permitting or approval from the City of Chicago or State of Illinois. Rather, these design guidelines are meant to be used as a starting point for the creation of a rainwater harvesting system that will be refined as needed for the project at hand.

Design Components

There are many options for system design. The basic components of a water reuse system, as illustrated on the Sample Rainwater Harvesting System Diagram include a water source, filtration component, purification strategies, delivery method, and an end use. Typical options for each component are given in the following text; however, options unique to each project should be pursued as necessary. The specifics of each system will vary based on size and use.

1 START: Rainwater Catchment (roof)

Potential sources: Several sources of water may be appropriate for use in a rainwater harvesting system, including rainwater from a roof catchment, groundwater, or condensate. Each source has a different set of design requirements, as outlined below. This manual will focus on rainwater catchment from roof sources.



Roof catchment: Capturing rainwater from a roof surface is a common method of obtaining water for a rainwater harvesting system. Smoother surfaces, such as metal or slate, are best for maximizing the amount of rainwater captured. Other materials, such as clay, concrete, or composite or asphalt shingles, may create inefficiencies, losing up to 10% of rainwater due to their texture, inefficient flow, and/or evaporation. Wood shingles, tar, and gravel roofs should be avoided for rainwater harvesting systems where water is reused to flush toilets or urinals to avoid unnecessary debris and pollutants in the water.

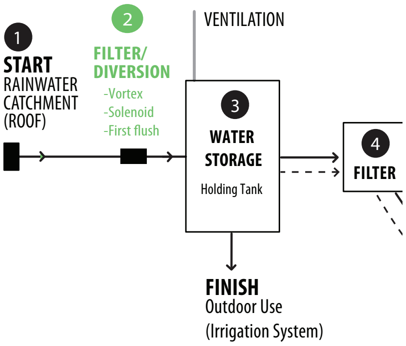
Gutter and downspouts are necessary to direct rainwater into the filtration system. Gutters and downspouts are typically comprised of half-round pvc, vinyl, seamless aluminum, or galvanized steel.

Condensate: Condensate from the cooling coils of an air conditioning system is a relatively clean source for a water harvesting system, with the exception of glycol/chemical systems. Such systems are more suitable for condensate make-up than for other uses, due to possible chemical/glycol leakage. Capturing condensate for reuse for a commercial or institutional building can result in millions of gallons of water saved during the course of a cooling season. Harvesting condensate is typically a simple process requiring the redirection of the condensate (via a rerouted waste line or addition of a discharge pit and pump) to the rainwater harvesting system to be filtered and purified.

Rainwater collected at ground level and Groundwater: Provided such rainwater is not contaminated by parking lot residues, runoff pollutants, etc., rainwater collected at ground level is also a great source for rainwater harvesting systems. Currently such systems, as well as groundwater systems require IDPH test site approval. They may be allowed on a case-by-case basis, and typically require pre-treatment prior to collection. An initial filter may include mechanical or natural filtration processes, such as sand, sediment, or geotextile fabric, as well as organic filtration (such as vegetated bioswales); often the wall of the sub-grade tank acts as the filter itself. Due to the volume of groundwater available to be harvested, storage in an underground tank is recommended; however, above ground cisterns may be used. Underground tanks should be constructed of materials such as reinforced polypropelene, fiberglass, or concrete that have sufficient strength under load-bearing surfaces. A sump pump may be needed to feed water into the rainwater harvesting system's filter prior to purification; rainwater from the underground storage tank should be drawn as needed to support minimum water levels in the day tank.

② Initial Filtration/ Diversion

Before the rainwater travels through the system, it is necessary to remove any leaves, twigs, blossoms, insect bodies, and other large objects from the rainwater to avoid clogging the system. This is typically accomplished through the use of a leaf screen or vortex filter. This filter can be located above or below ground and has to be cleaned out on a regular basis to avoid clogging. Roof surfaces typically contain a variety of contaminants including dust, pollen, animal feces, pesticides and sediment. The first flush diversion via a solenoid valve removes most of these contaminants by directing the first several minutes/gallons of the rainfall event to the sewer system instead of to the rainwater harvesting system.



First flush systems either designate a volume of rainwater to be diverted (# of gallons) or a preset amount of time to flush water (# of minutes). Volumetric first flush diverters are more expensive than timed diverters with little proven benefit; therefore timed first flush diverters are recommended unless there is a compelling reason to use a volumetric diverter.

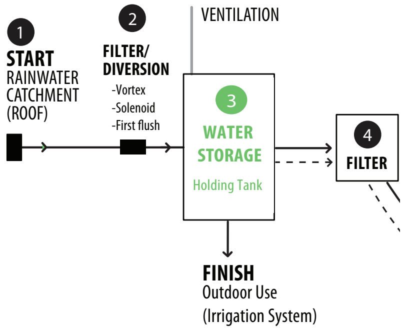
Solenoid valve: A solenoid valve is included to assist the first flush by directing the flow of rainwater to the sewer while the flush is occurring and switching over to channel rainwater to the rainwater harvesting system after the flush has occurred. The valve acts as a fail safe to divert rainwater to the sewer in the event of a problem with the system or if the tank is full. The solenoid valve should be located before the initial filter discussed below to avoid unnecessarily filtering water that will end up in the sewer system.

③ Holding Tank

A storage tank is a larger scale tank designed to hold a large quantity of rainwater until it is sent for treatment within the rainwater harvesting system; such a tank may be an above-ground cistern or underground storage tank. (See "#6: Day Tank" for more information on tank types, selections and locations.)

Smaller systems may just have one combined holding tank/day tank.

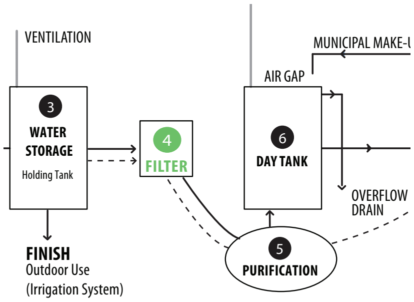
For water harvest systems used exterior to a building for irrigation only, water from the holding tank would be used directly. If make-up from municipal water is required, an air gap will be necessary to avoid possible contamination.



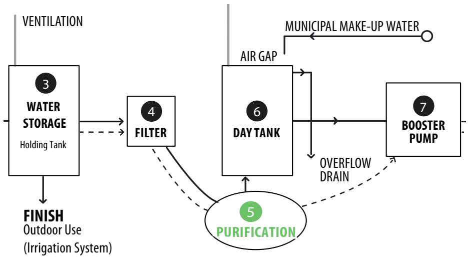
④ Filter

To further remove particulate matter and cloudiness, an in-line sediment filter or series of filters is recommended after the initial filter removes large impurities. These filters should remove particles larger than 25 microns.

If a UV purification system is used, a series of filters should filter the greywater to 1 micron prior to disinfection by the UV light. The greywater must be filtered prior to exposure to the UV because suspended particles in the water can shield pathogens from disinfection. The UV light should be located before the storage tank, although an additional UV light may be placed in the storage tank to continue disinfection.



5 Purification System



One of the following options should be utilized to purify the harvested rainwater prior to its entry into the storage tank.

Chlorination: Chlorination as a method of purification in rainwater harvesting systems has been the top choice of local municipalities due to its reliability. When chlorine is used to purify rainwater, residual chlorine remains, giving the rainwater lasting purification. On the other hand, after rainwater passes by a UV light, there is no purification after the point of contact with the UV, potentially allowing bacteria to grow after contact with the UV.

Sufficient contact time with chlorine is critical to kill bacteria. Contact time should be determined by considering water pH, temperature, and the amount of potential bacteria. The system should incorporate a fail-safe feature that reverts the system back to municipal make-up water if chlorine levels fall below the accepted standard.

Another potential drawback of using chlorine is that the smell of the chemical may be objectionable. The chemical itself also has negative environmental impacts, including the formation of trihalomethanes, which have been shown to cause several types of cancer. Another consideration is that chlorine does not kill giardia or cryptosporidium, both of which can cause parasitic infection allowed to exist in potable water. These two parasites may only be eliminated by a 1-micron filter or UV purification.

There are two major options to choose from if utilizing a chlorine-based purification system.

- Liquid chlorine can be used as a drip to continuously adjust chlorine levels. Use of liquid chlorine may be more appropriate for uses with full-time maintenance staff, as it needs consistent monitoring and maintenance attention. Liquid chlorine is also more dangerous than dry chlorine tablets, making it more appropriate for trained staff to handle. Liquid chlorine should be handled with care, as chlorine that comes into contact with skin will cause a potentially severe freeze burn.

- Chlorine tablets, such as calcium hypochlorite briquettes, are

Bio-Dynamic dry chlorine feeder and tablets the preferred option for chlorine purification systems. These are similar to what is used for large-scale water treatment facilities but are more user-friendly and safe for building maintenance staff (or residents) to handle. The tablets are combined with water in a hopper to create a liquid chlorine, which is then applied to the rainwater to achieve a satisfactory level. The tablets must be replenished; the frequency depends on the usage of the system. Use of briquettes or tablets is recommended for systems where a full-time maintenance staff is not employed.

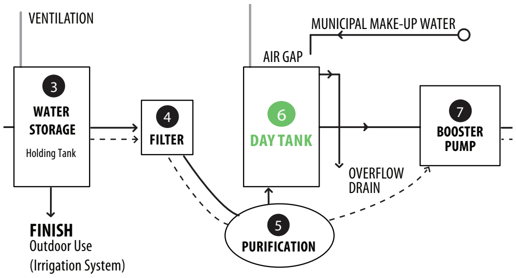
UV Light (top horizontal cylinder)
Texas Rainwater Manual

Ultraviolet (UV) light: UV light is an accepted purification alternative to chlorine. A specific wavelength of UV light destroys any organisms present in the rainwater. Typically, UV purification consists of a series of in-line sediment filters which filter the rainwater to 1 micron prior to disinfection by the UV light. The rainwater must be filtered prior to exposure to the UV because suspended particles in the water can shield pathogens from disinfection. The UV light should be located before the storage tank, although an additional UV light may be placed in the storage tank to continue disinfection. As an alternative to having another UV light in the tank, rainwater may be recirculated past the UV light in order to provide continual disinfection; however, this may heat the water over time.

UV purification systems have maintenance requirements as well. The UV bulb needs to be changed approximately once every 10,000 hours or after 12 months of continuous use; some bulbs come with an alarm that alerts occupants when the light quality is degrading. In addition, the sediment filters need to be replaced regularly.

6 Day Tank

There are two major types of tanks that may be used within a rainwater harvesting system, depending on the design of the system and quantity of water desired to be collected--a holding tank and a day tank. A day tank is smaller and meant to hold treated rainwater until it is needed for flushing.



Sizes of the system's tanks can be determined by several factors, including the demand for treated water, rainwater supply of the region, projected length of dry spells, catchment surface area, aesthetics, preference, and budget.

The size, location, and function of the tank should be considered in choosing the most appropriate material for the tank. Common materials for storage tanks include concrete, polyethylene, fiberglass, polypropylene, or galvanized metal. The tank must be opaque to protect against algae growth unless an agitator is included in the tank, in which case the tank may be semi-translucent. Opaque tanks may incorporate a translucent strip or floating indicator to show tank water level. When locating the tank, consider the proximity of building foundations and the ability to drain the tank effectively.

Where indoor space is at a premium or for larger tanks, i.e. greater than 5,000 gallons, burying the storage tanks underground may be considered to save space. Also, underground tanks open up the possibility of incorporating natural biological water filtration for groundwater. When considering burying the tank underground, the strength of the material should be of primary concern. Materials such as reinforced polypropylene, fiberglass, or concrete have high strength under load-bearing surfaces and are therefore the most appropriate for underground storage tanks.

The location of the tank(s) in a prominent location in the building may be considered to provide a learning opportunity for building occupants. Explanatory signage or linkage to the system control panel may also assist in conveying the system purpose and function to occupants. However, appropriate safety measures should be taken when necessary to protect against vandalism, such as placing the storage tank out of reach or behind protective glass.

Municipal make-up water: In case the rainwater supply runs short of the demand for irrigation or toilet/urinal flushing, the rainwater harvesting system must incorporate a municipal make-up water supply to the storage tank that will initiate when tank level sensors determine that the water level in the tank is low. The municipal water source must be protected from backflow contamination by incorporating a fixed air gap.

Overflow drain: If the storage tank becomes too full, an overflow drain should be incorporated to funnel excess water to the sewer through means of an indirect connection. A u-trap and rodent guard should be placed in the overflow drain to protect the supply from gasses and prevent rodents from climbing back into the storage tank and contaminating the harvested water supply.

Ventilation: When chlorination is utilized as a purification method, it is necessary to ventilate the tank room to the outdoors to remove any fumes that might occur. All storage tanks must be vented regardless of the purification system used.

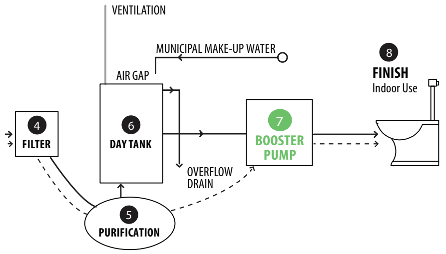
Water level sensors: The storage tank should contain 2 sensors: (1) to alert the control panel when the tank level is high and further rainwater is not needed (additional rainwater will be diverted to the sewer until water is needed for the system again) and (2) to alert the control panel when the tank level is low and municipal make-up water is needed.

Control panel: A centralized control panel is critical for proper maintenance of the system and to bring immediate attention to a cross-contamination issue. It also may be a useful learning tool in the appropriate setting (such as in a public area of the building like a lobby). The control panel may display such items as:

- Volume of harvested rainwater
- Volume of municipal make-up water used
- Any loss in pressure and its location in the system, which may indicate that a filter needs to be cleaned or other maintenance is necessary
- Indicator light for UV system - when bulbs needs replacement or if there is a problem with the system
- Indicator light for chlorination system - if chlorine levels have fallen below accepted standards, if chlorine is needed, or if there is a problem with the system

7 Booster Pump

When treated water is needed for flushing, it must be pressurized to get it to its destination. This is typically accomplished through the use of a booster pump after the water leaves the storage tank; however, this may not be necessary if gravity can be used to assist in moving the treated water.

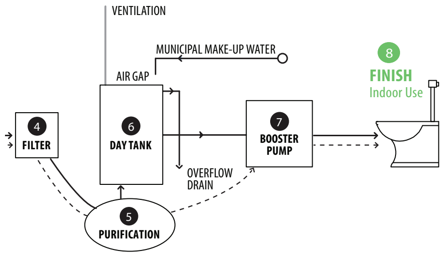


8 FINISH: Flushing Toilets & Urinals

The distribution piping from the rainwater harvesting system must itself be permanently identified by a distinctive yellow-colored paint or purple pipe. The piping or insulation must be marked as "non-potable" at intervals not to exceed ten feet.

In addition, each toilet or urinal supplied with harvested rainwater must be provided with a permanently affixed wall sign with yellow lettering stating, "This fixture is flushed with harvested rainwater. Not safe for drinking," or similar wording.

To further discourage potable use, non-residential applications may dye the treated water blue or green with food grade vegetable dye.



Greywater System Design

Introduction

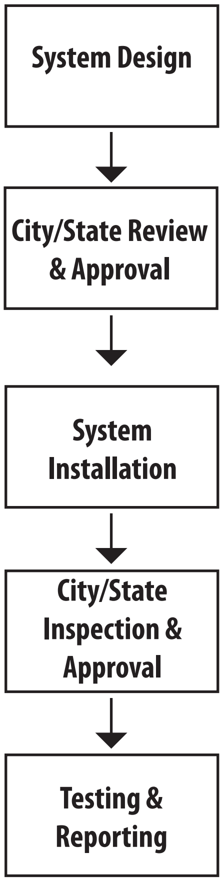
Greywater systems, although quickly growing in popularity around the world, have been slower to catch on in the Chicagoland area. This is likely due to the fact that this area gets adequate rainfall for irrigation and even for toilet flushing, if desired, and greywater systems are more complex and expensive than rainwater harvesting systems. However, as water conservation pressures increase internationally, and interest in environmental and water stewardship rises, greywater may become a more widespread and viable option in the Chicagoland area.

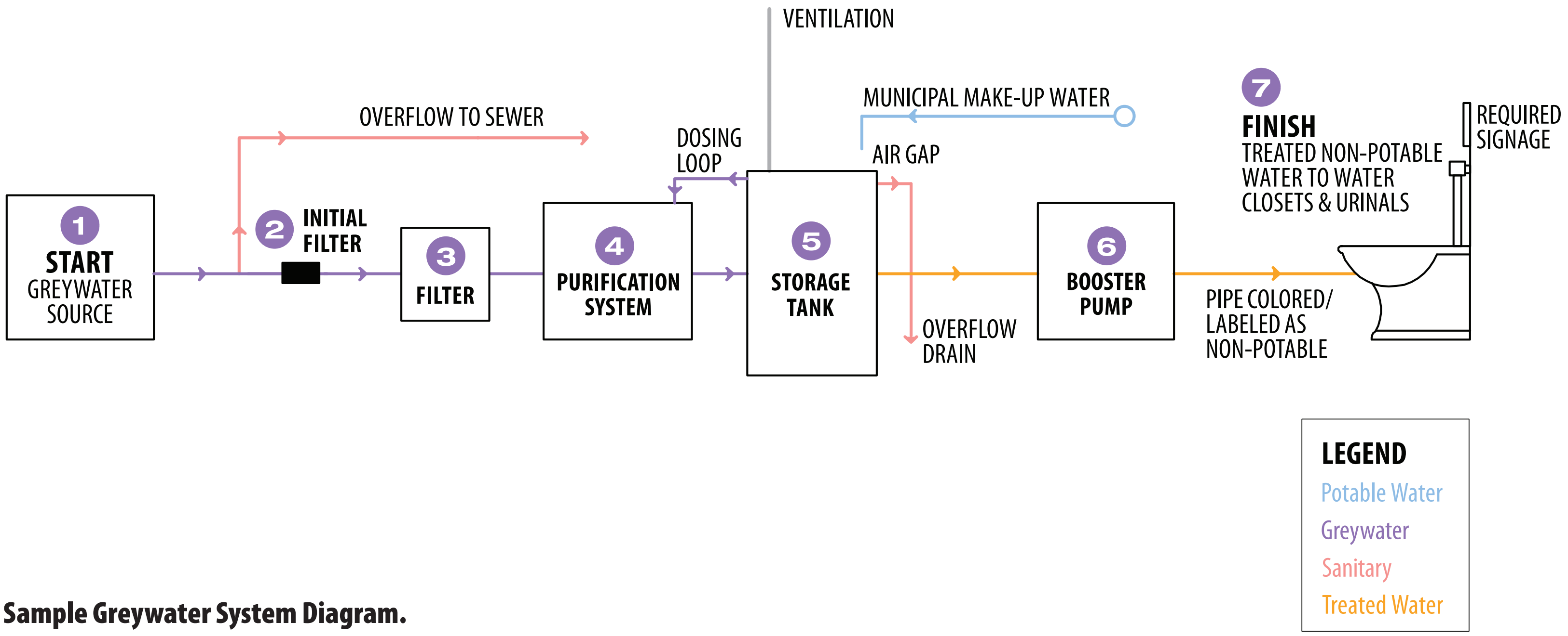
The basic strategy of a greywater system for interior building reuse is to harvest greywater from appropriate sources (such as shower, lavatory, and laundry water), filter and purify the water to an acceptable water quality standard, and store it until needed to flush toilets and/or urinals. Greywater reuse makes the most sense where an adequate source water is present and available to be harvested.

For example, a public restroom with only includes a few sinks and toilet/urinal fixtures and is likely not worth the expense of installing a greywater system when a rainwater harvesting system would be a better choice. Buildings that incorporate showers, such as fire stations or residential buildings, are good candidates for greywater systems as the water from one shower is approximately equal to one person's flushing needs for a day. See Planning for a Greywater System for more information on choosing the proper system.

This section provides a series of recommendations for the components believed to be needed for a greywater system to protect public safety. The components included in the diagram on the previous page, Sample Greywater System Diagram, are explained in greater detail and more options for system components are given in the narrative that follows.

Following the recommendations of this section does not guarantee system permitting or approval from the City of Chicago or State of Illinois. Rather, these design guidelines are meant to be used as a starting point for the creation of a greywater system specific to the project at hand.





Sample Greywater System Diagram.

Approval Process

Currently, greywater systems are not expressly allowed as an alternative to traditional plumbing systems in the Illinois Plumbing Code (the State has jurisdiction over plumbing issues in Chicago). Approval from the State must be sought for greywater systems until such an alternative is legislatively allowed. In addition, the City of Chicago Committee on Standards and Tests must review any systems that are not currently accepted under the Chicago Building Code. The approval process should roughly follow the flowchart on the previous page until regulations are enacted to approve greywater systems.

It should be noted that, due to the limited number of greywater systems built to date in the State of Illinois, the permitting process for such systems may be more involved and time-consuming than the process for rainwater harvesting systems. Additional time should be budgeted for City and State project review and minor system redesign.

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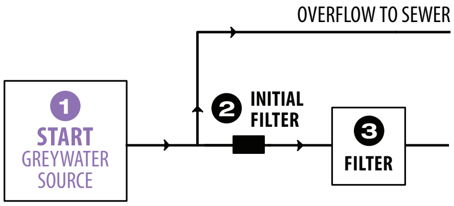
① **START: Greywater Source**

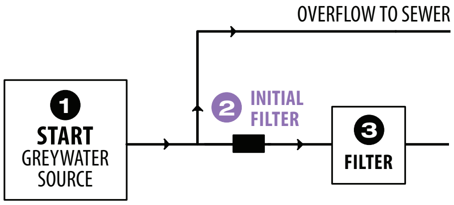
Several sources of water may be appropriate for use in a greywater system, including used water from showers, lavatories, or washing machines. Sources do not include water from the kitchen sink, dishwasher, or blackwater (wastewater from toilets and urinals). Kitchen wastewater and blackwater contain high amounts of organic and inorganic contaminants and bacteria which should be avoided for greywater systems.



All greywater sources, especially laundry water, should avoid cleaners that contain harsh chemicals, bleaches, disinfectants, or phosphates. Ammonia-based cleaners should not be used in washing machines contributing to a greywater system that uses chlorine purification, as such cleaners combined with chlorine may form chlorine gas. Hazardous chemicals should never be put down a drain that contributes to a greywater system. In addition, washing machines used as a greywater source should not be used to wash heavily soiled or human waste-soiled items (i.e. dirty diapers).

② Initial Filter

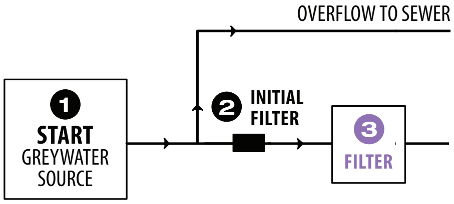
An initial filter serves to remove hair, lint, and other solids from the greywater source to reduce the risk of clogging the system downstream. Cleaning of this filter should occur regularly.



③ Filter

See the Rainwater Harvesting System discussion on filters. The majority of information included there is also applicable to greywater systems, with the following clarifications.

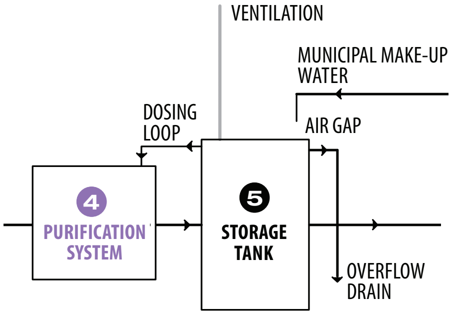
Ultrafiltration and reverse osmosis filter water to a finer degree than particle filters and may be useful to include in a greywater system, due to various contaminants and particles that source water may contain. These options should be explored during the design of the system.



④ Purification System

See the Rainwater Harvesting System discussion on UV and chlorination purification techniques. The majority of information included there is also applicable to greywater systems, with the following clarifications.

Chlorine loop (applies only if chlorination is used for purification of greywater): Due to higher levels of impurities and pollutants in greywater, the system should incorporate a dosing loop to recirculate water in the storage tank through the purification system to maintain the desired chlorine level. As an alternative, an automatic chlorine analyzer can continuously monitor chlorine levels and provide more chlorine via a chemical injection pump if necessary. The system should incorporate a fail-safe feature that automatically reverts the system to municipal make-up water if chlorine levels fall below the acceptable level.



UV in storage tank: If UV purification is used, an additional UV light and water agitator should be placed in the storage tank to continue disinfection. As an alternative to placing another UV light in the tank, greywater may be recirculated past the UV light to provide continual disinfection; however, this may heat the water over time.

Ozone: Ozone, although not as widely used as the other two purification methods, may be used as an alternative to UV or chlorine disinfection. The greywater should be afforded adequate contact time with the ozone system. Provisions must be made to off-gas the ozone to a safe environment. In addition, since ozone is a hazardous and powerful treatment method, its use may be better suited for larger scale applications where maintenance staff is on-hand to monitor the system closely.

Ultra filtration: Due to the contaminants that may be present in greywater, one option is to include ultra filtration membranes as an alternative filtering mechanism. Ultra filtration is very effective in removing pathogens, bacteria, viruses, and other particulate matter to 0.02 microns or better (see chart on page 54). Ultra filtration is also more efficient than other methods of filtration, consistent in its results regardless of load, easy to manage, and, when combined with chlorine purification, will produce pathogen-free water.

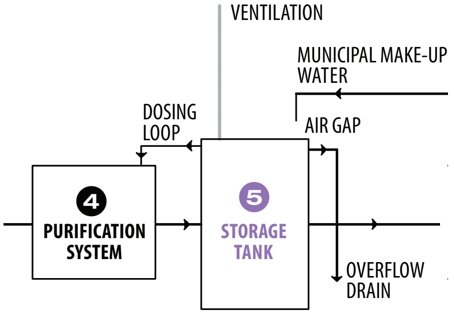
Reverse osmosis: Reverse osmosis is a technique which can filter water to an even finer grain than ultra filtration, down to 0.001 microns or less. Reverse osmosis (RO) is similar to ultra filtration, although there are some key differences. It works by applying pressure to the solution when it is on one side of a selective membrane, forcing pure solution to filter through while unwanted molecules and ions stay behind.

Depending on the contaminants that may be present in the water to be reused, reverse osmosis may be considered as an alternative to sand filtration. An activated carbon filter may be needed to trap organic chemicals and chlorine, which will attack and degrade certain types of reverse osmosis membranes.

5 Storage Tank

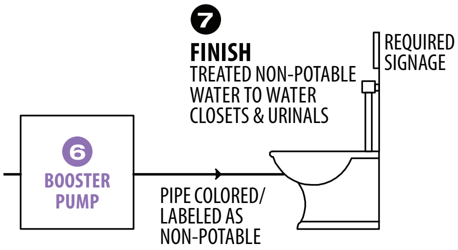
See the Rainwater Harvesting System discussion on storage tanks. The majority of information included there is also applicable to greywater systems, with the following clarifications.

The storage tank should contain 2 sensors: (1) to alert the control panel when the tank level is high and further greywater is not needed (additional greywater will be diverted to the sewer until greywater is needed for the system again) and (2) to alert the control panel when the tank level is low and municipal make-up water is needed.



6 Booster Pump

See the Rainwater Harvesting System discussion on booster pumps; this information is also applicable to greywater systems.

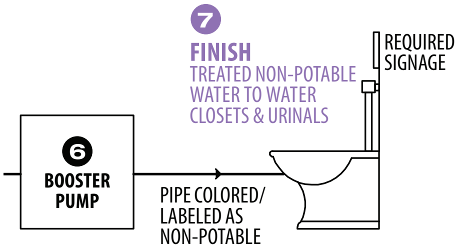


7 FINISH: Flushing Toilets & Urinals

The distribution piping from the rainwater harvesting system must be permanently identified by a distinctive yellow-colored paint or purple pipe. The piping or insulation must be marked as "non-potable" at intervals not to exceed ten feet.

In addition, each toilet or urinal supplied with greywater must be provided with a permanently affixed wall sign stating, "This fixture is flushed with greywater. Not safe for drinking," or similar wording.

To further discourage potable use, non-residential applications may dye the treated water blue or green with food grade vegetable dye.



Disinfection and Filtration Methods, Costs & Maintenance

	Upfront Cost	Maintenance	Effectiveness	Most Likely Application	Comments
Cartridge Filter	$	Filter must be changed regularly	Removes particles >3 microns	Rainwater or Greywater System	A disinfection treatment is also recommended
UV Light Disinfection	$$	Change UV bulb every 10,000 hours or yearly; protective cover must be cleaned regularly	Disinfects filtered water provided there are <1,000 coliforms per 100 milliliter	Rainwater or Greywater System	Water must be filtered prior to exposure for maximum effectiveness
Chlorine Disinfection	$-$$$	Monthly dose applied manually for tablet feeders; Continuous monitoring for liquid chlorine systems	Effective when water is filtered to at least 25 microns before disinfection	Rainwater or Greywater System	Excessive chlorination may be linked to negative health and environmental impacts
Reverse Osmosis Filter	$$	Change filter when clogged (depends on turbidity)	Removes particles >0.001 microns	Greywater System	A disinfection treatment is also recommended
Ultrafiltration	$$	Filter needs to be cleaned periodically	Removes particles >0.02 microns	Greywater System	A disinfection treatment is also recommended
Ozone Disinfection	$$$	Effectiveness must be monitored with frequent testing or an in-line monitor	Less effective in high turbidity, can be improved with pre-filtering	Greywater System	Requires a pump to circulate ozone molecules

Source: Texas Rainwater Manual

Blackwater Systems

Introduction

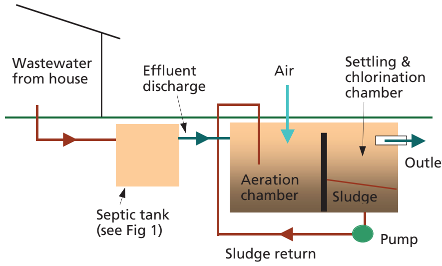
Blackwater systems take wastewater from flush fixtures, typically containing fecal matter and urine, process it, and enable it to be reused for toilet flushing, irrigation, or fertilization of gardens or agriculture. There are several different strategies that accomplish this purpose, which are outlined below.

While blackwater systems may provide a viable solution for processing wastewater, it should be noted that no aerated or wetland-based blackwater treatment systems exist in the State of Illinois. There are several blackwater systems around the country and even more abroad. There are no regulations in the State to permit such systems; therefore, any potential blackwater systems must be permitted specially first at the State level and then by the City of Chicago Committee on Standards and Tests.

Aeration-Based Blackwater System

Aerated systems work by using accelerated aerobic and anaerobic decomposition to remove bacteria and particles from the blackwater. Such systems typically have several key components:

- A septic tank providing an anaerobic bacterial environment to settle out and decompose large solids
- An aeration chamber where air is injected into the chamber, causing the tank contents to churn. Bacteria settle and multiply on the sludge particles, digesting a variety of nutrients and oxygen
- A sludge settling chamber where sludge sinks to the bottom of the tank and partially treated water is forced upwards through a mechanism that has another bacteria biomass covering it. This colony of bacteria then consumes most of the oxygen and breaks down any remaining solid particles.
- A purification chamber typically utilizing UV sterilization, chlorination, or ultrafiltration



One example of an aerated blackwater system (Water Sensitive Urban Design in the Sydney Region) http://www.wsud.org/downloads/Planning%20 Guide%20&%20PN%27s/09-Wastewater.pdf

Wetland-Based Blackwater System

Wetland-based blackwater systems, such as the proprietary Living Machine®, depend upon biomimicry and natural processes to filter blackwater. Typically, the system components include;

- An anaerobic settling tank to initially remove large solids from the blackwater
- A biofilter to initially filter the blackwater and reduce odors that may occur in anaerobic conditions
- A series of aerobic tanks containing a variety of algae, organisms, hydroponic plants, plankton, etc. help to process the water, removing fine particles and unwanted bacteria
- A purification chamber typically utilizing UV sterilization, chlorination, or ultrafiltration

Northern Zoo, City of Emmen, Netherlands
Wetland-based blackwater system (Living Machine®)
http://www.livingmachines.com/

Planning for a Water Reuse System

Planning for Rainwater Harvesting

System Supply and Demand

Step 1: Estimate demand

Treated rainwater can be reused in many ways, such as flushing toilets and urinals, irrigating landscape areas, or running clothes washers. To inform the rainwater harvesting system's design, it is critical to consider the end uses of the treated rainwater. The table* to the right lists fixtures that may reuse treated rainwater and their water demands per day per person. Demand for rainwater can typically be calculated by multiplying the number of building occupants by the average daily demand per person for the item (such as for toilet flushing). Demand for clothes washing and irrigation must also be included in this calculation. This number represents the approximate minimum daily rainwater supply (in gallons) needed to support that function.

Fixture	Flow Rate (per use)	Average # Uses/Day (per person)	Average Daily Demand per Person (gal)
Toilet (HET)	1.28 gpf	5.1 uses/day	6.5 gal.
Urinal (HEU)	0.5 gpf	5.1 uses/day	2.55 gal.

Estimating Demand for Rainwater.
*May vary based on application
Source: http://www.epa.gov/watersense/pubs/indoor.html

Step 2: Evaluate supply

Roof Catchment Calculation

The amount of rainwater that may be collected is often constrained by the amount of roof surface available. The amount of roof surface area, based on the needed water volume for the system, is summarized as:

$$\text{Surface area (sf)} = \text{Demand (gal)}/0.623 * \text{Precip Density (in)} * 0.85$$

- Surface area is the horizontal projection of roof surface in square feet. It is not the actual surface area. Measure the area the roof covers, not the actual roof.
- 0.623 gallons is 1 inch of water covering 1 square foot of surface area
- Precipitation density is the average amount of rainfall in inches for the time period that the system will be used (monthly or yearly averages)
- 0.85 represents the roof's collection efficiency and accounts for rainwater loss through leakage, evaporation, roof composition, etc. Roof coefficients typically range from 0.80 to 0.85.

Storage Sizing Calculation

The maximum amount of rain that can be collected can be calculated as such:

$$\text{Run-off (gal)} = A * (\text{Rainfall (in)} - B) * \text{Roof Area (sf)}$$

- A = Roof collection efficiency, ranging from 0.80 to 0.85
- B = Loss associated with absorption and wet surfaces - value of 0.08 inches per month has been used
- Rainfall is in inches and Roof Area is in square feet

See ARCSA Rainwater Catchment Design and Installation Standards for more information and average annual rainfalls for various regions.

Step 3: Design the system to meet needs

When planning a rainwater harvesting system, demand (fixtures that may use treated rainwater) should be balanced as closely as possible with supply (source water) harvested to avoid wasting space and money on a system that harvests and treats more water than is necessary. Also, different sources should be examined to determine which makes the most sense and will best suit the rainwater needs of the building. The system engineer is best suited to determine which sources are most advantageous to harvest.

Step 4: Continually adjust system as necessary

*The table summarizes the demand for rainwater harvesting systems. It is not exhaustive of the potential sources or applications for rainwater reuse, and are meant to be used as a starting point in planning a rainwater harvesting system.

Planning for Greywater

System Supply and Demand

Step 1: Estimate demand

Treated greywater can be reused in many ways, such as flushing toilets and urinals, irrigating landscape areas, or running clothes washers. To inform the greywater system's design, it is critical to consider the end uses of the treated greywater. The table* to the right lists fixtures that may reuse treated greywater and their water demands per day per person. Greywater demand can typically be calculated by multiplying the number of building occupants by the average daily demand per person for the item (such as for toilet flushing). This number represents the approximate minimum daily greywater supply (in gallons) needed to support that function.

Fixture	Flow Rate (per min or use)	Average # Uses/Day or Gal./Day (per person)	Average Daily Demand per Person (gal)
Toilet (HET)	1.28 gpf	5.1 uses/day	6.5 gal.
Urinal (HEU)	0.5 gpf	5.1 uses/day	2.55 gal.
Clothes washer*	27 gal/use	10 gal/day	10 gal.

Estimating Demand for Greywater.
*May vary based on application
Source: http://www.epa.gov/watersense/pubs/indoor.html

Step 2: Evaluate supply

Several sources of water may be appropriate for use in a greywater system, including used water from showers, lavatories, or washing machines. Sources do not include water from the kitchen sink, dishwasher, or blackwater (wastewater from toilets and urinals). The table* to the right lists sources of greywater and how much greywater one can expect on a daily basis from each source. The source(s) chosen for the greywater system should roughly equate to the amount of water needed as calculated in Step 1.

Fixture	Flow Rate (per min or use)	Average # Min./Day or Gal./Day (per person)	Average Daily Demand per Person (gal)
Shower	2 gpm	5.3 min/day	10.6 gal.
Faucet	0.5 gpm	8.1 min/day	4 gal.
Clothes washer	27 gal/use	10 gal/day	10 gal.

Estimating Supply of Greywater Sources.
Source: http://www.epa.gov/watersense/pubs/indoor.html

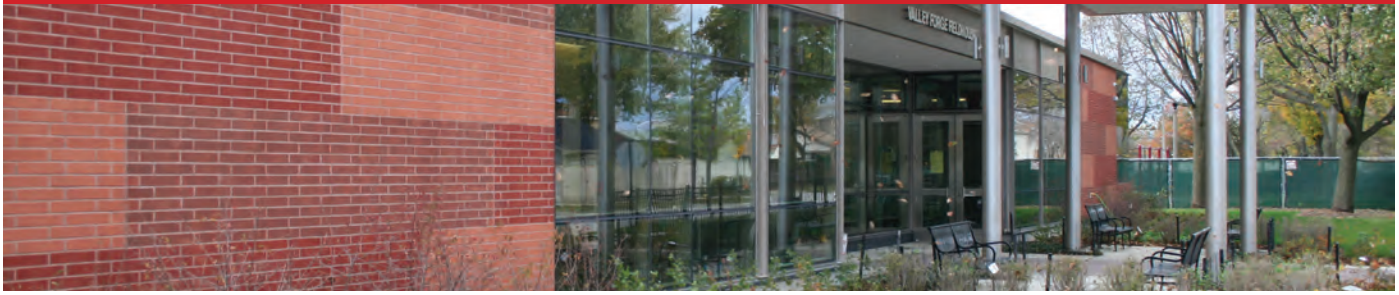
Step 3: Design the system to meet needs

When planning a greywater system, demand (fixtures that may use treated greywater) should be balanced as closely as possible with supply (source water) harvested to avoid wasting space and money on a system that harvests and treats more water than is necessary. Also, different sources should be examined to determine which makes the most sense and will best suit the greywater needs of the building. The system engineer is best suited to determine which sources are most advantageous to harvest.

Step 4: Continually adjust system as necessary

*The two tables on the right summarize supply and demand for greywater systems. These tables are not exhaustive of the potential sources or applications for greywater reuse, and are meant to be used as a starting point in planning a greywater system.

Building Operations and Maintenance



Timely, appropriate maintenance is required to ensure proper operation of rainwater harvesting or greywater systems. requires timely, appropriate maintenance. Proper maintenance is necessary to prevent system failure or inefficiency, leaking, or potential health implications.

Since these types of systems are relatively new, maintenance staff and building owners may need proper instruction to learn how to care for these systems. This section reviews the typical maintenance procedures for rainwater harvesting and greywater systems and provides a starting point for system engineers, maintenance staff, and building owners to learn maintenance procedures.

Operations and Maintenance

Operation & Maintenance Manual

To facilitate proper maintenance of any rainwater harvesting or greywater system, the system designer should provide an operation and maintenance manual to the building owner. The manual should be clearly organized and contain all pertinent information necessary to understand and maintain the system. It should include the following:

(1) Detailed diagram of the system and its components;
(2) Instructions on operating and maintaining the system;
(3) Maintenance worksheets (samples found on following pages);
(4) Cut sheets of all components and contact information for manufacturers;
(5) System testing information and water quality standards to be adhered to; and
(6) Information on disconnecting the system in the event of maintenance, repair, or other purposes.

After the system's installation, the system designer or another qualified individual should provide a training for maintenance staff during which the manual and maintenance tasks are reviewed. It may also be advisable to retain the system designer or engineer for a time after installation of the system to assist in troubleshooting and maintenance questions

Maintenance Worksheets

The worksheets on the following pages provide a general overview of maintenance tasks typically necessary to adequately maintain a rainwater harvesting system or greywater system. The list on each worksheet is not exhaustive of all maintenance tasks or components that could be present for all systems and should be modified as necessary to fit the needs of each particular system.

All system components should follow the maintenance recommendations made by the manufacturers of the components.

Rainwater Harvesting System Maintenance Worksheet

	Clean First Flush	**Change and/or Rinse Filters**	**Change UV Light***	**Replenish Chlorine Tablets***	**Replenish Liquid Chlorine***	**Flush & Clean Storage Tank(s)**	**System Water Quality Testing**
Frequency	Quarterly or after each rain	Quarterly or as needed	Annually	As needed	As needed	Quarterly	Quarterly
Date Done							
Date Done							
Date Done							
Date Done							
Date Done							
Date Done							
Date Done							
Date Done							
Date Done							
Date Done							

*If applicable

Greywater System Maintenance Worksheet

	Clean Initial Filter	**Change and/or Rinse Filters**	**Change UV Light***	**Replenish Chlorine Tablets***	**Replenish Liquid Chlorine***	**Flush & Clean Storage Tank(s)**	**System Water Quality Testing**
Frequency	As needed	Quarterly or as needed	Annually	As needed	As needed	Quarterly	Quarterly
Date Done							
Date Done							
Date Done							
Date Done							
Date Done							
Date Done							
Date Done							
Date Done							
Date Done							
Date Done							

*If applicable

Local Case Studies

In determining a reasonable set of design guidelines for water reuse systems, existing systems in the City of Chicago and the County of Cook were evaluated and these case studies are summarized in this section. The PBC has been leading by example in the City of Chicago by incorporating innovative water reuse systems into its buildings, with several reuse projects for landscape irrigation and flushing fixtures currently in the works or recently completed.

PBC projects featured in this section are Osterman Beach House, 41st Street Beach House and Valley Forge Park Fieldhouse. Although not a current case study, the PBC is currently developing a rainwater harvesting system for the Chicago 12th District Police Station. With a 20,000 gallon underground storage tank, 550 gallon day tank, and the capacity to flush 24 toilets and 7 urinals. The system, once constructed, will be one of the largest water reuse systems in the City.

Other case studies focus on rainwater harvesting and grey water reuse systems implemented by the private sector in the Chicagoland area.

Beach Houses

Fast Facts

Type of project: Two 2,500 sq. ft. beach houses at 41st Street Beach and Osterman Beach
Type of water reuse system: Rainwater harvesting from roof and ground for toilet and urinal flushing
Location: 4101 S Lakeshore Dr, Chicago, IL and
5701 N Lakeshore Dr, Chicago, IL
Occupancy: July 2010
Owner: PBC on behalf of Chicago Park District
Architect of Record: Muller + Muller Architects

Rendering of Osterman Beach Comfort Station

System Overview

Overview of system: Rainwater harvesting system to flush 11 toilets and 4 urinals at each beach house. Buildings will be used only during summer months. Major system components include (see diagram on page 48):

- Vortex filter
- 2000 gal. underground rainwater harvesting tank
- UV sterilization system (UV sterilization both before water enters day tank and within day tank)
- 125 gal. day tank
- Sump pump
- Booster pump with bladder pressure tank
- Air gap

Rendering of 41st Street Beach Comfort Station

Overview of design process: Architect advanced the idea of a rainwater harvesting system during preliminary design of the buildings. The PBC also supported the system's incorporation and assisted in implementation. A consultant was brought into the design process to guide the creation of the system.

Since these buildings are only open during summer months, UV sterilization was chosen instead of chlorination to make for simpler maintenance. The buildings' large storage tanks are located underground to save space, while the day tank is highly visible, located between the restrooms. There is a visible water line on the tanks with educational signage, which explains how the system works, to connect people with the concept.

Educational signage

Learning curve: The Illinois Department of Public Health (IDPH), the City of Chicago Department of Buildings, and the Committee on Standards & Tests (CST) reviewed the system. IDPH required changes including modifying the disinfection and filtration components, the incorporation of backflow prevention, and signage to indicate that the system's water is non-potable (including signage with yellow lettering on all fixtures flushed with Harvested Rainwater). IDPH required the plumbing contractor to repipe the UV sterilizer to ensure that UV sterilization would occur prior to rainwater entering the day tank. In addition, CST required a custom-fabricated air gap fitting to meet the City requirements to keep harvested water out of the municipal supply.

Post-Installation

Maintenance: Staff will need to change UV bulbs about once every three seasons or after 10,000 hours of use; the UV system has an hours-run meter to indicate when the bulb needs to be changed.

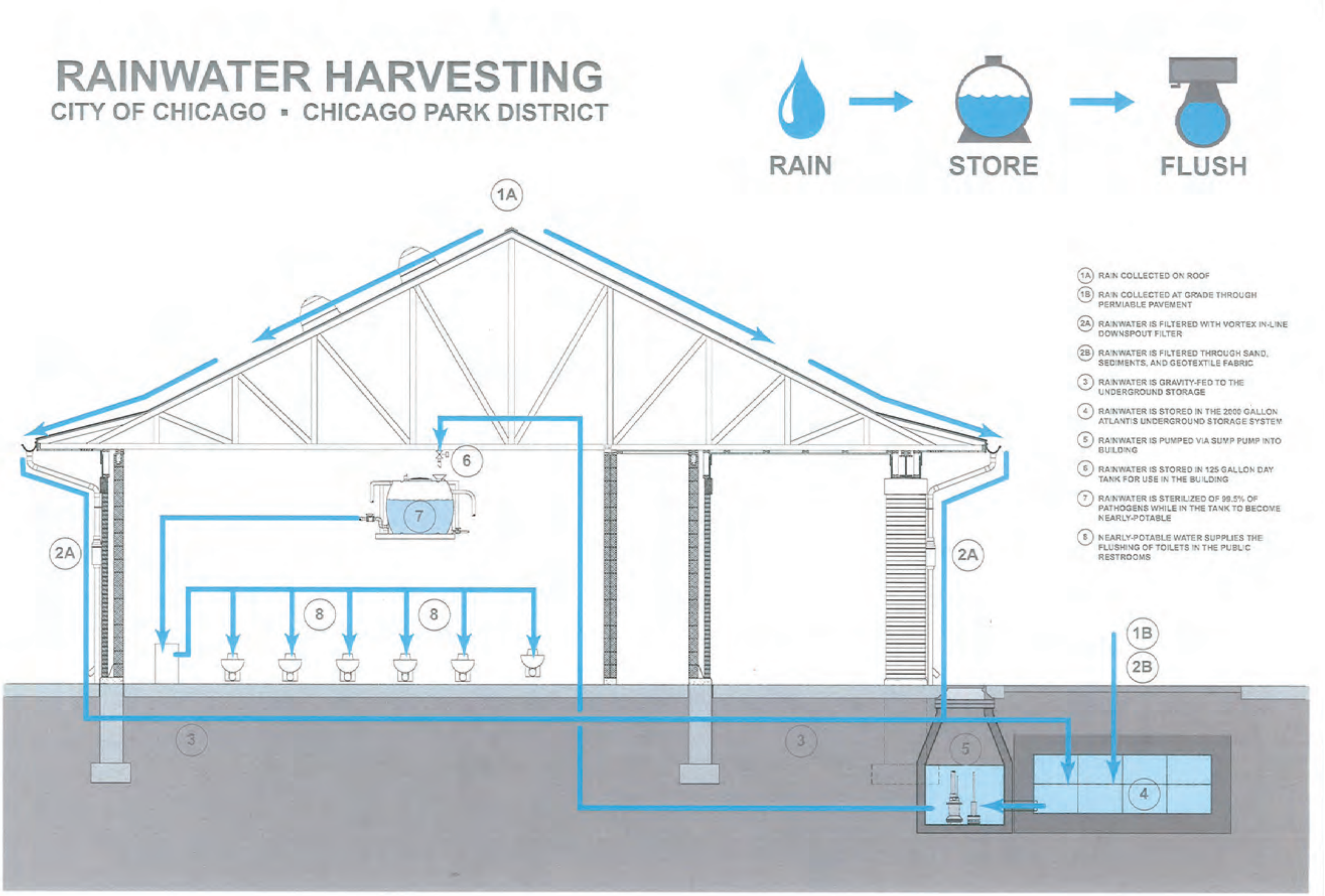
Due to the fact that the building is not heated (it is shut down during the winter months), winterization is necessary at the end of the summer and includes draining the day tank, both UVs , and the pump inside the building.

Monitoring: Remote panel will display: (1) volume of rainwater harvested; (2) volume of municipal water used as backup; (3) volume of water in underground storage; and (4) indicator light for when the UV bulb needs replacing or if there is a problem with the UV system.

Water quality monitoring is not being performed.

Lessons learned: The team learned that they should allow additional time to get the rainwater harvesting system through the non-standard review process involving the State and CST. Until water reuse standards are codified, future projects should budget additional time and expect some level of design changes to the system.

The solenoid valves initially did not work at the beach houses, which shut down the rainwater harvesting systems.



Beach House System Diagram. Image courtesy of Muller + Muller

Valley Forge Park Field House

Fast Facts

Type of project: 10,270 sq. ft. field house includes a large half court gymnasium, fitness and club rooms, locker rooms, pantry, gym storage, reception and an administrative office
Type of water reuse system: Rainwater harvesting from roof and playing fields for toilet and urinal flushing
Location: 7001 W. 59th St, Chicago, IL
Occupancy: December 2010
Owner: PBC on behalf of Chicago Park District
Architect of Record: Booth Hansen

Rendering of Valley Forge Field House
www.pbcchicago.com

System Overview

Overview of system: Rainwater and groundwater harvesting system to flush 13 toilets and 2 urinals. Building will be used year-round. Major system components include:

- Underlayment system for groundwater filtration
- Vortex filter
- 4200 gal. underground rainwater harvesting tank
- Chlorination system (Dry calcium hypochlorite briquettes)
- 125 gal. day tank
- Booster pump
- Final bag filter
- Air gap

Overview of design process: The City provided an impetus to include rainwater harvesting and a geothermal system in the project. The project budget allowed for incorporation of both systems. A local consulting firm specializing in the custom design of rainwater and greywater harvesting systems was brought into the design process to guide the creation of the system.

Learning curve: The system was initially reviewed by IDPH and the Chicago Department of Buildings, who required changes including the incorporation of backflow prevention and signage to indicate that the system's water is non-potable. IDPH initially required that the vortex filter be indirectly connected to the sewer system; however, due to difficulty in installing the filter above ground, installation of a butterfly valve with the solenoid was permitted to prevent sewerage back-up. The Committee on Standards and Tests (CST) was brought in after project team met with IDPH.

The Valley Forge Field House system utilizes semi-transparent storage tanks to limit the light emitted into the tanks, as light can foster bacterial growth. Future systems should incorporate such semi-transparent (or opaque) tanks or be placed in environments that are largely free of natural light.

Chlorinated water, such as that coming out of this rainwater harvesting system, is not recommended for use for irrigation, as inconsistent chlorine levels may kill plants. It is recommended to utilize a carbon filter before using chlorinated water (from this type of system) for irrigation.

Post-Installation

Maintenance: The chlorination purification system was a possibility for the Field House because maintenance staff is available on a year-round basis to monitor the system.

Monitoring: The field house is not performing testing for water quality. If chlorination levels are below acceptable levels, the rainwater harvesting system is automatically turned off and municipal potable water is used instead.

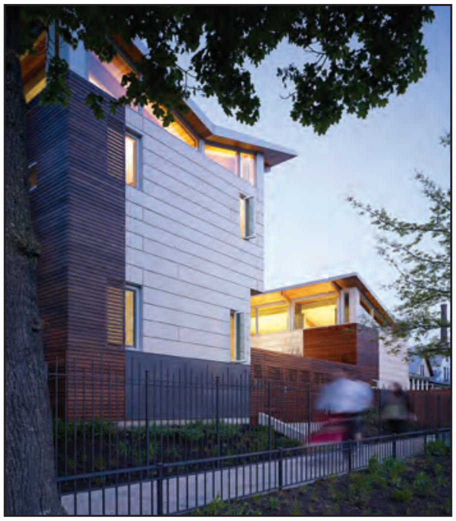
Lessons learned: A second plumbing line was included for each fixture as a way to provide each fixture with municipal potable water, which greatly increased cost. Such costs could be reduced by providing a municipal water bypass to the rainwater harvesting system.

Yannell Residence

Fast Facts

Type of project: Single family residence
Type of water reuse system: Greywater for toilet flushing
Location: 4895 N Ravenswood, Chicago, IL
Occupancy: 2009
Owner: Michael Yannell
Architect of Record: Farr Associates

System Overview



Exterior of Yannell Residence.
Photograph courtesy of Christopher Barrett

Overview of system: Washing machine water used to flush 2 toilets in single family home. Major system components include (see diagram on page 45):

- Vortex filter
- 30 gal. tank with lint filter
- Chlorination system (passive system utilizing dry tablets)
- 2 filters to filter water to 1 micron
- UV sterilization system
- Surge tank
- Air gap

Overview of design process: The owner wanted a demonstration greywater project to show greywater's feasibility in the City. The original design included both rainwater and washing machine water reused for toilet flushing and irrigation. However, concerns from IDPH about the linkage of the rainwater harvesting system with the greywater system led to washing machine water being the sole source for water reuse for toilet flushing. Rainwater harvested for irrigation was integrated as a separate system.

Learning curve: Treating water to Illinois Swimming Pool and Bathing Beach standards. The team met with CST initially, with minimal required change to system as originally proposed; one of the added requirements included agitation of the rainwater harvesting tank because of its connection with the greywater system.

IDPH review effectively required separation of the rainwater harvesting system from the greywater system. In lieu of going back to CST for a change to the system, the agitator was included even though it was likely not needed. This increased the cost associated with the rainwater harvesting system.

The design team examined previously-approved rainwater and greywater systems in the City to inform the Yannell design. However, the Yannell system was created from scratch (was not a predesigned system), which added time and expense.

Washing machine water was used as the sole source of greywater because of its perceived controllability in comparison to other greywater sources (e.g. showers and lavatories).

Post-Installation

Maintenance: Per CST requirements, the owner committed to a maintenance agreement, including assistance with routine maintenance, such as cleaning the lint interceptor, changing filters, refilling chlorine tablets, and replacing UV bulbs.

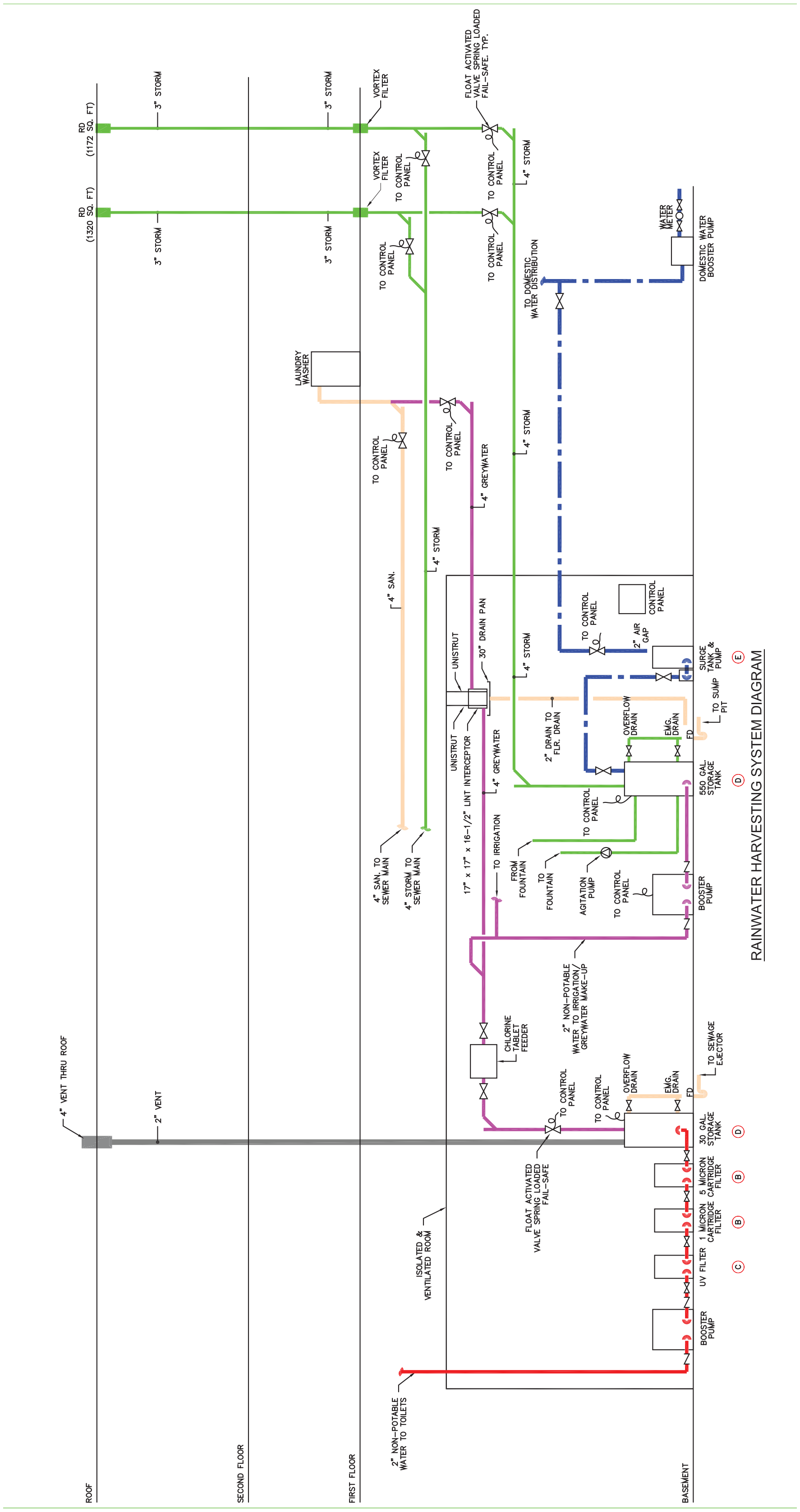
Monitoring: Monitoring system includes lights and audio alarms to alert owner when system components need attention.

Water quality testing is performed quarterly, with results submitted to the CST. Satisfactory results have been achieved thus far. System has covered 100% of toilet flushing water demand.

Lessons learned: Ammonia-based cleaners may not be used in the washing machine at the Yannell Residence, due to the chlorine sanitization used in the greywater system. The reaction of ammonia with chlorine may cause chlorine gas to form, which is deleterious to human health.

Additionally, the chlorination system requires a fan in the tank room running constantly to provide ventilation, which is energy intensive.

System photograph showing in line filtration from upper left - lint filter, chlorine tablet feeder, greywater tank (to right), 2 micron filters, UV lamp (rear) and pump.
Photograph courtesy of Farr Associates



Yannell Residence System Diagram. Image courtesy of dbHMS

Center on Halsted

Fast Facts

Type of project: 3 story, 175,000 sq ft community center
Type of water reuse system: Rainwater and groundwater harvesting for toilet and urinal flushing
Location: 3656 N Halsted, Chicago, IL
Occupancy: 2007
Owner: Center on Halsted
Architect of Record: Gensler Architects

Rendering of Center on Halsted.
www.centeronhalsted.org

System Overview

Overview of system: Harvests up to 1650 gallons of rainwater and groundwater daily to flush 35 toilets and 5 urinals in the community center. Also includes a dual valve to harvest rainwater for irrigation purposes in addition to toilet flushing. Major system components include (see diagram on page 44):

- Duplex basket strainer
- Tri-filters to filter water to 1 micron
- 77 gal. expansion tank
- 3 550 gal. holding tanks
- UV sterilization system
- Chlorination system (liquid)
- Sump pump
- Duplex booster pump system
- Air gap

Overview of design process: City of Chicago demonstration project for rainwater harvesting used for irrigation and toilet/urinal flushing.

Learning curve: The Center treats the harvested water to the Illinois Swimming Pool and Bathing Beach standards. CST required the Center to locate the backflow preventer in a separate room from the rainwater tanks due to concern raised about potential airborne contaminants from the harvested water. Also, as one of earliest projects in Chicago to incorporate a rainwater harvesting system, the

Center was required to include both chlorination and UV sanitizing systems. The system was also required to continuously recirculate water through the purification system to monitor water quality and apply redundant sterilization.

Estimation of how large the system capacity needs to be is based partially on regional rainfall data. Considering average monthly rainfall as opposed to average daily rainfall is more accurate, as monthly rainfall data is fairly consistent and does not vary as much over time.

Post-Installation

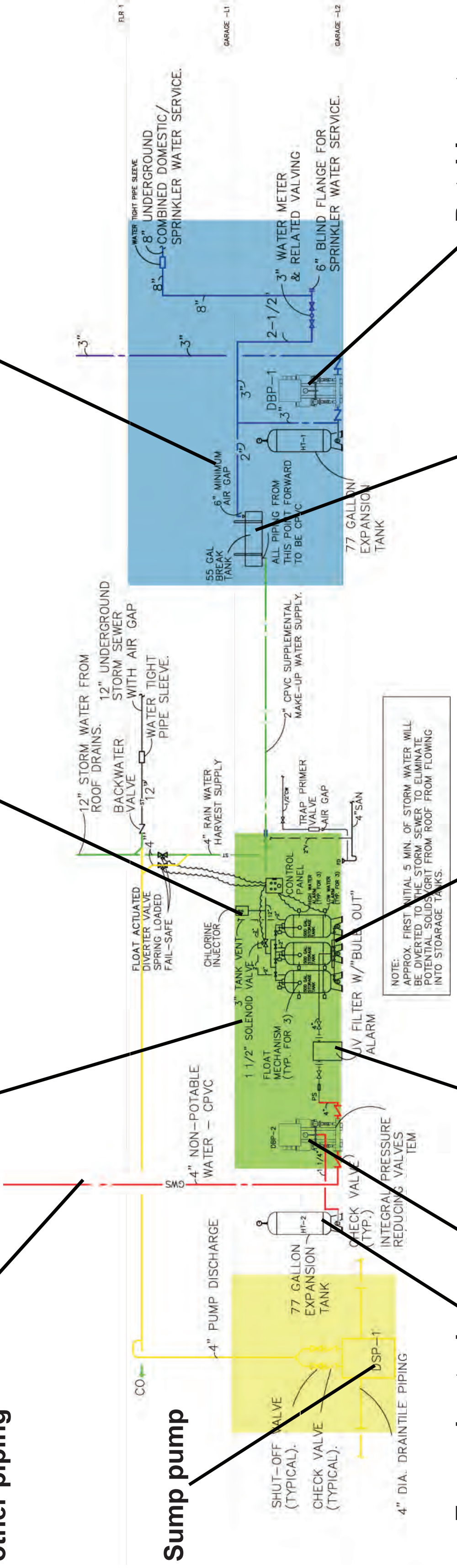
Maintenance: Included 3 separate rainwater holding tanks within the building ensure continuous service during maintenance. Center has arranged for a plumbing maintenance agreement for assistance in changing filters and maintaining the chlorination system.

Monitoring: Sensors and control panel monitor system component temperature, operation, flow, chlorine levels, and rainwater/groundwater quantity. All automatic systems are alarmed. Center is required to submit monthly water quality reports for both the groundwater and tank water to IDPH.

The system provides, on average, 50% of the building demand for toilet flushing water, saving approximately 540,000 gallons of water per year.

Lessons learned: System continuously recirculates water to monitor water quality and apply redundant sterilization. The UV lights have been found to wear out quickly and heat the water over time. Users of the building have provided negative feedback about heated water in the toilets. However, according to a study performed by the University of California-Berkeley, 89% of users are neutral or satisfied with the performance of the rainwater harvesting system.

Most subsequent systems in Chicago required to include *either* UV sanitation or chlorination, which reduces the cost of the system.



Air gap prevents backflow

Added chlorine drip eliminates contamination

Tank room sealed and vented

Piping labeled as non-potable; Schedule 80 CPVC piping material differentiates from other piping

Sump pump

Potable water booster pump

Surge tank

Multiple tanks allow for functionality during maintenance

Filtration system alarmed for fault; shut-off from roof drains / ground water

Expansion tank

Rainwater booster pump

Center on Halsted System Diagram. Image courtesy of Gensler

National and International Examples

To obtain a broad perspective on rainwater harvesting and greywater systems, it was informative to review water reuse systems across the country and abroad. The majority of innovation taking place with water reuse systems appears to be a direct reaction to water scarcity issues; many jurisdictions are primarily concerned with the harvesting of rainwater and greywater for irrigation purposes.

The national and international examples described in this section contain a variety of forward-thinking water conservation and reuse strategies which may help to frame the future of water reuse systems in the City and the County of Cook. These include blackwater systems, package greywater and rainwater harvesting systems, and alternative filtration devices for greywater systems not yet commonly used in the region.

State Legislation

Introduction

Rainwater harvesting legislation has been advancing steadily across the nation for a number of years, starting with the landmark document adopted by the State of Texas in 2001, "The Texas Manual on Rainwater Harvesting."

While not as common as legislation related to rainwater harvesting systems, several states across the U.S. are in the process of enacting or have already enacted legislation that enables greywater reuse, including Washington, Massachusetts, New York, South Dakota, Montana, Texas, Nevada, Arizona, California, Utah, New Mexico, Georgia, Idaho, Wisconsin, and Florida. Generally speaking, greywater reuse is more broadly permitted for subsurface irrigation than it is for flushing toilets. When greywater is reused for irrigation, purification of the greywater is typically not required, particularly for smaller scale systems. However, greywater reuse for flushing toilets typically must include a purification process such as chlorine or UV treatment.

Much of the efforts to legalize greywater use have been spearheaded in arid areas of the country that are prone to drought; the same is true on the international level where drought and water quality are serious issues. Therefore, a majority of initiatives worldwide related to greywater reuse focus to a greater extent on irrigation issues (for agricultural uses for example).

The following outlines key greywater legislation at the state level, illustrates how other areas are approaching the regulation of greywater systems. See the Bibliography section for further information and links.

Arizona

Arizona's Gray Water Law, enacted in 2001, is widely considered to be the trailblazer in the U.S. with regard to greywater legislation. Many other states have modeled their greywater regulations after the Arizona law. It establishes a 3-tier regulatory approach according to the size of the greywater system:

1. Type 1 systems (single-family only) under 400 gallons per day are permitted by right as long as they follow certain design criteria;
2. Type 2 systems (commercial, multi-family, and institutional) utilizing between 400 and 3000 gallons per day are allowed by general permit; and
3. Type 3 systems over 3000 gallons per day are considered on a case-by-case basis.

Greywater may be reused for toilet flushing (non-single family homes only) and/or irrigation if it is treated to a minimum quality standard before reuse. Design specifications for the systems are not provided. Arizona offers tax credits for gray-water construction projects and plumbing systems. In 2010, the City of Tuscan began requiring all residential new construction to incorporate dual plumbing that will enable the reuse of greywater in the future.

http://www.azdeq.gov/environ/water/permits/download/graybro.pdf

California

California has also been recognized nationally for its sweeping greywater legislation, first passed in 1997 and revised recently in 2008. The 1997 appendix to the State Plumbing Code permitted the use of greywater for subsurface irrigation, while the recent revision made it legal to use gray water from bathroom sinks, showers, and laundry for irrigation without extensive underground systems and, in some cases, without a construction permit. Utilizing greywater for toilet flushing is permitted in California provided that an on-site water treatment system is approved by the Enforcing Agency. The presence of such regulations enables greywater systems to proliferate in California.

PROJECT EXAMPLE:
Port of Portland Headquarters, Portland, Oregon

Fast Facts

Type of project: 205,000 sq ft Port of Portland Headquarters
Type of water reuse system: Living Machine® filtering greywater and blackwater for toilet flushing and makeup water for cooling towers
Location: 7200 NE Airport Way, Portland, OR
Occupancy: 2010
Owner: Port of Portland
Architect of Record: ZGF Architects

Port of Portland Living Machine®
DJC Photos photostream on Flickr http://www.flickr.com/photos/djc_photos/4485278532/

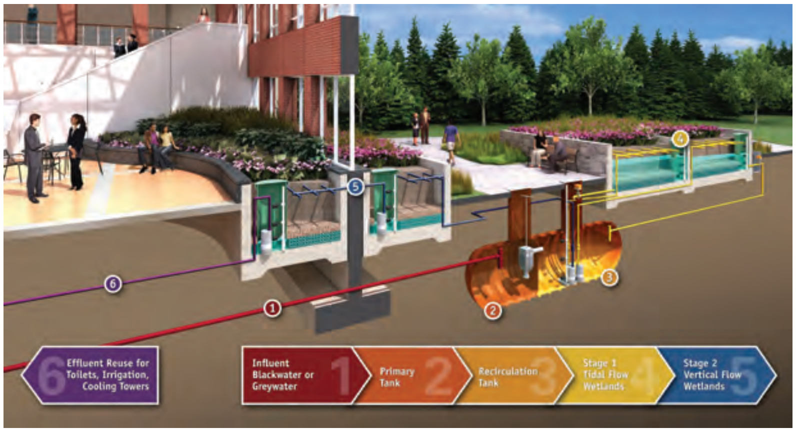
System Overview

The heart of the Living Machine®, a proprietary system by Worrell Water Technologies, is a series of wetland beds which contain gravel aggregate, specially engineered films of beneficial microorganisms, and plants working together in an ecosystem to clean wastewater and greywater. The Port of Portland wanted to showcase the cutting edge of wastewater technology with the incorporation of the Living Machine® as a showcase feature.

The system will treat up to 5,000 gallons of wastewater and greywater per day and, at the end of the treatment process, the water will meet typical permit requirements for water quality standards.

Major system components include (see diagram at right):

- Primary and equalization tanks
- Control system
- Tidal flow wetlands
- Polishing vertical flow wetland
- UV sterilization
- Clean effluent tank

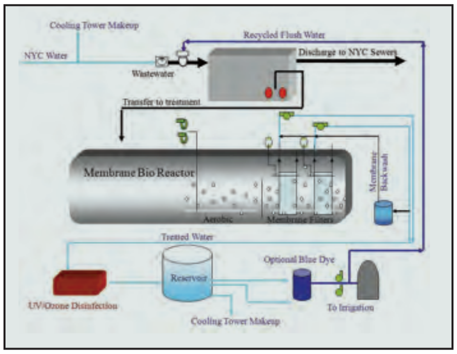


Living Machine® Sample Diagram. www.livingmachines.com/about/howitworks

PROJECT EXAMPLE:
The Solaire, New York, New York

Fast Facts

Type of project: 357,000 sq ft, 293-unit residential tower
Type of water reuse system: Blackwater processing system. Membrane bioreactor and aeration system to filter blackwater to flush toilets and provide water to cooling towers
Location: 20 River Terrace, New York, NY
Occupancy: August 2003
Owner: Albanese Organization, Inc. & Northwestern Mutual Life
Architect of Record: Schuman, Lichtenstein, Claman, Efron Architects



The Solaire's blackwater system
http://www.hpbmagazine.com/images/stories/articles/NYCs%20Living%20Lesson.pdf

System Overview

The Solaire is the first high-rise residential tower in the United States to incorporate a blackwater system. The system processes around 30,000 gallons of blackwater from toilets per day and reuses that water to flush 293 toilets, reducing the building's potable water usage by 43 percent. Process sludge is directed back to the municipal sewer system for treatment. The building also incorporates a rainwater harvesting system that captures and purifies water for drip irrigation.

- Major system components include (see diagram at right):
- Digestion system
- Membrane bioreactor with aeration system and membrane filters
- UV disinfection

The Solaire http://www.thesolaire.com/documents/livegreen.html

PROJECT EXAMPLE:
Toronto Healthy House, Toronto, Ontario (Canada)

Fast Facts

Type of project: 1700 sf demonstration home
Type of water reuse system: Rainwater, greywater and blackwater recycling; Home does not use municipal water service
Location: Toronto, Ontario, CA
Occupancy: 1996
Cost: 12% above cost of conventional construction
Owner: Creative Communities Research
Architect of Record: Martin Liefhebber Architect Incorporated

System Overview

The Toronto Healthy House provides clean water for all household and landscaping needs without the use of municipal water. The house has both a rainwater harvesting and greywater/blackwater system that work together to supply all water needs for a family of four. The rainwater harvesting system provides water for potable use in kitchen and bathroom sinks and the dishwasher.

The greywater output from those sources, along with all other wastewater and greywater, is processed through the wastewater reclamation system. The water treated through the wastewater system is then reused for toilet flushing, laundry, bathing and showering, and irrigation. To meet the water demands of the residents, this process is typically repeated several times, with wastewater repeatedly collected and reused before it is expelled from the building. Microorganisms, oxygen, ultraviolet light, and charcoal are used to treat waste water flowing into the soil so that it is not harmful to the environment.

Toronto Healthy House Exterior
University of Waterloo http://www.architecture.uwaterloo.ca/faculty_projects/terri/cmhc.html

Rainwater Harvesting

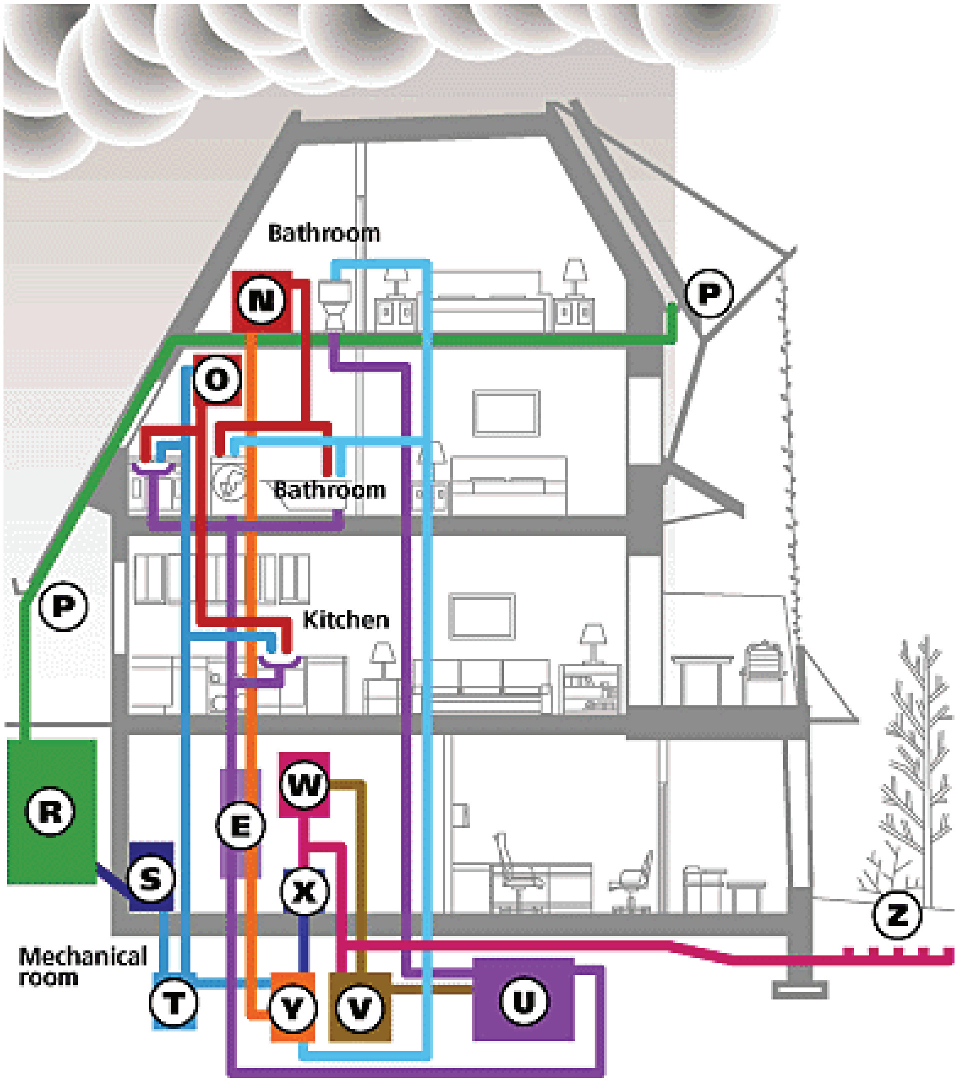
Major system components include (see diagram at right):

- 5300 gal. cistern
- Eavestroughs with filter screens
- Combination roughing, slow sand, & carbon filter
- UV sterilization

Wastewater Treatment

Major system components include (see diagram below):

- Preliminary & primary treatment: septic tank
- Secondary treatment: Waterloo™ biofilter
- Tertiary treatment: 2-stage combination roughing, slow sand, & carbon filter
- Disinfection: Ozone



KEY

Drinkable Water System
O — Drinkable-Hot-Water Tank
P — Eavestroughs
R — Rainwater Cistern
S — Combination Filter
T — Drinkable-Cold-Water Tank

Waste Water Management
E — Grey Water Heat Exchanger
N — Reclaimed-Hot-Water Tank
U — Septic Tank
V — Recirculation Tank
W — Waterloo Biofilter™
X — Twin Combination Filters
Y — Reclaimed-Cold-Water Tank
Z — Garden Irrigation

Toronto Healthy House Systems Diagram
http://www.cmhc-schl.gc.ca/en/co/maho/yohoyohe/heho/hehoto/wawawama/

PROJECT EXAMPLE:
Harold Washington Social Security Building, Chicago, Illinois

Fast Facts

Type of project: Selective renovation of 10-story 1970's era office building.
Type of water reuse system: Multi-source, multi-use non-potable water
Location: 600 W. Madison Street, Chicago, IL
Occupancy: 1976
Owner: GSA
System Design Wahaso Water Harvesting Solutions, Inc.

System Overview

The Harold Washington Building has been exploring "green" strategies since the early 1990's. The building had already instituted water savings measures that saved 2 million gallons per year. A federal facility, it is not bound by City of Chicago or State of Illinois regulations for water reuse. This project started with an interest in using rooftop rainwater for irrigation, but was expanded to a multi-source, multi use system after an audit revealed opportunities, including large capacity tanks which were slated for demolition.

- The system captures water from multiple sources on-site:
  - -Rainwater from approximately 70% of the building's 58,000 square foot roof contributes nearly 800,000 gallons per year.
  - -Cooling Condensate from the building's four large air handling units deliver 12 gallons per minute during the cooling season, or over 2 million gallons per year
  - -Groundwater from the building's foundation sumps contribute 600,000 - 700,000 gallons of water per year.
- Water is pre-filtered and then stored in four 8,000 gallon steel tanks that had once been used to store chilled glycol, but were decommissioned decades ago.
- The stored water is treated with a calcium hypochlorite (chlorine) solution that is circulated through the tanks. Residual chlorine levels are monitored to ensure the water's safety.

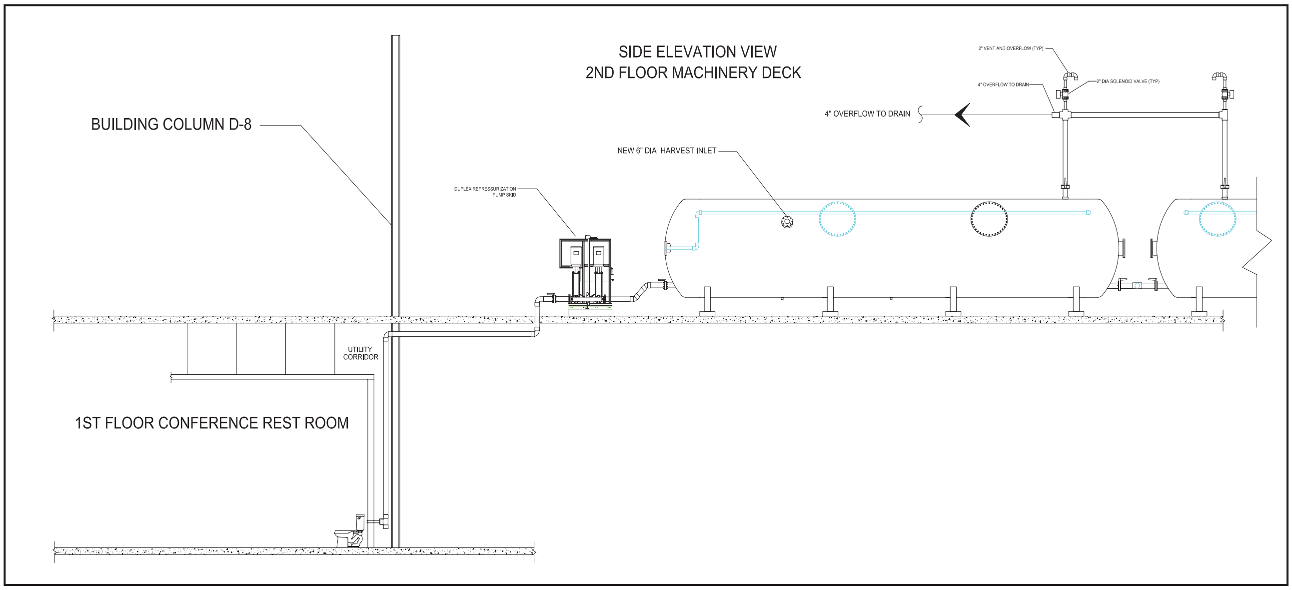
Pump Station

- The on-site treated, non-potable water is supplied to a number of uses in the building:
  - -Nearly 3 million gallons are supplied to the building's chiller units in the summer.
  - -150,000 gallons are supplied as make-up to the boilers in the winter
  - -Toilets in a new addition are flushed with the non-potable water - about 82,000 gallons per year.
  - -All of the building's modest irrigation requirements are met - 55,000 gallons per year.
- The entire process is controlled by a PLC panel that monitors the system and tracks the amount of water saved each month and reports performance information to the building automation system.

Control System and Monitor

Water Harvesting System

- 4-8,000 gallon re-commissioned steel tanks
- Dry calcium hypochlorite system for sanitation
- Duplex repressurization system
- Custom-programmed Wahaso control system with color touch screen is linked to the building automation system and tracks all system functions and logs and reports system statistics.



Plumbing Schematic

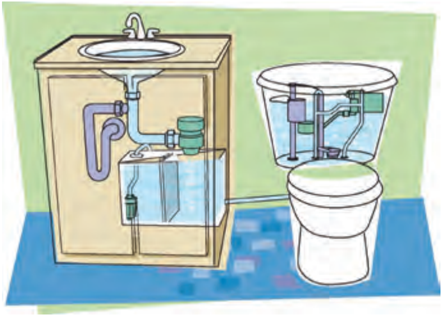
Systems and Technologies: Package Systems

Introduction

While the engineered systems outlined in the case studies and System Design sections of this document accomplish largely the same goals, package rainwater harvesting and greywater systems combine the essential elements of such systems into one streamlined, compact unit. These package systems eliminate the need to design from scratch, saving time and money. While they have been more widely used on the international level, package systems are starting take hold in the U.S. as well, as rainwater harvesting and greywater reuse gain popularity. The following package systems are a sampling of what is currently available. Depending on specifics of the systems, they may not be permitted currently in the City of Chicago and the State of Illinois. However, their use should be periodically reevaluated as a more cost- and time-effective option.

AQUS® System

Type of water reuse system: Greywater from sinks to flush toilets
Cost: Approximately $295 plus installation
Case studies: California, New York, Kentucky, Colorado, New Mexico
Manufacturer: WaterSaver Technologies



AQUS System®
WaterSaver Technologies http://www.watersavertech.com/

This type of water reuse system captures water from lavatories to flush toilets, saving municipal potable water from use. It is estimated that a 2-person household could save up to 12 gallons of potable water per day by using a system such as the AQUS® system. It is very widely used in Japan. It is likely that the amount of water savings for commercial and institutional uses would be less, due to fewer restroom activities (shaving, brushing teeth, etc) taking place in such a setting. However, the AQUS® system should still be considered as a cost-effective water reduction strategy. Maintenance is minimal and involves refilling chlorine tablets and cleaning the filter/screen once per year. Installation takes only a couple of hours. Such systems have not been permitted in the State of Illinois.

Major system components include (see diagram at right):

- 5.5 gal holding tank
- 12 volt submersible pump
- Screen filter
- Chlorine tablet sterilization
- Fill control unit
- Air gap

Brac Systems

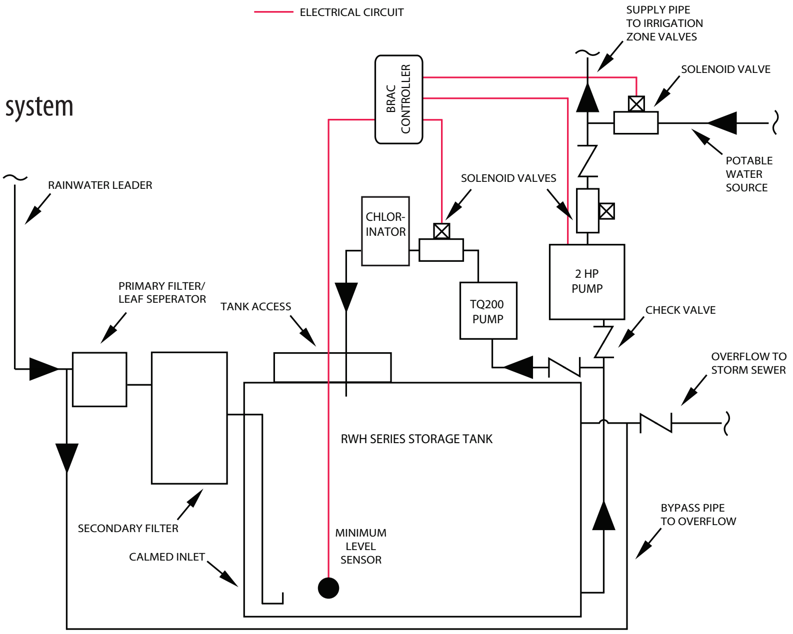
Type of water reuse system: Greywater from showers, sinks, & laundry to flush toilets; Rainwater harvesting to flush toilets & irrigate
Cost: Greywater systems start at $34,650 for commercial applications; Rainwater harvesting systems are $14,000-15,000 for commercial applications. Prices do not include installation.
Approved for use: Mississippi, Arkansas, Texas, Indiana, Arizona, Washington, Colorado, Florida, Wisconsin, Canada, Dubai
Manufacturer: Brac Systems

Example of a Brac System®
Photo courtesy of Brac Systems®

Brac Systems manufactures a variety of greywater and rainwater harvesting package systems for use in a multitude of applications. These systems are more cost-effective and expedited than designing a system from scratch. Depending on project specifics, they may be permitted in the City of Chicago and the State of Illinois.

Major system components vary by system, but typically include (see diagram below):

- Primary/secondary filters
- Holding tank
- Pressure pump
- Managed chlorination system
- Cartridge filtration system
- Pressure filter alarms
- Integrated building management system



Brac Rainwater Harvesting System Schematic Drawing
Brac Systems http://www.bracsystems.com/

Systems and Technologies: Filtration Systems

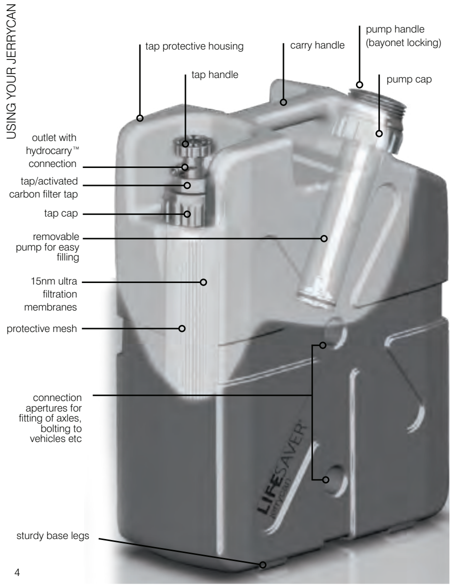
Ultrafiltration: Lifesaver® Systems

Type of water reuse system: Greywater and blackwater for any application, including drinking
Cost: Approximately $300-400 for a Lifesaver Jerrycan®
Case studies: Available nationally and internationally
Manufacturer: Lifesaver Systems®

Ultra filtration has been used in many greywater projects around the world, and, as one example, is being used by the Lifesaver product line to filter contaminated water for drinking in third world countries.

The Lifesaver Jerrycan® can filter up to 5300 gallons of heavily polluted water, creating clean sterile drinking water without the use of chemicals. This is achieved through use of an activated carbon filter and ultra filtration. The activated carbon filter is designed to reduce chemical residues, such as pesticides, endocrine disrupting compounds, medical residues, and heavy metals. The Jerrycan meets the EPA National Primary Drinking Water Regulations under the Safe Drinking Water Act.

While it is not likely that Lifesaver products will be used broadly in Chicago to produce drinking water in the near future, the option of ultra filtration should remain on the radar of those wishing to create greywater and blackwater systems. The effectiveness of the system at eliminating pollutants could pave the way in the future for creating more streamlined, efficient greywater systems.



Livesaver Jerrycan®
Lifesaver® Systems http://www.lifesaversystems.com/

Reverse Osmosis Water Purification Unit (ROWPU)

Type of water reuse system: Greywater and blackwater for any application, including drinking
Case studies: US and Canadian militaries
Manufacturer: US and Canadian governments

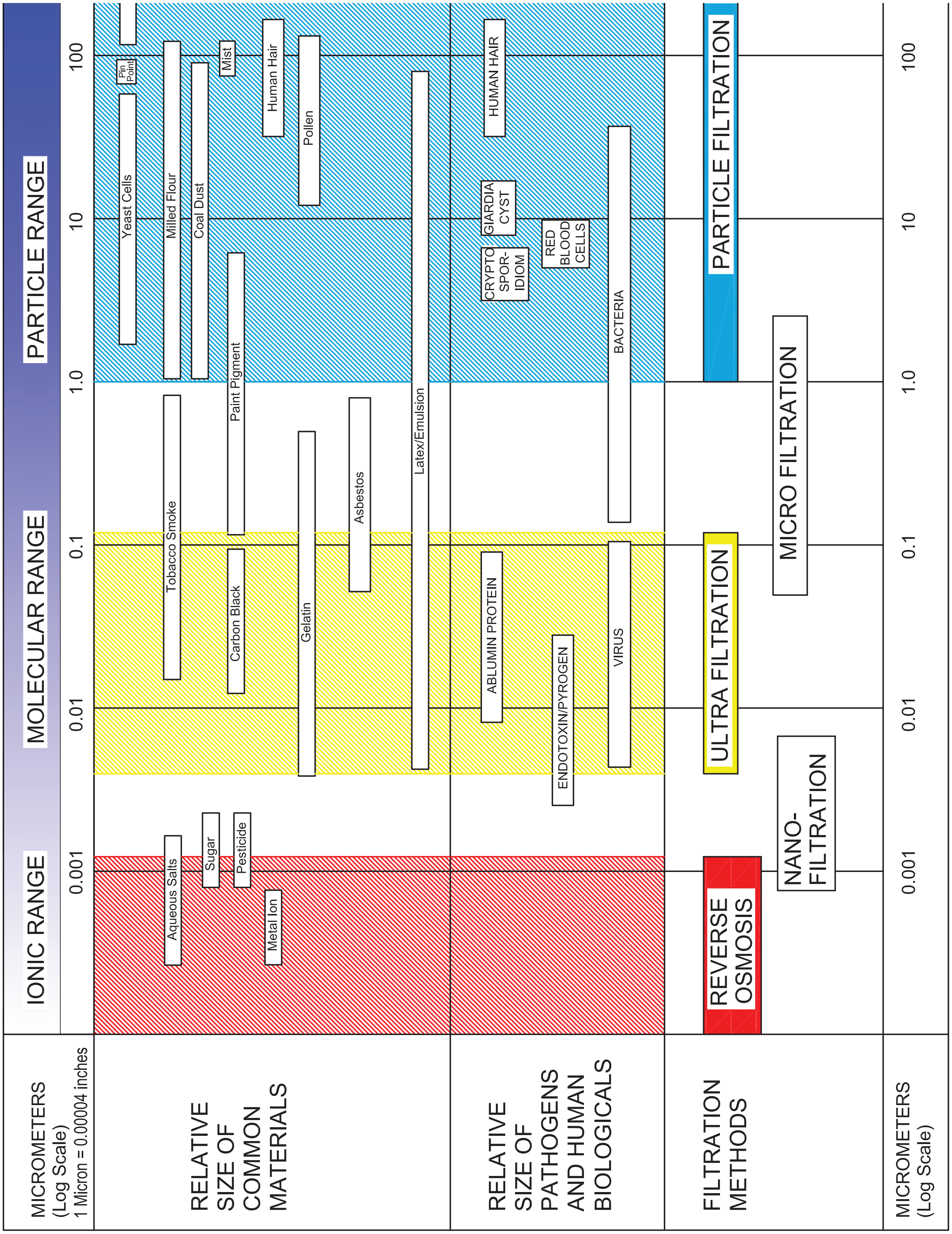
Reverse osmosis is used to filter water in many different applications, and is used by the US Military in a package system called a "ROWPU" that provides potable water where supplies may be short.

The ROWPU is a portable, self-contained water purification plant that can create potable water from nearly any source. It works by utilizing

Canadian ROWPU System
Global Hydration http://www.armedforces-int.com/suppliers/global-hydration.html

reverse osmosis as well as several micro filters and chlorine or UV purification. The water is initially treated with a polymer to begin coagulation, and is then run through multimedia and cartridge filters, which remove particles to 5 microns. The water is subsequently run through the reverse osmosis system and disinfected, at which point it is ready for potable use. Several sizes of machines are used in the military and may take the form of containers, trucks, or independent vehicles.

Although such a system is likely cost prohibitive for many applications at this point in time, such technology should be considered in the future as a potential way to purify contaminated water efficiently.



Filter Methodology
Image courtesy of Water Harvesting Solutions Inc.

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Appendix

Definitions

Blackwater: Liquid and solid human body waste and the carriage waters generated through toilet usage (Ref: EPA); Blackwater is a relatively recent term used to describe wastewater containing fecal matter and urine. It is also known as brown water, foul water, or sewage.

Greywater: Untreated waste water that has not come into contact with toilet waste, kitchen sink waste, dishwasher waste, or similarly contaminated sources. Greywater includes waste water from bathtubs, showers, lavatories, clothes washers, and laundry tubs, as well as from condensate from air conditioners and pools. Also known as graywater, gray water, or grey water (Ref: IAPMO Green Plumbing & Mechanical Code Supplement proposed); Waste water, such as dishwater, or other waste water not containing fecal matter or urine (Ref: IL Plumbing Code).

Groundwater: Water that saturates into the ground and no longer flows across the surface. Also known as ground water (Ref: ARCSA Rainwater Catchment Design and Installation Standards); Water that exists beneath the earth's surface in underground streams and aquifers.

Non-Potable Water: Water that does not meet drinking water quality standards specified in 35 Ill. Adm. Code 611, Primary Drinking Water Standards, and is not suitable for human consumption or culinary use, or is of unknown quality (Ref: IL Plumbing Code).

Potable Water: Water that is safe for human consumption and meets the water quality standards of 35 Ill. Adm. Code 611, Primary Drinking Water Standards (Ref: IL Plumbing Code).

Rainwater: Natural precipitation that has not been contaminated by use (Ref: IAPMO Green Plumbing & Mechanical Code Supplement); Water that has precipitated from the atmosphere (e.g. rain, snow, mist, dew) (Ref: ARCSA Rainwater Catchment Design and Installation Standards).

Rainwater Harvesting System: A system that utilizes the principal of collecting, storing, and using rainwater from a rooftop or other manmade, aboveground collection surface (Ref: IAPMO Green Plumbing & Mechanical Code Supplement proposed).

Reverse Osmosis: A membrane separation process designed to treat wastewater containing a variety of contaminants including organic compounds (Ref: EPA); A liquid filtration method which removes many types of large atomic molecules from smaller molecules by forcing the liquid at high pressure through a membrane with pores just big enough to allow the small molecules (typically smaller than 0.001 micron) to pass through.

Stormwater: Stormwater runoff, snow melt runoff, and surface runoff and drainage (Ref: EPA NPDES); does not include water collected from a roof or the ground for a rainwater harvesting system.

Treated Non-Potable Water: Non-potable water, including rainwater, stormwater, and greywater that has been collected, treated, and intended to be used on-site and is suitable for direct beneficial use. The level of treatment and quality of the treated non-potable water shall be approved by the Illinois Department of Public Health (Ref: IAPMO Green Plumbing & Mechanical Code Supplement proposed).

Ultrafiltration: Filtration through a semipermeable membrane which only allows small molecules through that are typically smaller than 0.1 micron.

Toilet: A fixture with a water-containing receptor that receives liquid and solid body waste and on actuation conveys the waste through an exposed integral trap into a drainage system. Also referred to as a toilet (Ref: IAPMO Green Plumbing & Mechanical Code Supplement proposed).

Wastewater: Sewage containing excrement and liquid wastes or ordinary wastes derived from a plumbing system [Sanitary Waste] (Ref: IL Plumbing Code).

Acronyms

ARCSA: American Rainwater Catchment Systems Association

ASME: American Society of Mechanical Engineers

CBC: Chicago Building Code

CSO: Combined sewer overflow

CST: Committee on Building Standards and Tests

EPA: Environmental Protection Agency

HET: High-efficiency toilet

HEU: High-efficiency urinal

IAPMO: International Association of Plumbing and Mechanical Officials

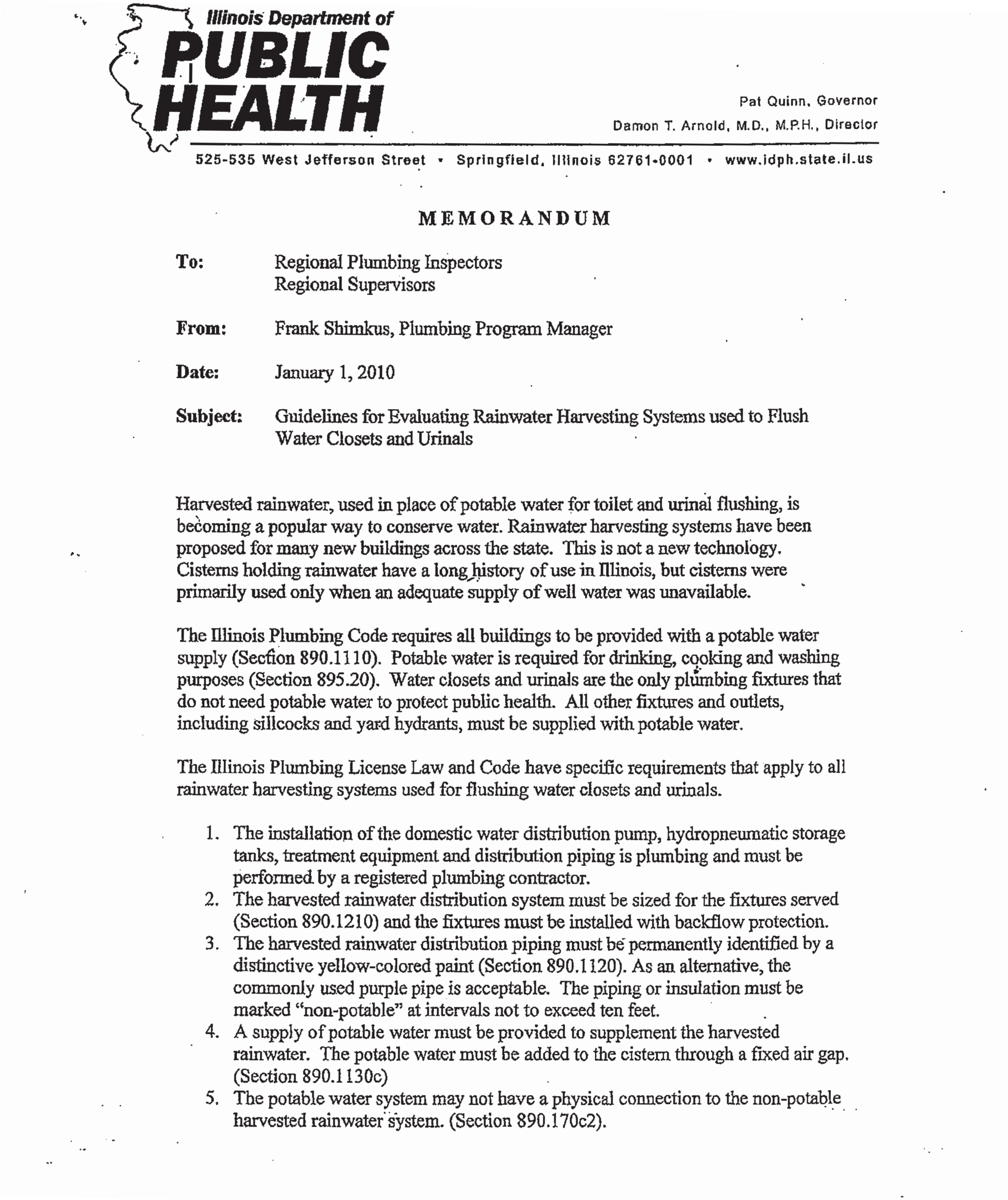
IDPH: Illinois Department of Public Health

LEED: Leadership in Energy and Environmental Design

PBC: Public Building Commission of Chicago

ROWPU: Reverse Osmosis Water Purification Unit

UV: Ultraviolet



Illinois Department of
PUBLIC HEALTH

Pat Quinn, Governor
Damon T. Arnold, M.D., M.P.H., Director

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MEMORANDUM

To: Regional Plumbing Inspectors
Regional Supervisors

From: Frank Shimkus, Plumbing Program Manager

Date: January 1, 2010

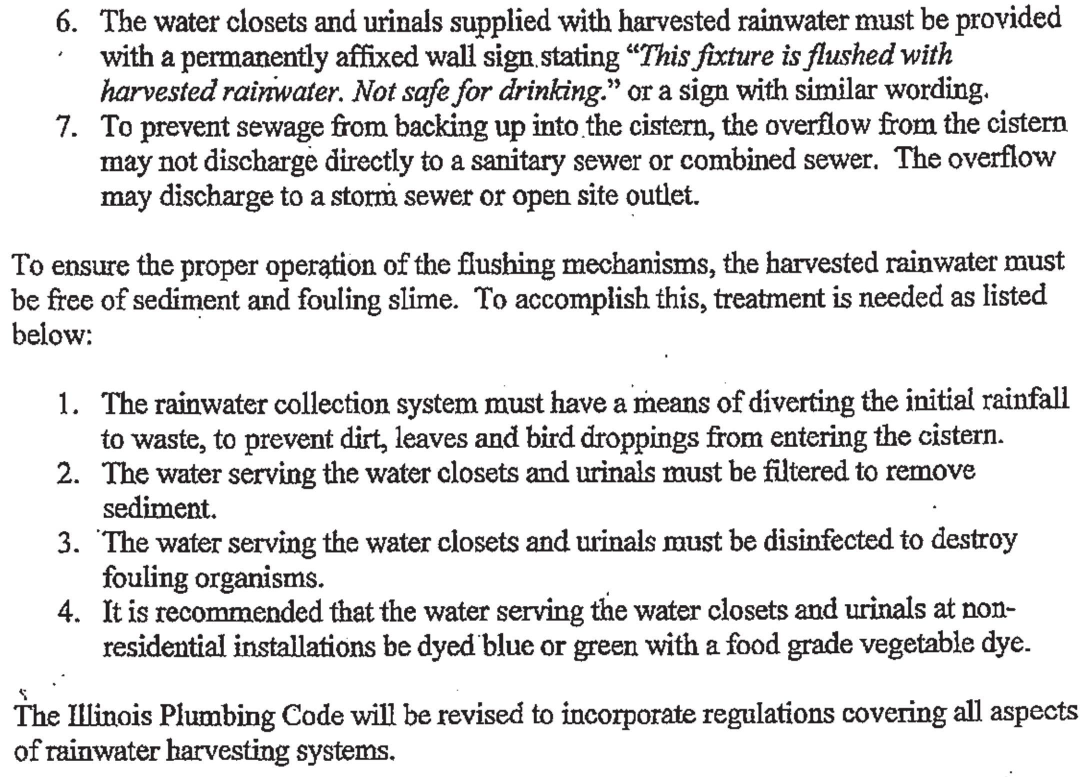
Subject: Guidelines for Evaluating Rainwater Harvesting Systems used to Flush Water Closets and Urinals

Harvested rainwater, used in place of potable water for toilet and urinal flushing, is becoming a popular way to conserve water. Rainwater harvesting systems have been proposed for many new buildings across the state. This is not a new technology. Cisterns holding rainwater have a long history of use in Illinois, but cisterns were primarily used only when an adequate supply of well water was unavailable.

The Illinois Plumbing Code requires all buildings to be provided with a potable water supply (Section 890.1110). Potable water is required for drinking, cooking and washing purposes (Section 895.20). Water closets and urinals are the only plumbing fixtures that do not need potable water to protect public health. All other fixtures and outlets, including sillcocks and yard hydrants, must be supplied with potable water.

The Illinois Plumbing License Law and Code have specific requirements that apply to all rainwater harvesting systems used for flushing water closets and urinals.

1. The installation of the domestic water distribution pump, hydropneumatic storage tanks, treatment equipment and distribution piping is plumbing and must be performed by a registered plumbing contractor.
2. The harvested rainwater distribution system must be sized for the fixtures served (Section 890.1210) and the fixtures must be installed with backflow protection.
3. The harvested rainwater distribution piping must be permanently identified by a distinctive yellow-colored paint (Section 890.1120). As an alternative, the commonly used purple pipe is acceptable. The piping or insulation must be marked "non-potable" at intervals not to exceed ten feet.
4. A supply of potable water must be provided to supplement the harvested rainwater. The potable water must be added to the cistern through a fixed air gap. (Section 890.1130c)
5. The potable water system may not have a physical connection to the non-potable harvested rainwater system. (Section 890.170c2).

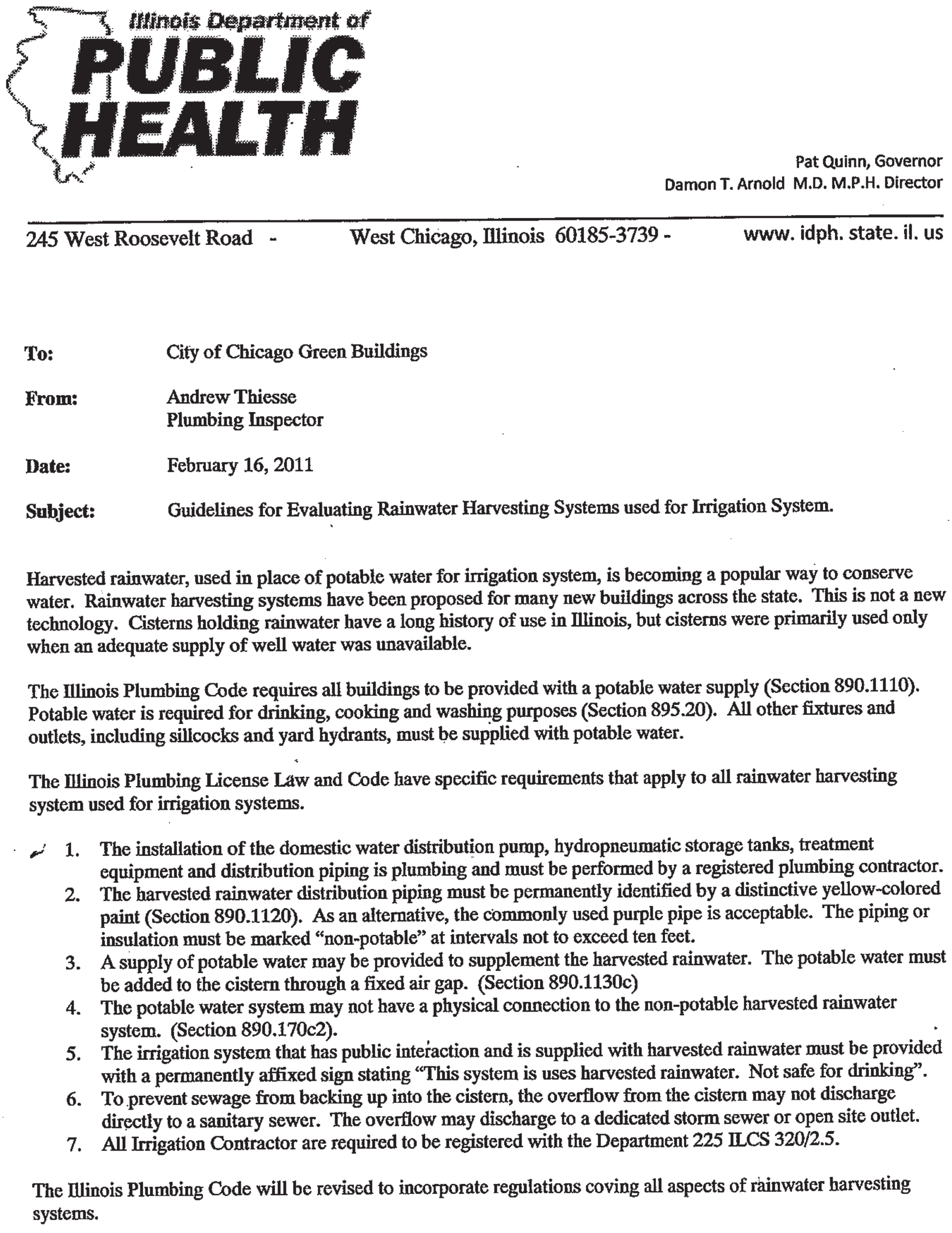


6. The water closets and urinals supplied with harvested rainwater must be provided with a permanently affixed wall sign stating "*This fixture is flushed with harvested rainwater. Not safe for drinking.*" or a sign with similar wording.
7. To prevent sewage from backing up into the cistern, the overflow from the cistern may not discharge directly to a sanitary sewer or combined sewer. The overflow may discharge to a storm sewer or open site outlet.

To ensure the proper operation of the flushing mechanisms, the harvested rainwater must be free of sediment and fouling slime. To accomplish this, treatment is needed as listed below:

1. The rainwater collection system must have a means of diverting the initial rainfall to waste, to prevent dirt, leaves and bird droppings from entering the cistern.
2. The water serving the water closets and urinals must be filtered to remove sediment.
3. The water serving the water closets and urinals must be disinfected to destroy fouling organisms.
4. It is recommended that the water serving the water closets and urinals at non-residential installations be dyed blue or green with a food grade vegetable dye.

The Illinois Plumbing Code will be revised to incorporate regulations covering all aspects of rainwater harvesting systems.



Illinois Department of
PUBLIC
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Pat Quinn, Governor
Damon T. Arnold M.D. M.P.H. Director

245 West Roosevelt Road - West Chicago, Illinois 60185-3739 - www. idph. state. il. us

To: City of Chicago Green Buildings

From: Andrew Thiesse
Plumbing Inspector

Date: February 16, 2011

Subject: Guidelines for Evaluating Rainwater Harvesting Systems used for Irrigation System.

Harvested rainwater, used in place of potable water for irrigation system, is becoming a popular way to conserve water. Rainwater harvesting systems have been proposed for many new buildings across the state. This is not a new technology. Cisterns holding rainwater have a long history of use in Illinois, but cisterns were primarily used only when an adequate supply of well water was unavailable.

The Illinois Plumbing Code requires all buildings to be provided with a potable water supply (Section 890.1110). Potable water is required for drinking, cooking and washing purposes (Section 895.20). All other fixtures and outlets, including sillcocks and yard hydrants, must be supplied with potable water.

The Illinois Plumbing License Law and Code have specific requirements that apply to all rainwater harvesting system used for irrigation systems.

1. The installation of the domestic water distribution pump, hydropneumatic storage tanks, treatment equipment and distribution piping is plumbing and must be performed by a registered plumbing contractor.
2. The harvested rainwater distribution piping must be permanently identified by a distinctive yellow-colored paint (Section 890.1120). As an alternative, the commonly used purple pipe is acceptable. The piping or insulation must be marked "non-potable" at intervals not to exceed ten feet.
3. A supply of potable water may be provided to supplement the harvested rainwater. The potable water must be added to the cistern through a fixed air gap. (Section 890.1130c)
4. The potable water system may not have a physical connection to the non-potable harvested rainwater system. (Section 890.170c2).
5. The irrigation system that has public interaction and is supplied with harvested rainwater must be provided with a permanently affixed sign stating "This system is uses harvested rainwater. Not safe for drinking".
6. To prevent sewage from backing up into the cistern, the overflow from the cistern may not discharge directly to a sanitary sewer. The overflow may discharge to a dedicated storm sewer or open site outlet.
7. All Irrigation Contractor are required to be registered with the Department 225 ILCS 320/2.5.

The Illinois Plumbing Code will be revised to incorporate regulations coving all aspects of rainwater harvesting systems.

PUBLIC BUILDING COMMISSION OF CHICAGO

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