ONSITE WATER RECYCLING

An Innovative Approach to Solving an Old Problem

Living Machine™ at the SFPUC Headquarters

San Francisco
Water Power Sewer
Services of the San Francisco Public Utilities Commission

Water is a defining issue of the 21st Century.

Water and sanitation systems are increasingly stressed as infrastructure systems are aging, climate and weather patterns are changing, and communities are rapidly growing. As a result, the ability to provide safe and reliable water and sanitation services is becoming increasingly difficult for urban and rural communities across the world.

This e-book highlights global challenges for water and sanitation services, as well as localized solutions to treating wastewater for reuse on a smaller, decentralized scale. Numerous people around the world were contacted to share their stories, projects, and lessons learned to encourage transformation in the water sector. Several cases studies are shared throughout the e-book and complied in the Appendix.

The purpose of this e-book is to inspire utilities and government leaders to consider onsite water treatment systems as an effective strategy in their long-term water resource and resilience planning. This information can help water and wastewater utilities, government agencies, and other interested stakeholders understand the benefits and drivers behind onsite non-potable reuse, how other utilities have addressed potential challenges, and best practices for the ongoing operation of these systems.

Ultimately, utilities and governments have the opportunity to expand traditional water portfolios by enabling onsite water treatment and create a shared responsibility of managing water resources within a community.

When considering how and where it makes sense to integrate onsite water systems in a community, it's important to first honor local context and acknowledge that each community has different drivers that influence decisions around water management. For example, while water scarcity may drive water reuse in some locales and regions, other areas are turning to onsite water reuse to help alleviate stormwater and combined sewer overflow issues.

As we look to the future, additional opportunities for onsite water treatment systems include resource recovery by tapping into the potential for thermal heat, nutrient and biosolids recovery as well as a potential source of drinking water.

Paula Kehoe and Taylor Nokhoudian
January 2022

1 Bligh Street's onsite reuse system (image courtesy of Aquacell)

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WATER AND SANITATION CHALLENGES

In many parts of the world, the approach to water and sanitation services incorporates large-scale centralized systems with extensive piping networks. Water networks are generally designed to transport water from great distances, often requiring significant energy to pump the water to urban centers where the water is needed. In many cases, a separate piping network is installed to treat, pump, and discharge the wastewater away from urban centers. This linear approach of "water in and water out" became the norm during the late 19th century and continued throughout the 20th century. This approach became common practice for many good reasons: providing clean sources of fresh water to consumers and discharging polluted waters far away from humans with the goal of protecting public health.

Aging Water and Sanitation Infrastructure

Many centralized water and sanitation systems built in the early 19th and 20th centuries are in need of significant upgrades and pose a number of economic, social, and environmental costs to communities. According to the American Society of Civil Engineers, it is estimated that over 2.2 million miles (3.5 million kilometers) of underground drinking water pipes in the United States (U.S.) are aging and underfunded. There is a water main break every two minutes with an estimated 6 billion gallons (22.7 million m^3) of treated water are lost each day. Furthermore, the annual drinking water and wastewater investment gap will grow to $434 billion U.S. dollars (USD) by 2029. Given these costs associated with aging infrastructure, many cities are struggling to provide safe water and sanitation at an affordable rate.

Accessing Water and Sanitation

It has been recognized that access to safe drinking water and sanitation is a basic human right. While substantial progress has been made in the U.S. to ensure access to clean drinking water and sanitation, millions of people still lack these basic services. According to the United Nations (UN), around the world 3 in 10 people lack access to safely managed drinking water services and 6 in 10 people lack access to safely managed sanitation facilities. Throughout the world, more than 80 percent of wastewater resulting from human activities is discharged into rivers or water bodies without any treatment or pollution removal. According to the World Water Council, to meet the future needs for water supply and sanitation worldwide, it has been estimated that $6.6 trillion USD will be needed by 2030, and $22.6 trillion USD by 2050.

Adapting Centralized Infrastructure

Large-scale centralized water and sanitation systems were built for conditions very different than the conditions we face in the 21st century. Throughout the world, extreme weather events have brought dramatic flooding and drought conditions degrading water quality and threatening public health. To address the impacts of climate change, communities will need to make substantial changes in the way the infrastructure is designed and managed to withstand shocks from extreme weather events.

Expanding Centralized Infrastructure

The UN estimates that the world's population is expected to increase to over 9 billion people by 2050, with the number of people living in urban areas expected to double to over 6 billion. In many cases, water and sanitation centralized systems are difficult to scale up quickly to meet rapid population growth as they require significant capital and can take decades to design and build. With a rapid pace of urbanization expected, new approaches to water and sanitation services are urgently needed.

NEW APPROACHES TO OLD PROBLEMS ARE NEEDED

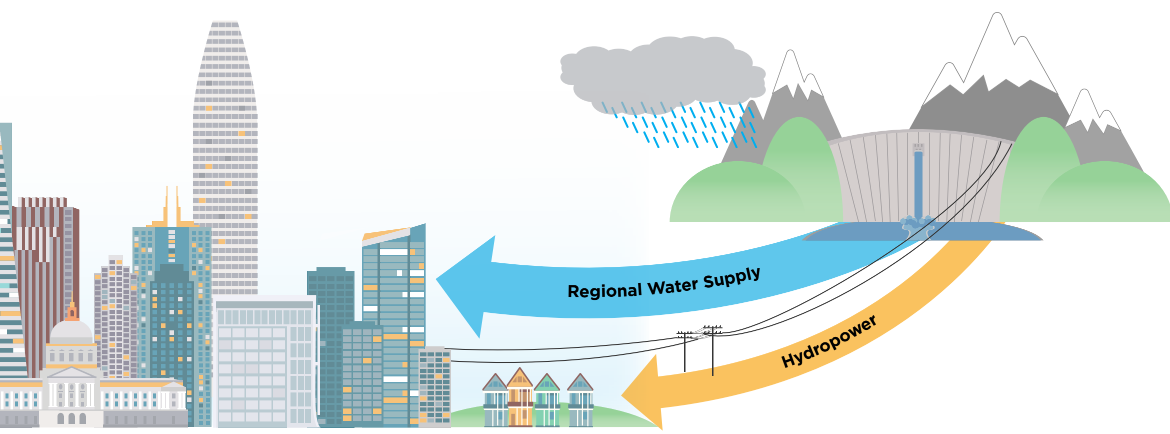
Centralized water and sanitation systems are one of the most significant public health advancements of our time. However, to meet the many water and sanitation challenges in the future, it will require us to transform not just our water infrastructure, but how we think about water by creating opportunities to engage and mobilize local communities. These changes will require that we manage water in different ways and adapt our traditional governance and utility business practices. As utilities reimagine their traditional role, they can engage new partners to advance economic growth, environmental sustainability, and equity within their communities.

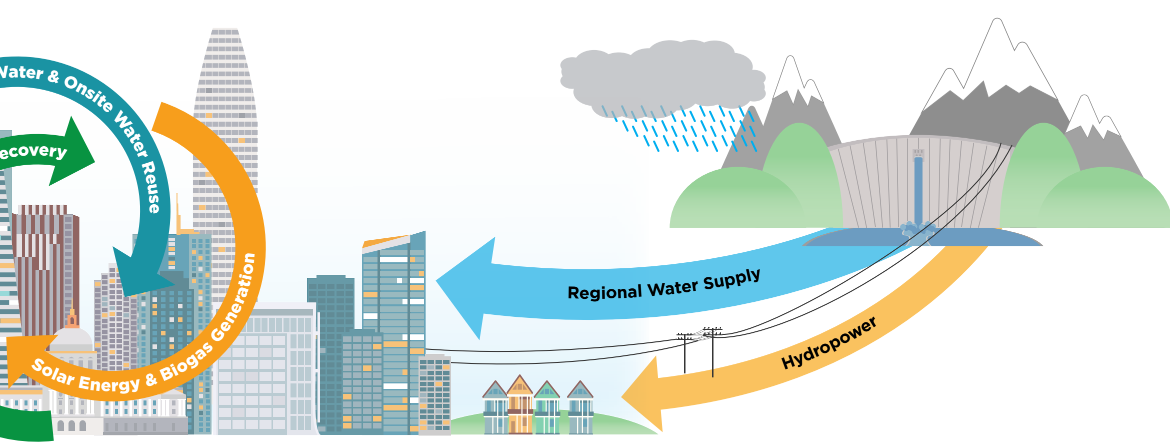
Adjusting Our Thinking with One Water

Traditional water and sanitation resource management takes a linear “resources in, waste out” approach. This approach fails to recognize the synergies and resource potential across water, wastewater, and energy boundaries. Transitioning to a new approach requires us to adjust our old ways of thinking to develop a new vision for delivering water and sanitation services. This new path forward includes integrated water, sanitation, and energy management approaches such as One Water.

One Water is an integrated planning approach that allows us to think differently about resource management. By collaborating across traditional boundaries, utilities and governments can identify opportunities to better utilize our resources through reuse and resource recovery. With One Water providers can take a more holistic view of their work so that they can optimize resources, create more opportunities for innovation and collaboration, and identify more ways to adapt to future changes.

The good news is that water managers across the world are implementing One Water approaches. Many water utilities are incorporating innovative strategies to conserve, reuse, and diversify their water supplies. For example, water utilities are actively working with customers to install low flow fixtures in their homes and businesses to reduce their water consumption. Many are treating wastewater to irrigate golf courses, parks, and agriculture. And, a growing number of utilities are turning to treating wastewater to supplement traditional drinking water supplies.

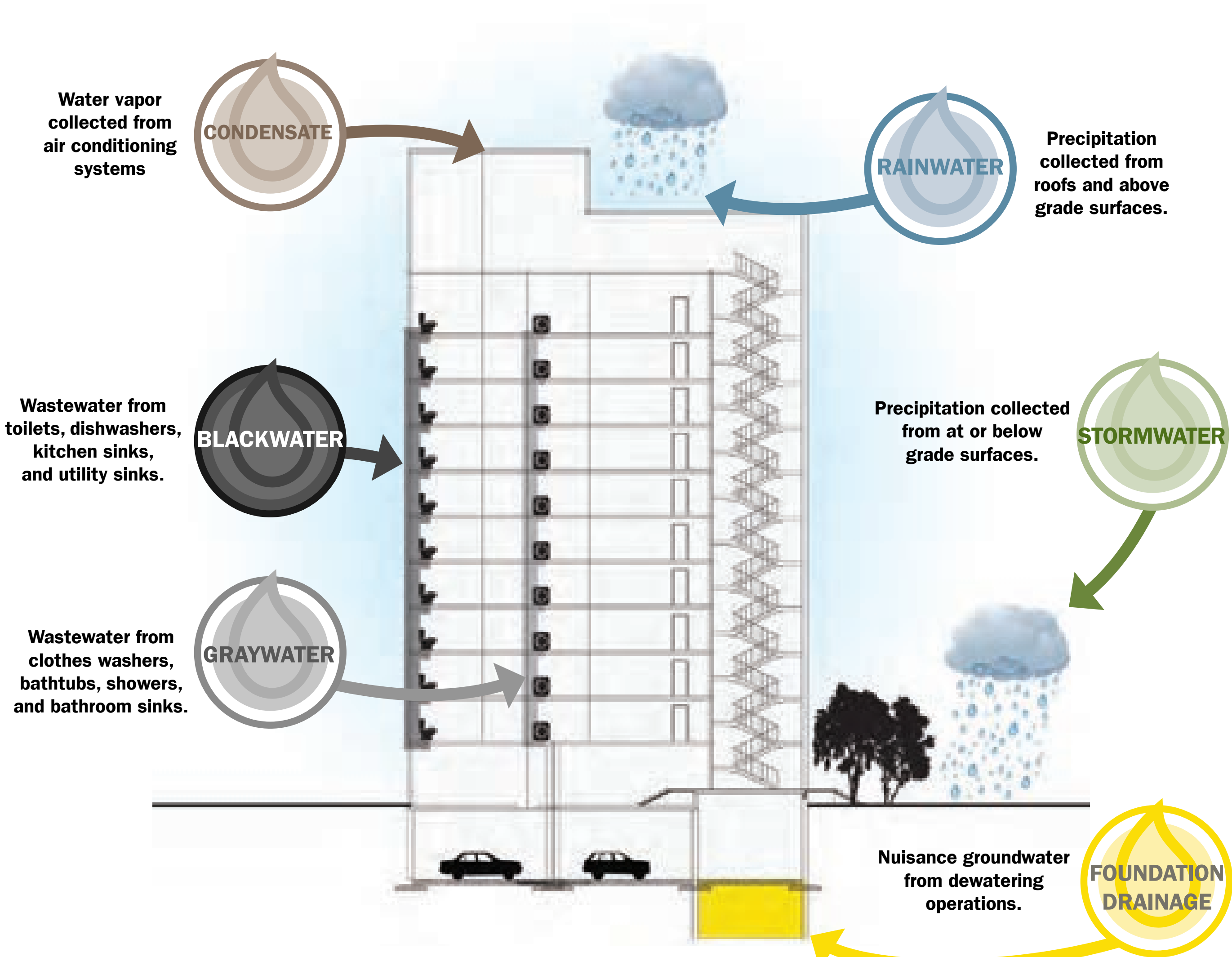




Re-Thinking Building Designs

One promising approach to One Water management is the use of onsite water treatment systems to collect and treat alternate water sources for non-potable uses within individual buildings or across multiple properties. Buildings produce a number of water resources, including rainwater, stormwater, foundation drainage, condensate, graywater, and blackwater. When collected and treated properly, these water sources can be used for non-potable applications such as toilet flushing, irrigation, clothes washing, and cooling towers. Onsite water systems can also reduce potable water use up to 45% in residential buildings and up to 75% in commercial buildings. As a result, we have an opportunity to build and manage our cities to be more resilient and sustainable with onsite treatment systems on a smaller scale than what traditionally occurs with complex centralized water and sanitation systems. Small-scale water reuse is an innovative solution with demonstrated success in addressing today's pressing water challenges. Interest in funding such advancements is growing. For example, the U.S. Department of Energy (DOE) is investing $20 million USD to advance innovation in water and wastewater treatment.

TYPES OF ALTERNATE WATER SOURCES PRODUCED IN BUILDINGS



REALIZING BENEFITS WITH ONSITE WATER TREATMENT SYSTEMS

Onsite non-potable water systems can be a vital part of the next wave of innovation in One Water management, especially for cities and large water-reliant businesses. These systems can mobilize and engage the community and private sector in the management of water as well as reduce capital expenditures for utilities. By integrating onsite non-potable water systems into broader One Water planning, these systems can help leaders optimize the balance between their investments and the benefits they reap for ratepayers and their communities.

Deferring Capital Costs

As urban and suburban areas continue to grow, centralized infrastructure is straining to keep up. Major capital projects such as building new dams, treatment plants, and transmission systems may not be financially feasible for ratepayers. Onsite treatment systems can be a valuable tool in helping to extend system capacity, while reducing costs related to energy use, treatment, and delivery. This relief may allow utilities to shift investment priorities to other infrastructure needs like upgrading wastewater treatment plants or replacing aging service lines and collection systems. In places where onsite non-potable water systems are deployed at scale, the reduced burden on the sewer system may reduce the size of needed water and sewer infrastructure, thus saving capital.

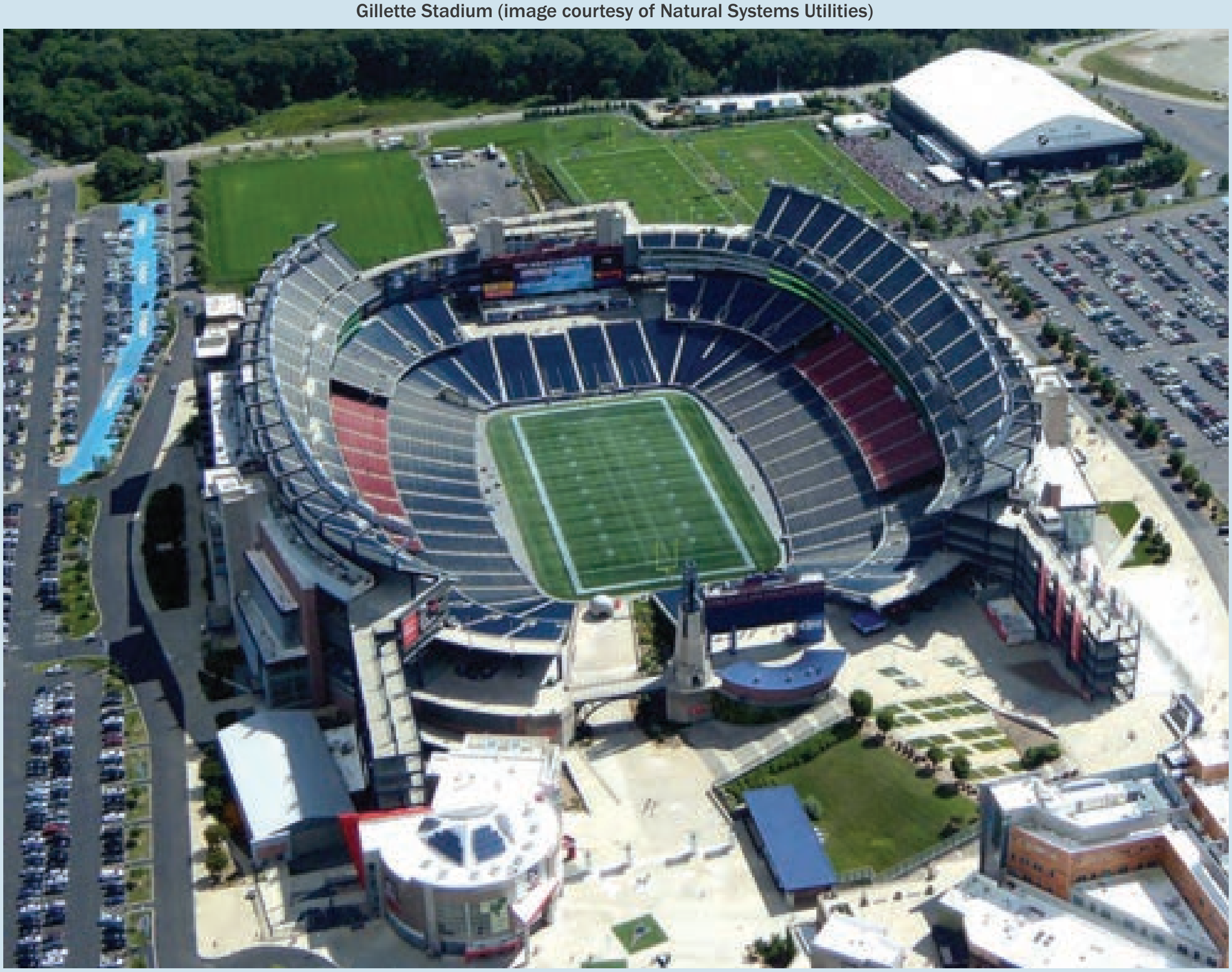
Rendering of 49 South Van Ness (image courtesy of SOM)

CASE STUDY: Onsite Water System Provides Reuse at Gillette Stadium

In 2001, during planning of Gillette Stadium, home of the New England Patriots football team, engineers, and city managers faced a challenge of supplying enough water for the stadium from limited supply aquifers and managing the wastewater flow from the stadium without harming sensitive local headwaters. To handle the anticipated water and wastewater demand on game day, it would have required new sources of water supply and new wastewater facilities for this small New England community, which was then served entirely by individual onsite septic systems.

According to Natural Systems Utilities, to secure this highly valued economic development project while maintaining the town's village character, the project included an onsite non-potable water reuse system capable of collecting, treating, and recycling up to 25,000 gallons (94,635 liters) per day of wastewater. Because of this innovative water reuse approach, the town was able to avoid the need for a centralized wastewater system while continuing to supply potable water via existing aquifers and providing economic benefits to the local community.

Gillette Stadium (image courtesy of Natural Systems Utilities)



Emory University's onsite water treatment system (image courtesy of Sustainable Water)

Balancing Infrastructure Investments

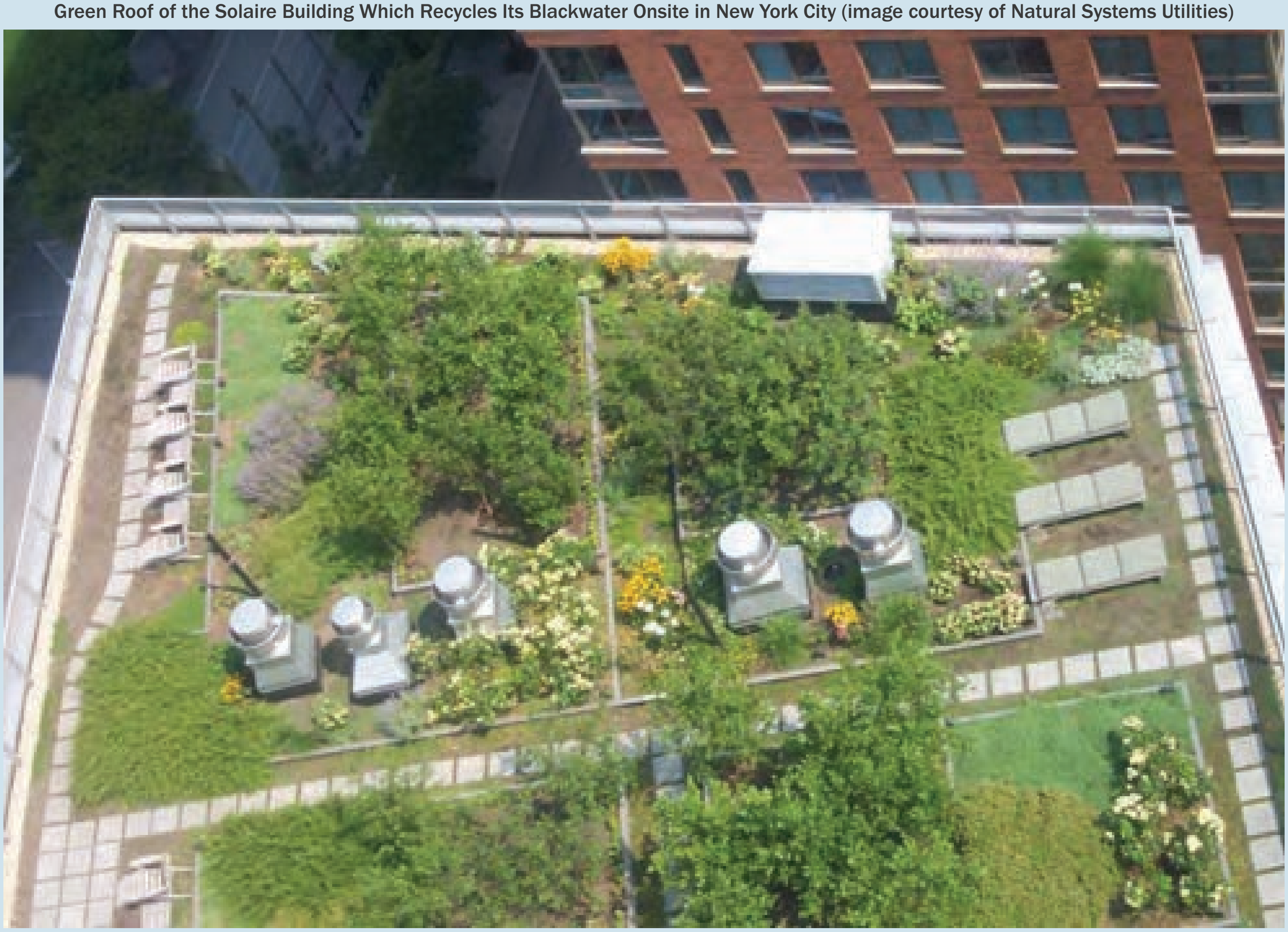
Around the world, water and wastewater utilities must make decisions about when and how to size and sequence significant infrastructure improvements and capital investments. Often these pressing capital projects have precluded utilities from considering new investments in onsite non-potable water systems. On the other hand, many leading utilities are finding that onsite non-potable water systems can serve as a tool to be leveraged in balancing infrastructure priorities, rather than seeing them as a competing priority. Especially when deployed at scale, onsite non-potable water systems can help maintain and optimize centralized water and wastewater systems. They can expand the capacity of existing systems, reduce the size or scale of planned replacement projects, and change the calculus of larger infrastructure investments. For example, some utilities that have deployed onsite non-potable water systems have seen reductions in the magnitude of large infrastructure investments they will need to make in the future. Onsite water treatment systems also enable cost-sharing on infrastructure investments with private developers and property owners. Leveraging funds can take some of the burden off utilities, allowing them to set aside capital for other priorities.

CASE STUDY: Onsite Non-potable Water Systems Help New York Prepare for Future Infrastructure Investments

The New York City Department of Environmental Protection (DEP) has initiated a large-scale Water Demand Management Program targeting an overall reduction of 20 million gallons (75,708,235 liters) per day in water consumption citywide by the year 2022. The program focuses on six primary strategies: municipal water efficiency; residential efficiency; non-residential efficiency; wholesale customer efficiency; water distribution system optimization; and water supply shortage management.

To further encourage water efficiency in the non-residential sector, DEP launched the Onsite Water Reuse Grant Pilot Program. The grant is a cost-sharing program providing incentives for property owners to install onsite non-potable water systems and facilitate both single building projects and district-scale projects that span across multiple properties. DEP structured the grant program to achieve a total water demand reduction of one million gallons (3,785,411 liters) per day and provide benefits to New York City through deferred capital costs of large scale infrastructure, reduced loading to sewers and water bodies, improved environmental stewardship, and increased capacity to manage water supply system demands.

Green Roof of the Solaire Building Which Recycles Its Blackwater Onsite in New York City (image courtesy of Natural Systems Utilities)



Fostering System Resilience

Centralized water and wastewater systems are one of the most significant public health advancements of our time. However, many were built nearly a century ago and for conditions very different than those cities currently face, leaving them often inflexible when it comes to adapting to rapidly changing climatic conditions. By integrating onsite non-potable water systems in buildings, utilities can improve their ability to respond to disruptions in water service delivery that may come from droughts, increased storm events, or other impacts of changing climates.

CASE STUDY: Onsite Systems Remain Operational During Hurricane

In 2012, Hurricane Sandy caused significant power outages, flooding and damage to wastewater treatment systems in the New York/New Jersey region of the U.S. The storm caused widespread failures and outages of centralized wastewater systems sending billons of gallons of raw and partially treated sewage into waterways. However, more than 80 distributed and onsite water systems remained operational. Furthermore, none of the onsite systems exceeded effluent permit requirements while many centralized facilities were down for weeks or longer discharging untreated sanitary wastewater into the local water bodies.

The New School in New York City, NY reuses blackwater for toilet flushing, cooling tower make-up, irrigation, and clothes washing. (image courtesy of NSU)

Generating Environmental and Community Amenities

Many buildings with onsite non-potable water systems integrate rain gardens, wetlands, and green roofs. In some cases, these serve as an essential component in the onsite treatment process. In other cases, these amenities provide green streets, public open space, reduced heat island effects, improved air quality, and transform corridors by connecting people with nature where they work and live. Where it makes sense designing onsite non-potable water systems to use green space for water treatment, these systems can transform hard urban landscapes, especially in underserved communities, into more vibrant natural public spaces.

CASE STUDY: Hassalo on Eighth Redefines Green Living in Portland

Hassalo on Eighth is a cluster of high rise, residential, commercial, and mixed-use buildings situated across four city blocks in Portland, Oregon, U.S. It's also home to NORM, the Natural Organic Recycling Machine, which collects 100 percent of water from sinks, toilets, showers, and laundry, and treats it onsite to flush toilets and irrigate landscaping. According to the project sponsors, NORM prevents up to 45,000 gallons (170,343 liters) of water per day from entering Portland's sewer system and saves up to 7,000,000 gallons (26,497,882 liters) of potable water per year. NORM also features wetlands and trickling filters, both of which are integrated directly into the pedestrian streetscape, providing visibility to a process that is often out of sight and out of mind.

Hassalo on Eighth Wastewater Treatment System (image courtesy of Jim G. Maloney/Biohabitats, Inc.)

CASE STUDY: New Sustainable Community in Denmark

Communities such as Nye, a new suburb of Aarhus, Denmark, are seeing the value of onsite water reuse. Nye is a city-driven initiative to meet Aarhus's increasing housing demand with a water-wise urban district that will make sustainable living more effortless for its citizens. Nye is designed to be resilient to climate change by incorporating blue/green structures that will also serve as natural amenities for residents and increase biodiversity. The private developer, local water utility Aarhus Vand, and Aarhus municipality collaborated to build a district-scale rainwater harvesting system, which is the first of its kind in Denmark. Rainwater from roofs, roads, and open areas will be conveyed through a network of trenches and ponds to a central lake, which will serve as a storage reservoir. A central treatment plant will treat and distribute recycled water to meet the non-potable water demands of the community's households, such as toilet flushing and laundry. It is anticipated that the district-scale rainwater system will reduce total household water use by approximately 40%.

Homes surrounding Nye's central lake/storage reservoir (image courtesy of Aarhus Vand)

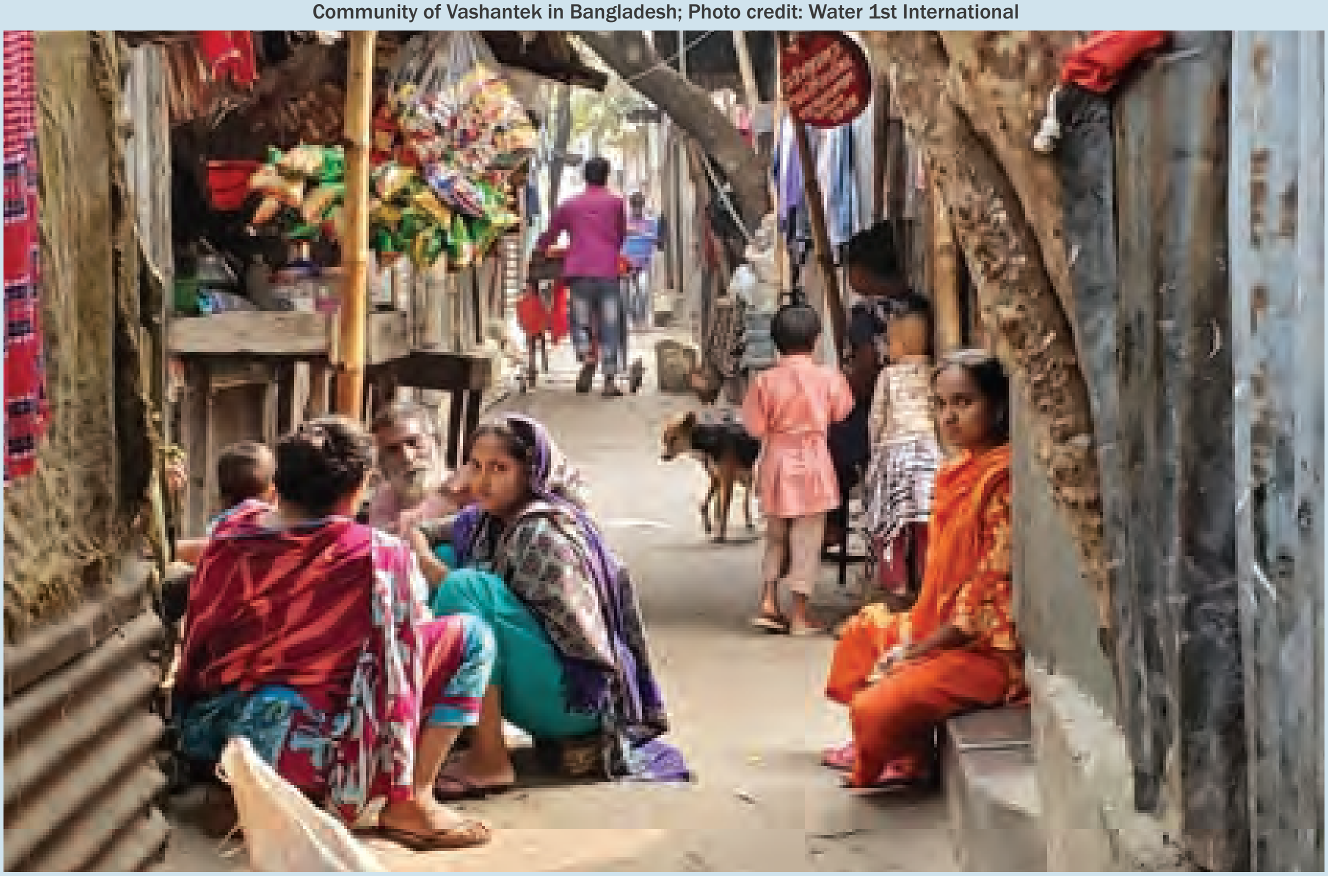
Engaging the Community

Onsite water treatment systems can also benefit communities without centralized or comprehensive sanitation collection and treatment systems and enable the community to become an active partner in water management. Encouraging community engagement promotes partnerships, cultivates trust, promotes a feeling of community ownership over the assets, and can lead to greater success in the long-term operation and maintenance. Engaging the community in water management also ensures an equitable approach by encompassing fairness into decision-making, representation of the end users, and improved access to services.

CASE STUDY: Community Governance to Sanitation in Bangladesh

In Bangladesh, 80 percent of Dhaka's 18 million people are not connected to any sanitation system. In the communities of Vashantek in the Pallabi Slum and Tarabo in the Demra Slum areas of Dhaka, improvements in sanitation were made by implementing a local, decentralized wastewater collection and treatment system with funding support by a non-profit organization Water 1st International. By installing a decentralized system it has significantly improved local living conditions, engaged the local community to provide ongoing maintenance and governance of the system, and enhanced the community's resiliency to recover from the monsoon conditions.

Community of Vashantek in Bangladesh; Photo credit: Water 1st International



Advancing Water Use Efficie y

Studies have demonstrated that efforts to manage water demand, including conservation, efficient fixtures, and related measures, are the most cost-effective ways to manage or extend water supplies. Onsite non-potable water systems are an emerging conservation measure that can contribute to demand reduction. Additionally, by reducing water demands onsite water treatment systems can also reduce the impacts on sanitation systems.

CASE STUDY: Transforming Landscapes and Reducing Water Demands

Located on the site of a former coal-fired power plant, the WaterHub at Philip Morris in Richmond, Virginia, U.S. is a symbol of an industrial park's turn to green infrastructure. The WaterHub, which began operation in 2019, treats up to 650,000 gallons (2,460,500 liters) per day of blackwater, which serves as the primary water supply for the industrial campus' energy system. The WaterHub is expected to decrease total potable water use for the industrial park by approximately 40% and decrease total wastewater discharge by up to 70%.

WaterHub at Philip Morris USA in Richmond, VA; Photo credit: Sustainable Water

Diversifying and Stretching Water Supplies

Whether driven by decreased water supplies or increased water demands, utilities are proactively pursuing new strategies that combine water conservation and efficiency with untapped local supplies. As major water users, commercial and mixed-use buildings can reduce their water footprint and stretch water supplies by collecting and treating rainwater, stormwater, graywater, and/or blackwater onsite and reusing it to meet local demands. Diversifying and stretching water supplies helps utilities reduce system burdens in peak use times, be resilient in the face of drought, and defer costs associated with system expansions.

CASE STUDY: City of Austin Promoting Sustainable Water Management

Completed in the summer of 2020, Austin's Permitting and Development Center demonstrates and promotes sustainable water management practices. The building incorporates an onsite blackwater system that treats 100 percent of the building's wastewater through a 5,000 gallon (18,927 liter) per day membrane aerated bioreactor (MABR) and recycles the water for toilet and urinal flushing. Rainwater from the building's roof and air conditioning condensate are also collected in two 20,000 gallon (75,700 liter) storage tanks and reused for landscape irrigation and a circulating water feature.

City of Austin Permitting and Development Center in Austin, TX (image courtesy of Austin Water)

Managing Stormwater Flows and Reducing Pollution

Onsite non-potable water systems can reduce demand on stormwater infrastructure, divert runoff, help reduce surface flooding, and prevent stormwater from polluting local waterways. Onsite water systems can boost compliance with local stormwater management ordinances while simultaneously providing other water quality benefits to local receiving waters.

CASE STUDY: Capturing Stormwater and Protecting Infrastructure in Japan

In Hiroshima, Japan, the Mazda Zoom-Zoom Stadium, home to the baseball team the Toyo Carp, underwent a massive renovation to incorporate an onsite rainwater reuse system. Completed in 2019, the renovation installed a reservoir below the baseball field to collect stormwater runoff from the stadium and surrounding area, managing a total drainage area of 128 acres (517,998 m^2). About 7% of the reservoir (264,000 gallons or 999,340 liters) is segmented for the rainwater reuse system, while the other 3.5 million gallons (13,248,940 liters) of storage capacity prevent stormwater from inundating the sewer system, and most critically preventing flooding of the nearby underground Hiroshima subway station. The rainwater treatment system disinfects the runoff with chlorine and passes it through a filtration system before it is used for the baseball field sprinkler irrigation, stadium toilet flushing, and publicly accessible and interactive circulating water feature outside the stadium called the “Amaoto no Komichi”.

Rainwater Used to Irrigate Mazda Stadium in Hiroshima, Japan (image courtesy of the City of Hiroshima)

Inspiring Innovation in Technology

The role of utilities is evolving. Around the world, water and wastewater agencies are redefining what it means to provide water and wastewater service in the 21st century. With the deployment of new technologies and innovations, utilities and other water leaders are changing the way we view, value, and manage water across its lifecycle. As utilities embrace new and proven technologies for onsite non-potable water systems, they are charting a new course in One Water management and signaling to the private sector the innovative priorities for the future.

CASE STUDY: Leading Innovation at Denver Water

Located in a high plains desert, where its water supply is frequently threatened by drought and climate change, the City of Denver, Colorado, U.S. is actively taking measures to secure future water supply resiliency. With construction recently completed, Denver Water's Administration Building will capture rainwater from the roof and solar panels that cover a portion of the new parking garage. The rainwater will be filtered and stored for landscape irrigation. In addition, the building will also be treating and reusing 100 percent of its blackwater. Blackwater collected from sinks, toilets, drinking fountains, and cafeteria operations in the building will undergo large-object screening, aerobic and anaerobic biological treatment, three stages of wetland treatment (tidal and plug flow), cartridge filtration, ultraviolet light disinfection, and chlorination. The treated blackwater will then be reused for toilet flushing and irrigation.

Denver Water's Wetland System Treating the Building's Blackwater in Denver, CO (image courtesy of Denver Water)

Creating Opportunities for Public-Private Partnerships that Meet Market Demands

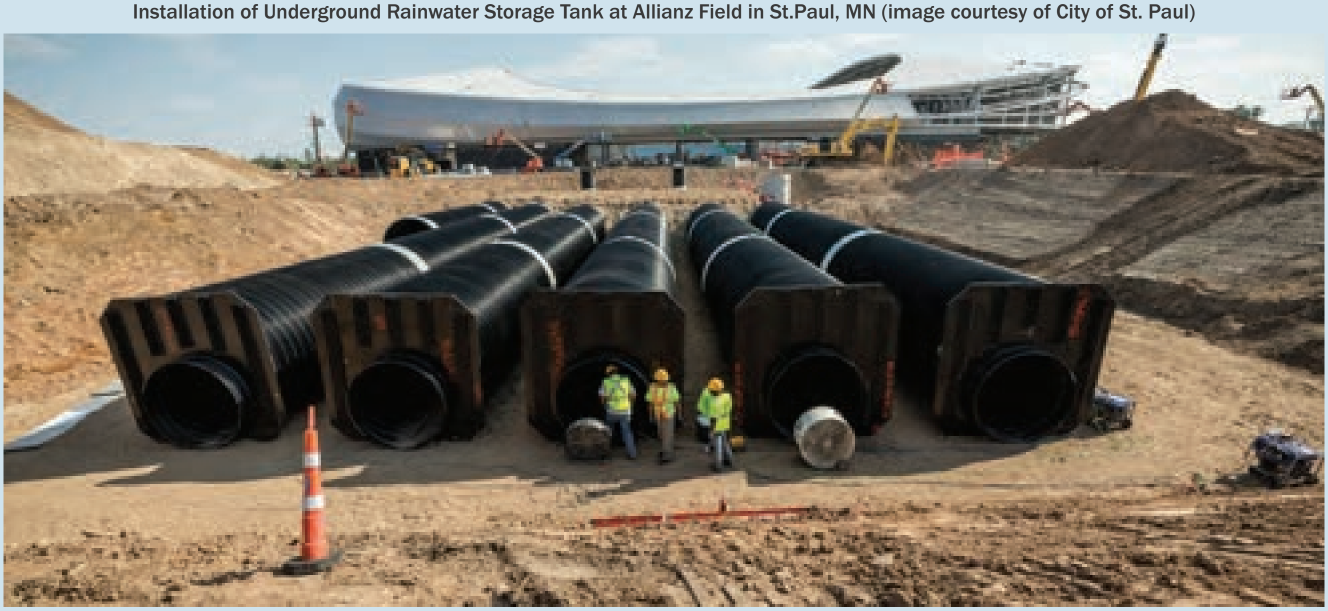
Developers are responding to market demands as more people want to live, work, and recreate in green buildings that have lower water, energy, and carbon footprints. Increasingly, developers are turning to the latest innovations in water in order to earn more green building credits for water-efficiency. And in turn, cities will reap the benefits of attracting new business and housing developments without placing undue pressure on existing natural resources and water systems. This is also an opportunity for utilities to explore partnerships with developers to share costs and reach mutually beneficial goals.

CASE STUDY: Managing Rainwater in the City of Saint Paul

In collaboration with the Capitol Region Watershed District, the City of Saint Paul developed a district-scale rainwater harvesting system capable of saving over 2,000,000 gallons (7,570,820 liters) of water annually. Completed in 2019, the project is located at Allianz Field, the new stadium for the soccer team, the Minnesota United FC.

The rainwater harvesting system utilizes a 675,000 gallon (2,555,153 liter) underground storage tank to collect roof runoff from the stadium and in the future from neighboring buildings once they are built. Water is pumped from the storage tank through a treatment system called a "smart hub", which can read weather forecasts to predict rainfall and adjust water levels accordingly. The treated water is used to irrigate the entire stadium site, which includes 150,000 ft^2 (13,395 m^2) of green public space and 200 mature trees. New development in the area will be able to connect to the system for supply of recycled water for non-potable uses such as laundry, irrigation, and restroom flushing.

Installation of Underground Rainwater Storage Tank at Allianz Field in St.Paul, MN (image courtesy of City of St. Paul)



TRANSFORMING WATER MANAGEMENT IN SAN FRANCISCO

The San Francisco Public Utilities Commission (SFPUC) located in San Francisco, CA, U.S. is actively embracing One Water. In 2016, the SFPUC adopted a OneWaterSF Vision and Guiding Principles. Under the OneWaterSF umbrella, the SFPUC is actively promoting water use efficiency and developing new local water supplies, including groundwater, recycled water, and onsite water reuse.

In 2012, the SFPUC piloted the city's first onsite blackwater treatment system at their own headquarters. In addition, the building incorporated a rainwater harvesting system to further demonstrate water use efficiency and innovation. The constructed wetland system treats all of the building's blackwater using a series of tidal and vertical flow wetlands. Known as the Living Machine, the wetland system treats about 5,000 gallons (18,927 liters) per day of wastewater, which is then pumped for reuse for toilet and urinal flushing throughout the building. The rainwater harvesting system captures rainwater in a 25,000 gallon (94,635 liter) cistern, treats, and uses it for landscape irrigation. Combined, the two non-potable water systems reduce the SFPUC building's potable water usage by approximately 50%.

Living Machine™ at SFPUC Headquarters (image courtesy of SFPUC)

Transforming Water Management in San Francisco with Onsite Water Reuse

Recognizing the opportunities to transform water management, in 2012 San Francisco became the first municipality in the U.S. to adopt a groundbreaking ordinance to streamline the process for the collection and treatment of alternate water sources, such as rainwater, stormwater, foundation drainage, graywater, and blackwater, for non-potable end uses such as toilet flushing and irrigation in commercial, mixed-use, and residential buildings. The purpose of the ordinance was to establish a local oversight and management program for public health protection.

The ordinance is implemented by four city departments: SFPUC, San Francisco Department of Public Health-Environmental Health (SFDPH-EH), San Francisco Department of Building Inspection (SFDBI), and San Francisco Public Works (SFPW). The four city agencies collaborate on an ongoing basis to review projects, discuss ways to improve communication, and further streamline the permitting process.

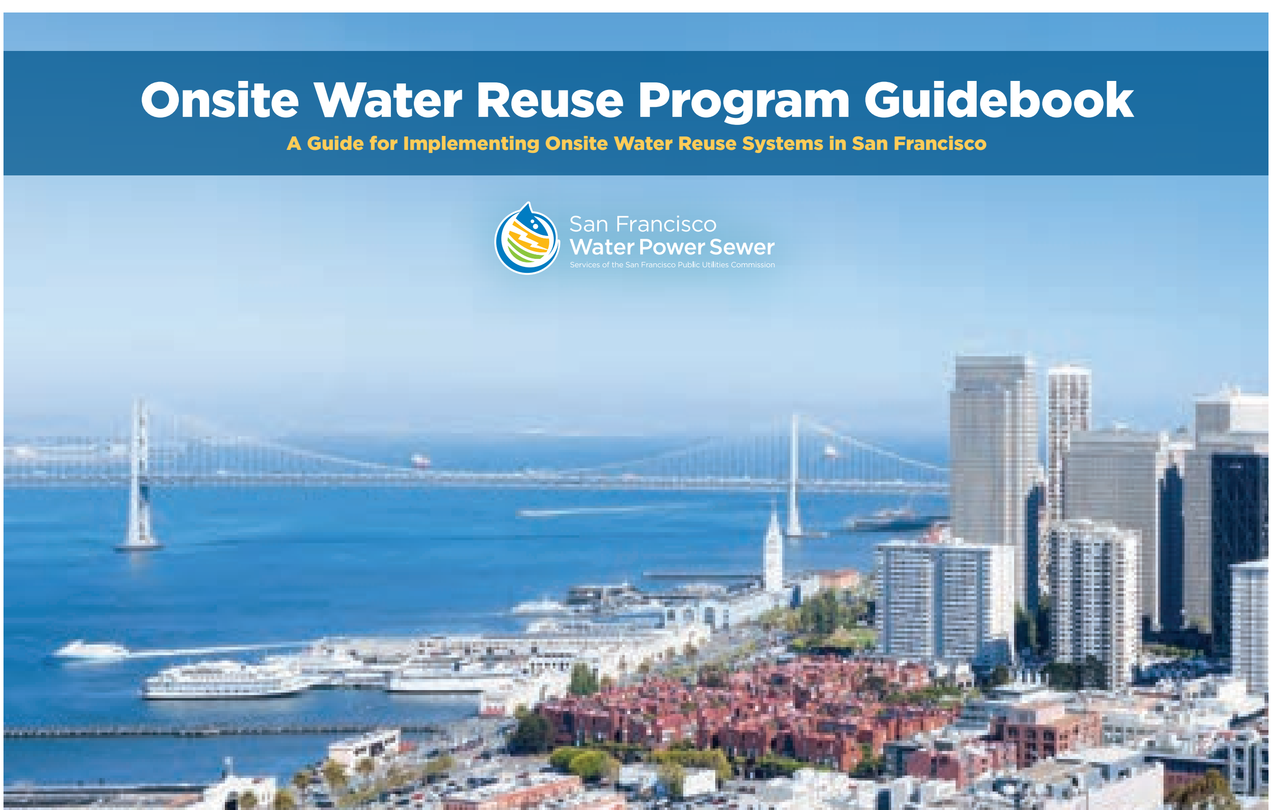
SFDPH-EH serves as the key enforcement agency and is responsible for issuing water quality requirements, reviewing engineering reports, and issuing permits-to-operate for the onsite non-potable water system.

SFDBI oversees construction and reviews plumbing plans.

SFPW reviews potential utility conflicts in the street and issue an encroachment permit for infrastructure located in the public right-of-way for district-scale or neighborhood-scale projects.

SFPUC serves as program administrator and is responsible for approving water budget applications, tracking potable water offsets, and managing a robust cross-connection control program.

To assist developers with onsite water treatment systems, the SFPUC developed the Onsite Water Reuse Program Guidebook.



An Evolving Program

San Francisco's Non-potable Water Ordinance has evolved over time to increase potable water savings from new developments. While the program began on a voluntary basis, the installation and operation of onsite water systems became mandatory in 2015 for new development projects with a footprint of 250,000 ft^2 (23,225 m^2) or greater. The SFPUC recognized the opportunity to streamline the integration of onsite water systems by modifying the requirements over time and to increase opportunities for potable water savings from new developments. For example, San Francisco's Non-potable Water Ordinance now requires commercial buildings to collect, treat, and reuse available blackwater and air conditioning condensate to meet its toilet and urinal flushing and drain trap priming demands. The ordinance change was made because reusing blackwater can offset 100% of a commercial building's toilet and urinal flushing demands, which can increase water savings substantially when compared to commercial buildings reusing graywater onsite. Graywater reuse can offset only about 15% of total building indoor water demands as compared to 75% with blackwater reuse. In 2021, the ordinance was also modified to require new developments of 100,000 ft^2 (9,290 m^2) or greater to install and operate an onsite water system.

OVERVIEW OF SAN FRANCISCO'S REGULATIONS

September 2012: The City and County of San Francisco adopts Article 12C in the San Francisco Health Code. Also known as the Non-potable Water Ordinance, it established an oversight program to allow for the onsite collection, treatment, and use of alternate water sources for non-potable applications at the building scale.

October 2013: The Non-potable Water Ordinance is amended to allow district-scale non-potable water systems consisting of two or more buildings to share non-potable water.

July 2015: The Non-potable Water Ordinance is amended to mandate the installation of onsite non-potable water systems in new developments 250,000 ft^2 (23,225 m^2) or greater.

December 2016: The Non-potable Water Ordinance is amended to clarify the requirements for implementation of district-scale non-potable water systems.

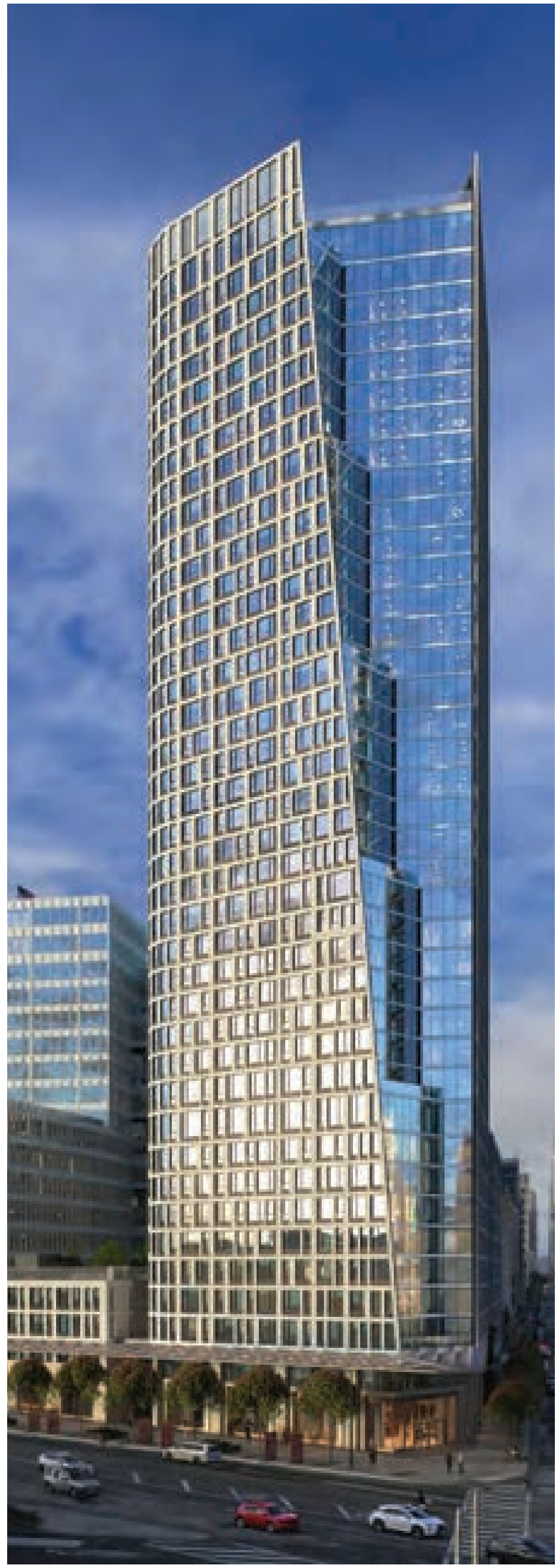
October 2021: The Non-potable Water Ordinance is amended to require new developments 100,000 ft^2 (9,290 m^2) or greater to install an onsite water reuse system. It also added new requirements based on development project type. Commercial buildings must meet its toilet and urinal flushing and drain trap priming demands through the collection, treatment, and use of available blackwater and condensate. Residential and mixed-use buildings must meet its toilet and urinal flushing, irrigation, clothes washing, and drain trap priming demands through the collection, treatment, and use of available graywater and condensate.

Providing Grants to Encourage Onsite Treatment Systems

In 2012, when the Non-potable Water Ordinance was first adopted, the SFPUC initiated the development of a grant program to partially offset the cost of installing an onsite water system. The grant program was an important first step to spur adoption of onsite water treatment systems at a time when onsite reuse was still a new concept in San Francisco. The availability of financial incentives helped to develop the business case for onsite water reuse. The SFPUC's grant funding ranges from $200,000 to $1,000,000 USD.

Considerations for the Integration of Onsite Water Systems

San Francisco strategically targeted new construction and areas of the city where major redevelopment is occurring to require the installation of onsite water reuse. By first targeting new construction, onsite water reuse projects can reduce capital costs when compared to retrofitting an existing building to incorporate an onsite water system. Furthermore, requiring new construction to install and operate onsite water systems can result in more immediate water savings rather than relying on the utility to build a centralized recycled water source. In addition, buildings within flood vulnerable zones are encouraged to consider infrastructure solutions by installing onsite water treatment systems to capture and treat nuisance groundwater rather than relying on continuous de-watering operations.



Fifteen Fifty, a high-rise residential tower in San Francisco, CA is reusing graywater and rainwater for toilet and urinal flushing and irrigation. (image courtesy of Epic Cleantec)

Addressing Reduced Flows in Sanitation System

Requiring new developments to install onsite water treatment systems in new large developments, the SFPUC addressed the potential impacts of these systems on the city's municipal sanitation system. Perceptions that onsite systems lead to declining flows and cause odor problems in the wastewater system created an institutional barrier. To overcome this challenge, the SFPUC's water and wastewater divisions collaborated internally to develop a process for assessing impacts on flow and odor. The process involves conducting a wastewater hydraulic analysis for each proposed development to evaluate impacts in terms of odor and flow. The SFPUC also models any city-wide impacts from significant proliferation of onsite systems throughout the city. Model results indicate that the impacts of odor and flow issues on the wastewater system are minimal. The SFPUC also offers guidance to projects on alternatives to discharging solids from the onsite reuse system directly to the sewer including occasional flushing of sewer lines or trucking the solids offsite.

Addressing Potential Revenue Impacts

Reduced water consumption as a result of onsite water reuse can raise concerns about revenue impacts for some utilities, especially as onsite water systems grow in popularity and scale. Therefore, it is important to consider the effect it may have on revenue projections. In San Francisco, all onsite systems are required to connect to the municipal potable water and wastewater systems, so the SFPUC does not lose customers; nor do these systems result in a complete loss of revenue from onsite non-potable water systems customers. Furthermore, the SFPUC assessed the annual financial impacts on water and wastewater revenue from the implementation of onsite systems and found minimal impacts. The SFPUC has found that conservation related measures, including onsite water reuse, are the most cost-effective ways to manage water supplies, and therefore utilities should apply management philosophies and cost/benefit analyses similar to those used in planning for other demand reduction and conservation tactics.

Understanding Potential Greenhouse Gas Implications

Other areas of consideration that have been explored in the context of San Francisco include the energy use and greenhouse gas implications of onsite water systems. Studies conducted by the University of California, Berkeley conducted a life cycle assessment and geospatial analysis to determine the cost, energy use, and greenhouse gas emissions trade-offs when comparing centralized and decentralized systems providing non-potable recycled water at various locations in San Francisco. The study concluded that onsite reuse systems can compare favorably in terms of energy use, greenhouse gas emissions, and flexibility in implementation when compared to centralized reuse systems. Furthermore, the studies emphasized the importance of incorporating innovative technologies that reduce the energy consumption of onsite water treatment, such as energy recovery or generation.

Examples of Onsite Reuse Projects in San Francisco

Currently, several developments in San Francisco are operating or planning to install onsite water treatment systems. A few examples are highlighted below to show proof of concepts and encourage transformation in the water sector. Additional projects in San Francisco can be found in the Appendix.

San Francisco Permit Center at 49 South Van Ness Avenue

The new 16-story Permit Center provides office space for city employees. Graywater and rainwater are collected, treated, and reused for toilet and urinal flushing and irrigation.

Fifteen Fifty

Fifteen Fifty is a high-rise residential building that installed a graywater membrane bioreactor system to capture, treat, and reuse graywater in the building for toilet flushing and irrigation.

Chase Center

The Chase Center arena is a new state-of-the-art sports and entertainment complex in San Francisco. The project installed an onsite water reuse system to collect rainwater, stormwater, graywater, and condensate. The treated water provides for toilet and urinal flushing inside the arena and two office towers, as well as irrigation demand for the landscaped roof spaces.

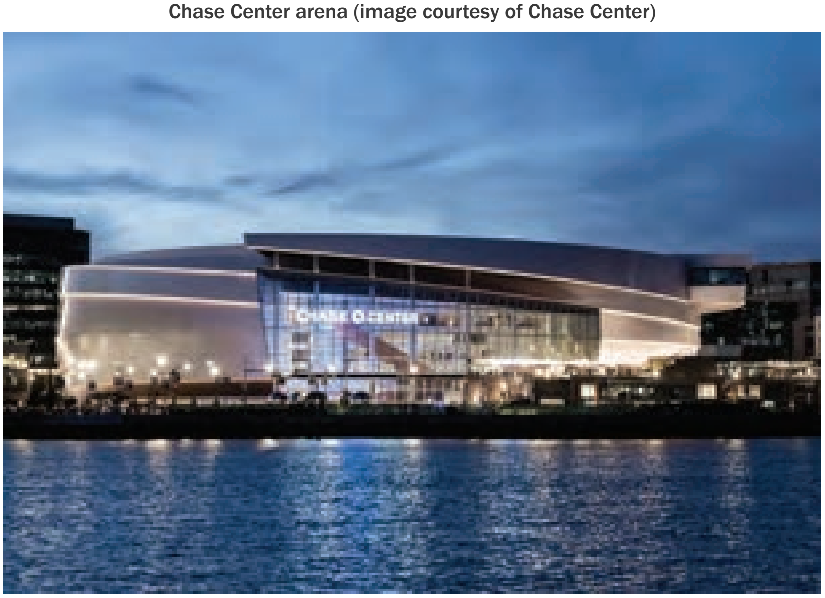
Mission Rock

Mission Rock is a new mixed-used neighborhood with 11 buildings currently under construction. The buildings within the district will be connected to a district-scale blackwater system to provide treated water for toilet flushing and irrigation.

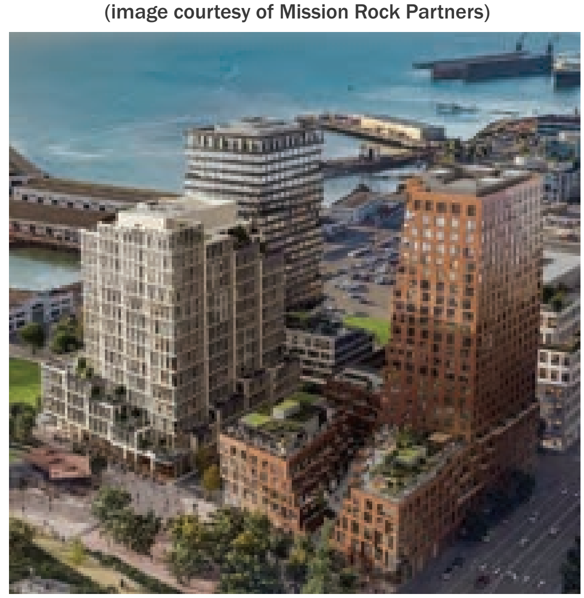
Uber Headquarters

Uber Technologies installed an onsite water reuse system to collect rainwater and graywater from two office buildings to meet the toilet flushing and irrigation demands.

Chase Center arena (image courtesy of Chase Center)



Rendering of Mission Rock
(image courtesy of Mission Rock Partners)

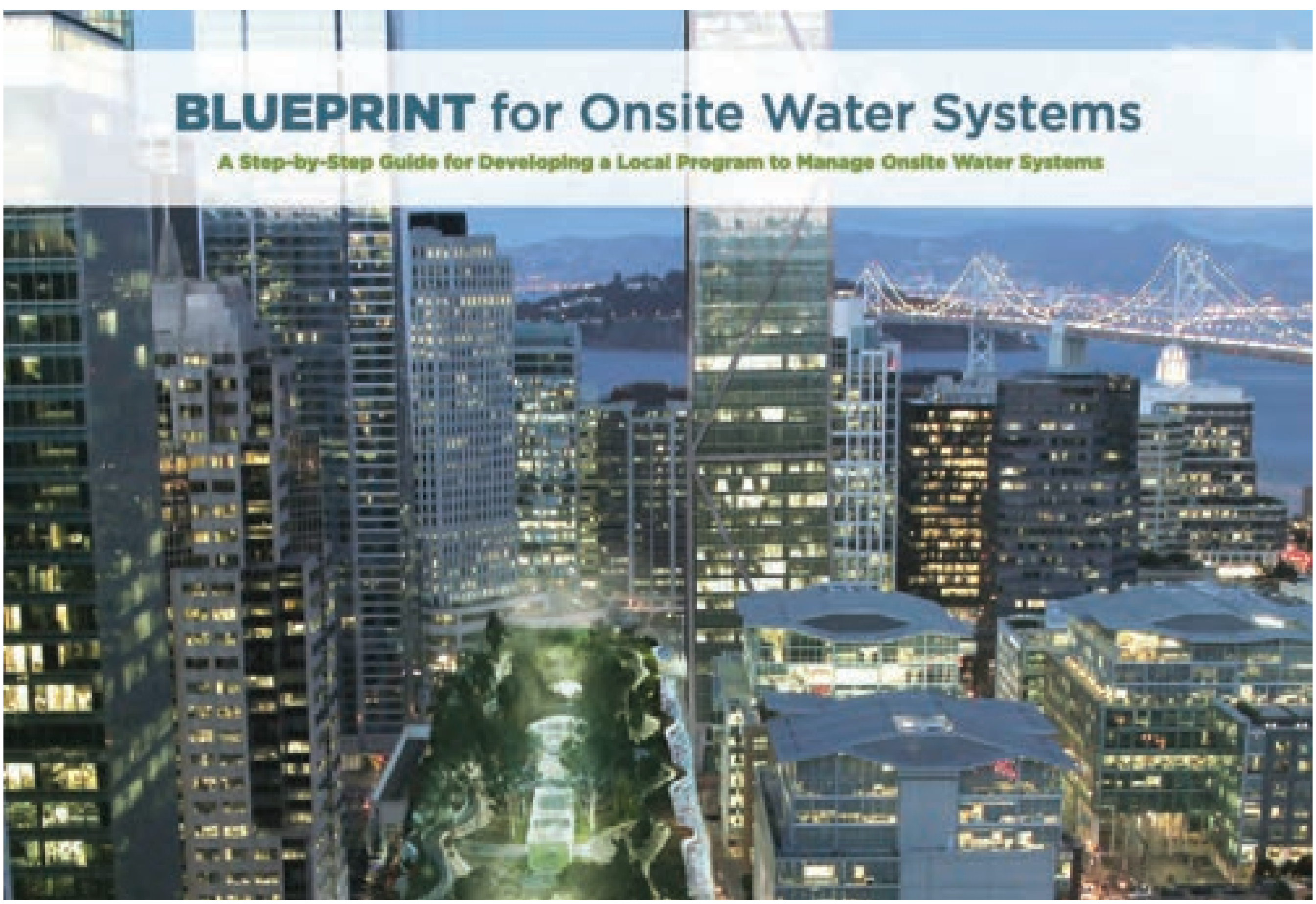


SCALING UP ONSITE WATER SYSTEMS ACROSS NORTH AMERICA

As previously described, communities around the world are embracing onsite water treatment systems. (Additional cases are presented in the Appendix.) As these systems scale up, it is critical to ensure ongoing public health protection. However, across North America there is a lack state or national standards and regulatory guidance for onsite water treatment systems. To address these challenges, the SFPUC, with support from the Water Research Foundation (WRF) and the Water Environment Research Foundation (WE&RF), convened a meeting of public health agencies, water agencies, and research institutions from across North America. The 2014 Innovation in Urban Water Systems conference identified the need for guidelines to develop oversight and management programs and to establish water quality standards that are protective of public health.

Developing Local Programs for Oversight and Management

Blueprint for Onsite Water Systems: A Step-by-Step Guide for Developing a Local Program to Manage Onsite Water Systems was published in 2014 to assist communities with developing an oversight and management program. The document describes ten key steps to develop a comprehensive oversight program.

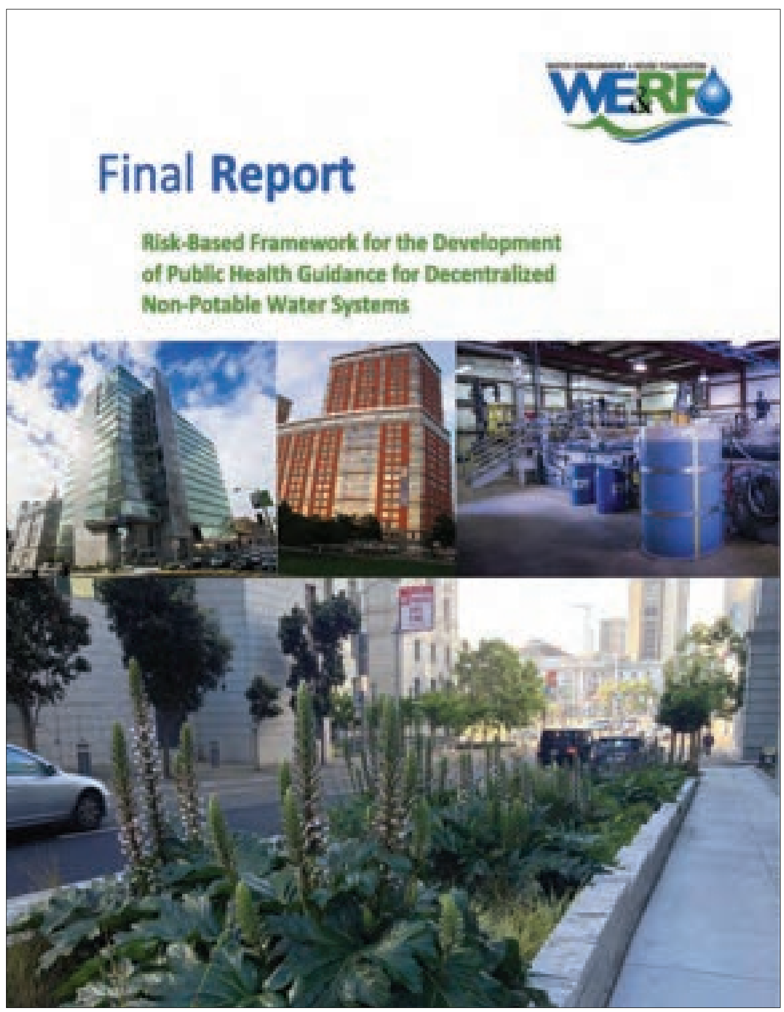


Establishing Water Quality Standards to Protect Public Health

To address the need for appropriate water quality standards, SFPUC convened a coalition of public health regulators and partnered with WRF and WE&RF to conduct research to develop recommendations for appropriate water quality criteria and monitoring for treating alternative water sources onsite. The research resulted in the landmark report, Risk-Based Framework for the Development of Public Health Guidance for Decentralized Non-potable Water Systems published in 2017.

The report was prepared by a 6-member Independent Advisory Panel, appointed by the National Water Research Institute (NWRI), with input provided by the public health coalition and a stakeholder advisory committee consisting of additional public health agencies and water utilities. Using Quantitative Microbial Risk Assessment (QMRA) modeling, the NWRI Panel established a water quality approach centered on risk-based log reduction targets (LRTs) for the treatment of pathogens including viruses, protozoa, and bacteria. (The research did not include chemical exposures because it was concluded that the removal of pathogens are considered the greatest concern to human health with onsite water treatment systems for non-potable applications.) The risk-based approach for pathogen reduction uses a methodology widely accepted for potable reuse and drinking water practices and is in alignment with the Water Safety Plan approach promoted by the World Health Organization.

In addition to establishing the LRTs, the Independent Advisory Panel emphasized continuous online monitoring as critical to the success of this approach. Continuous monitoring involves the ongoing verification of system performance using sensors that allow operators to monitor each treatment process in real time. Coupled with the ability to perform automatic diversions of off-spec water, this framework is increasing the reliability and effectiveness of onsite water reuse systems during operation. Continuous online monitoring is also broadly accepted in drinking water and potable reuse regulations, and this research extends the approach to onsite non-potable water systems.

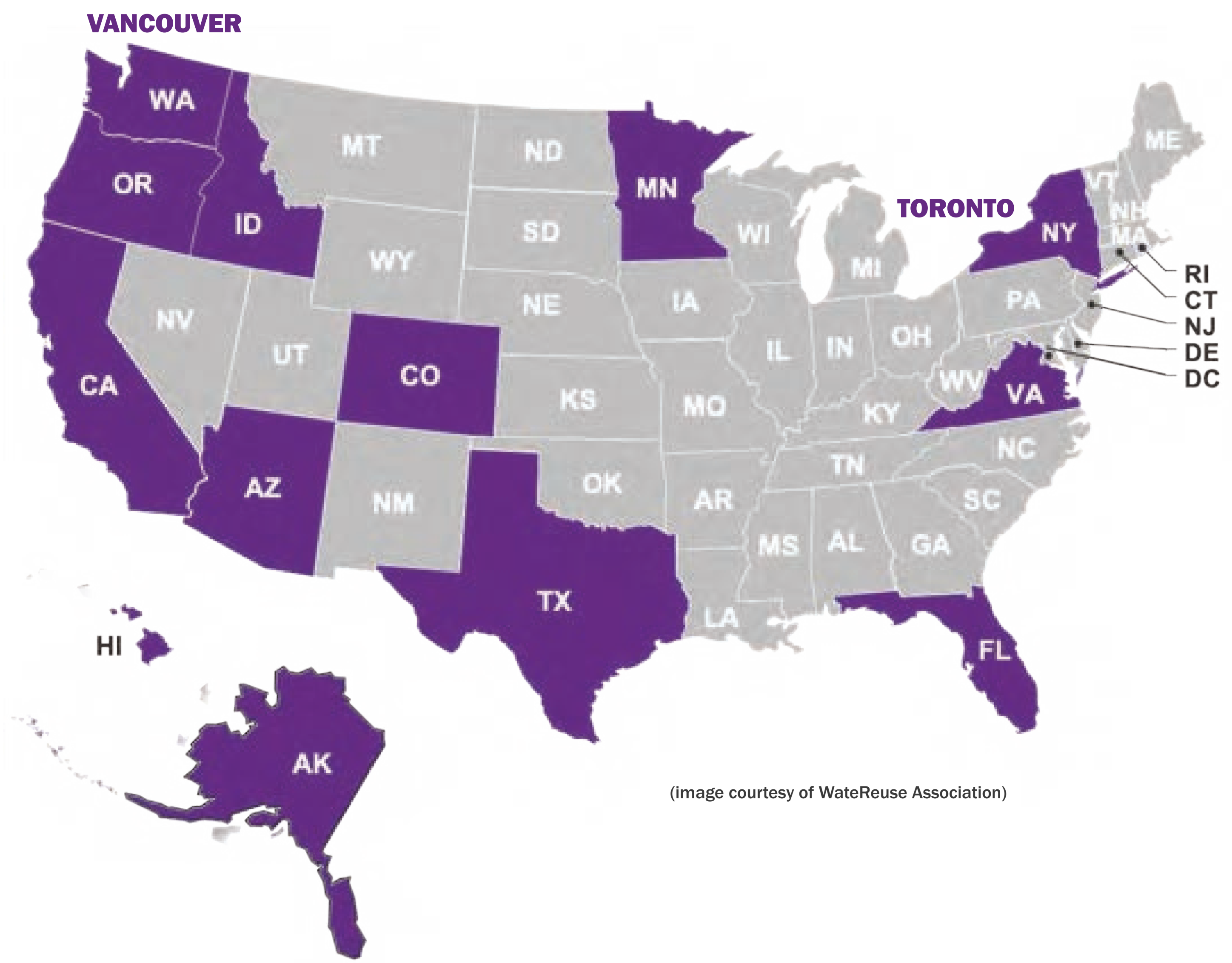


NATIONAL BLUE RIBBON COMMISSION

Building upon the collaboration formed in 2014, the National Blue Ribbon Commission for Onsite Non-potable Water Systems (NBRC) was established in March 2016 at the White House Water Summit. The Commission was established to craft model state policy and develop resources for the safe, practical, and sustainable implementation of onsite non-potable water systems.

Chaired by SFPUC, the Commission is comprised of representatives from municipalities, water utilities and public health agencies from 14 states, the District of Columbia, US EPA, and US Army Engineer Research and Development Center, the city of Vancouver, and the city of Toronto. Additional partners include WateReuse Association, Water Research Foundation, and US Water Alliance.

Cities and States Represented in National Blue Ribbon Commission



(image courtesy of WateReuse Association)

About the National Blue Ribbon Commission

The mission of the National Blue Ribbon Commission for Onsite Non-potable Water Systems is to advance best management practices that support the use of onsite non-potable water systems for individual buildings or at the local scale. We are committed to protecting public health and the environment, and to sustainably managing water—now and for future generations.

The National Blue Ribbon Commission is convened by the WateReuse Association in partnership with the US Water Alliance and the Water Research Foundation, and chaired by the San Francisco Public Utilities Commission.

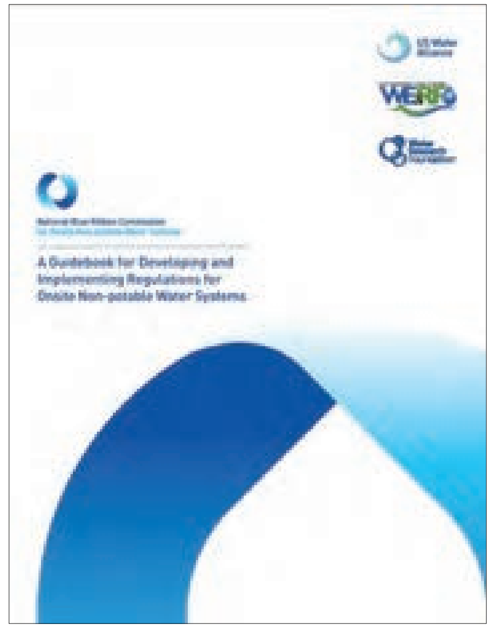
The commission is comprised of representatives from municipalities, water and wastewater utilities, and public health agencies from 14 states, the District of Columbia, United States Environmental Protection Agency, United States Army, the City of Toronto, and the City of Vancouver.

The goals of the commission are to:

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

National Blue Ribbon Commission convening in Seattle, WA

CREATING RESOURCES FOR ONSITE TREATMENT SYSTEMS



The NBRC is focused on creating tools and resources based on best available science that can support the implementation of onsite water treatment systems.

Model Regulations for Consistency

The NBRC advocates for consistent policy frameworks across cities and states to increase the adoption of onsite non-potable water systems. The NBRC in partnership with WRF developed the Guidebook for Developing and Implementing Regulations for Onsite Non-potable Water Systems to provide templates for state and local legislation for establishing regulatory programs and implementation rules.

Jurisdictions across the U.S. are implementing legislation and policies to advance onsite water reuse. These initiatives are increasing national momentum for adopting a One Water approach:

San Francisco, California

San Francisco's Onsite Water Reuse Program established local oversight and a streamlined permitting process for treating and reusing alternate water sources onsite for non-potable applications. In 2015, San Francisco was the first city to require new commercial, mixed-use, and multi-family development projects to install and operate an onsite water reuse system. In 2017, San Francisco updated its Onsite Water Reuse Program Rules and Regulations to align with the risk-based water quality standards.

Minnesota

Increasing interest in water reuse prompted the Minnesota Department of Public Health to develop recommendations for a statewide water reuse policy. In March 2018, the Minnesota Department of Public Health published the report Advancing Safe and Sustainable Water Reuse in Minnesota, which included recommendations to adopt the risk-based approach.

Colorado

As a result of Colorado's history of water supply challenges, increased political support for water reuse, and the publication of the risk-based public health guidance, Colorado Department of Public Health and Environment updated Regulation #84 to allow localized non-potable water systems to treat onsite blackwater for toilet flushing and irrigation using the risk-based approach.

California

The push for uniform standards for onsite water reuse garnered support from practitioners, the public, and the legislature, and in September 2018, California passed Senate Bill 966. SB 966 directs the State Water Resources Control Board to establish risk-based water quality standards for onsite non-potable water systems by December 2022. The legislation directs local jurisdictions to permit and oversee onsite water systems. (Amendments to San Francisco's program may occur to comply with the state's new standards.)

Hawaii

Hawaii is experiencing new found momentum for scaling water reuse as stakeholders from across the state engaged in a Water Reuse Task Force in 2018. As a result, Hawaii passed House Bill 444 in 2019 directing the Hawaii Department of Health to adopt rules for onsite non-potable water systems with guidance from the NBRC.

Austin, Texas

The City of Austin adopted the Onsite Water Reuse Systems Ordinance in 2020 to regulate the collection, treatment, and use of alternative water sources for non-potable uses. In 2021, Austin Water launched an Onsite Water Reuse System Pilot Incentive Program, offering up to $500,000 to developers seeking to voluntarily incorporate onsite water reuse.

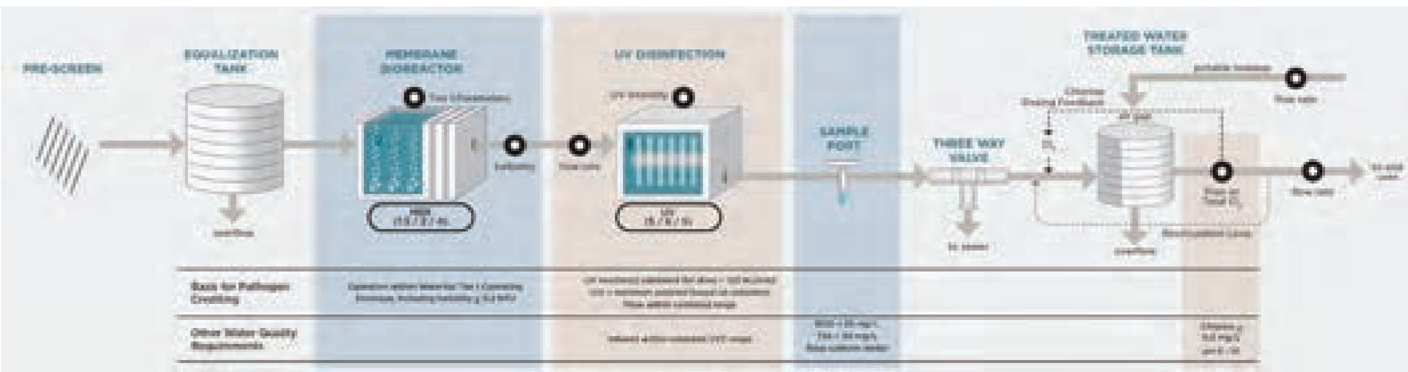
Washington

Recognizing the need for a regulatory structure for the safe and efficient use of onsite non-potable water systems, the Washington Legislature passed House Bill 1184 in 2021, which directs the Washington Department of Health to develop risk-based water quality standards for onsite non-potable water reuse systems in commercial and multi-family buildings.

DGS Natural Resources Building in Sacramento, CA will capture graywater, treat, and reuse it for toilet flushing. (Image courtesy of HTEC)

Guidance Manual for Program Implementation

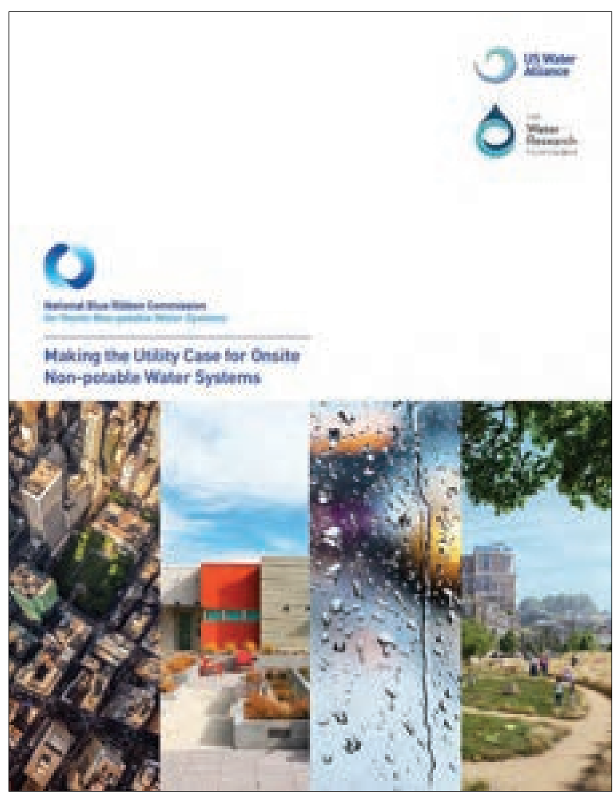
With the establishment of water quality standards and legislation, states and cities needed guidance on how best to implement the risk-based water quality standards into practice. SFPUC recognized early on the need for more guidance for practitioners seeking to implement the risk-based LRTs and developed a pathogen crediting approach and guidance on designing treatment systems. The guidance ultimately focused on available treatment technologies that could be used to achieve the LRTs with existing regulatory frameworks for crediting these technologies with pathogen removal or inactivation. San Francisco's guidance ultimately led to the NBRC developing the Onsite Non-potable Water System Guidance Manual which includes detailed information about designing and regulating onsite water reuse systems to meet the LRTs, including model treatment trains.



Example Graywater Treatment Train Meeting the LRTs

Making the Utility Case for Onsite Non-potable Water Systems

The NBRC developed a report Making the Utility Case for Onsite Non-potable Water Systems to assist utilities to help utilities and other stakeholder understand the benefits and drivers behind onsite reuse, how other utilities have addressed potential challenges, and best practices for the ongoing operation of these systems.



Life Cycle Assessment

In addition, the NBRC's key research partner, the U.S. Environmental Protection Agency (EPA), recently developed a web-based calculator that provides an initial life cycle assessment for any large building in the U.S. implementing an onsite non-potable water system. The Non-potable Environmental and Economic Water Reuse (NEWR) calculator is intended to help practitioners understand what are the most environmentally and cost-effective alternate water sources to meet large building non-potable water needs.

Building a Skilled Workforce

As cities turn to onsite non-potable water reuse, the operator workforce and sufficient operator training will be critical to ensuring onsite water systems are successful long-term. Given their industry experience, utilities can cultivate a skilled workforce for onsite water systems. Utilities can train their workers and contract them out to private system owners, or offer training to other utilities or property owners who would pay to have their employees learn how to operate and manage onsite non-potable water systems. This represents an emerging business opportunity, especially for utilities leading the field in onsite non-potable water systems. In addition, new workforce development programs can present opportunities for cities and communities to create local jobs and bolster much needed job skills, especially for low-income and underemployed citizens.

An Operator of an Onsite Water Treatment System

The need for certified operators is clear, however, there are no existing operator certificate programs that cover onsite non-potable water system specific knowledge. While relying on existing municipal water and wastewater operator certifications may seem appealing, specialized training that focuses on onsite non-potable reuse skill-specific knowledge is needed. This training should consider the types of technologies typically associated with both wastewater and water treatment. For example, an onsite blackwater system may need a membrane bioreactor (MBR), which is a wastewater treatment technology, followed by UV and chlorine, which are water treatment technologies.

To address these challenges, the NBRC is partnering with Water Environment Federation (WEF) and Association of

Boards of Certification (ABC) to develop an operator training and exam program, which is anticipated to be complete in December 2022. The program is initiating the effort by identifying the core subject areas and knowledge needed to operate both water and wastewater treatment technologies, which will be followed by the development of a training manual for exam takers, and ultimately the development of a certificate exam. This kind of program is preparing people with the skills the market will demand as more communities move towards realizing an integrated One Water future.

NBRC Continuing to Advance Science, Policy, and Implementation

In addition to pushing forward on developing guidance, research is underway to improve pathogen characterization in rainwater and stormwater, validate and assess assumptions in the underlying QMRA models, identify additional surrogates for online monitoring, pathogen crediting for natural treatment systems (i.e. wetland treatment systems), and develop systems analysis to inform planning.

Work is underway to examine the treatment requirements for using treated graywater for bathing and showering in rural Alaskan communities.

Additional research underway includes aligning plumbing codes and standards with the risk-based water quality approach. Having uniformity in plumbing codes and standards is an important consideration moving forward as states and municipalities adopt legislation promoting onsite water reuse.

Rural Alaskan Community

ADDITIONAL TRANSFORMATIVE OPPORTUNITIES FOR ONSITE WATER SYSTEMS

Treating water onsite provides the opportunity to save potable water for non-potable end uses. Onsite water treatment systems need not be limited to producing non-potable water; they can reduce the energy footprint in a building through heat recovery, generate nutrients, and produce drinking water. These market trends call on utilities and governments to create an enabling environment to deploy these innovations.

Producing Thermal Energy

Buildings incorporating onsite water systems can benefit from thinking beyond water savings by also considering wastewater heat recovery. Wastewater heat recovery refers to the extraction of thermal energy from warm wastewater, or treated non-potable water, and subsequent beneficial use of this energy to offset existing energy requirements. The benefits of wastewater heat recovery include offsetting some or all of the energy needed for onsite water treatment, decreasing energy costs, reducing greenhouse gas emissions and reliance of fossil fuels, and achieving potential green building certification credits. Recognizing these benefits, the SFPUC provides financial assistance for buildings with onsite water reuse systems to install wastewater heat recovery systems.

CASE STUDY: Reducing the Carbon Footprint in New York City

In early 2000, the Solaire building in New York City, U.S. incorporated an onsite blackwater treatment system to produce non-potable water for toilet flushing in residential units, cooling tower make-up water, and irrigation of the green roof. More recently, the onsite water system was upgraded by Natural Systems Utilities to reduce its energy consumption by installing a thermal energy recovery process which has allowed the system to achieve net zero energy use. The heat recovery system is designed to extract sensible heat from treated effluent and pre-heat the domestic hot water. This has resulted in a net energy neutral operation reducing the buildings overall carbon footprint. It also increases cooling tower efficiency by reducing the temperature of the make-up water.

Wastewater Heat Recovery System at the Solaire in New York City (image courtesy of Natural Systems Utilities)

CASE STUDY: Research on Reducing Global Warming Potential

Researchers with the U.S. EPA studied onsite non-potable water systems and their ability to reduce potable water demand, their environmental impacts, and their economic cost. The paper, *Onsite Non-potable Reuse for Large Buildings: Environmental and Economic Suitability as a Function of Building Characteristics and Location* also highlights the net benefits of incorporating onsite water treatment at the building-scale when considering cumulative global warming potential and the avoided costs of delivering drinking water. Furthermore, the incorporation of thermal energy recovery from wastewater can help offset building hot water heating requirements, thus reducing global warming potential, particularly when replacing electricity consumption over natural gas.

Nutrient Recovery

In addition to saving water, onsite water reuse systems can produce positive environmental benefits from nutrient recovery. Nutrient recovery is the practice of recovering nutrients such as nitrogen and phosphorus from wastewater and converting them into fertilizer. By utilizing nutrient recovery, can help mitigate problems such as eutrophication in sanitation systems and/or waterbodies.

CASE STUDY: Extracting Nutrients for Soil Amendments in San Francisco

A San Francisco based company, Epic CleanTec, is promoting a modern, circular approach for more sustainable cities by enabling buildings to recover value from biosolids. Epic CleanTec piloted a solids recovery system at NEMA, a residential tower in San Francisco. Solid waste from the building is filtered from the wastewater, dewatered, and captured. The solids are collected and transported off-site where it is converted into a high-quality sterile soil amendment. EpicCleanTec plans to use the soil product for bulk amendment for public parks as well as for use in bagged products for distribution and sale in gardening stores.

NEMA in San Francisco, CA (image courtesy of Epic CleanTec)

CASE STUDY: Resource Recovery in Nepal

The innovative Fecal Sludge Treatment Plant (FSTP) located in Lubhu, Nepal was built by the Environment and Public Health Organization (ENPHO) in collaboration with Mahalaxmi Municipality, BORDA, the CDD Society, and Nepalhilfe Beilngries. The FSTP piloted the use of prefabricated modules for construction, and is designed for resource recovery,with a treatment process that generates water suitable for irrigation, transforms bio-solids into soil fertilizers, and captures biogas that can be used for cooking. As the first of its kind in Nepal, the FSTP provides a model for how waste can be transformed into valuable resources.

A view of the treatment plant's prefabricated modules (photo courtesy of ENPHO)

Treating Process Water at Breweries

Water collection and treatment is not limited to the building sector. It most certainly can apply to the beverage industry. Water plays an important role in breweries, as a typical brewery can use up to 7 gallons (26 liters) of water to produce about 1 gallon (4 liters) of beer. Much of this water is used for rinsing bottles and cleaning equipment. This type of water, also known as 'process water'. Treating and reusing process water onsite can help breweries reduce their water footprint by as much as 50%.

However, breweries have limited guidance in how to safely reuse process water onsite. In San Francisco, CA, U.S., breweries interested in process water reuse looked to the SFPUC for help. To address this gap, the SFPUC developed guidance for brewery process water treatment systems, including pathogen and chemical control strategies for process water to be reused for tank and bottle rinses, floor wash down, boiler feed water, and as a source water for the beer. The SFPUC guidance includes requirements for source water characterization, source control, treatment, and ongoing monitoring to ensure the water is safe for these uses. The guidelines also ensure the same level of public health protection as the California drinking water standards for chemicals and is consistent with the risk-reduction goals of the California drinking water standards for microbial pathogens.

CASE STUDY: Oldest Brewery in San Francisco Recycles Process Water

With a $1 million grant from the SFPUC, San Francisco's oldest brewery Anchor Brewing Company installed a brewery process water treatment system to reduce their water consumption. The new water reuse system will treat 100% of process water at the brewery, with the capacity to recycle up to 20 million gallons (75,708,235 liters) of water annually, the yearly equivalent of about 1,300 San Francisco residents.

Anchor Brewing Company's Brewery
Process Water Reuse System in San Francisco, CA

CASE STUDY: Brewery Process Water Reuse at Seismic Brewing Company

Breweries are excellent applications for water reuse systems due to high water demand and numerous suitable uses for non-potable water. Seismic Brewing's onsite water reuse system was installed in 2016 as the brewery completed construction. The system treats wastewater from the brewing process so it can be reused onsite, helping to reduce the brewery's potable water demand by about 50%. The Seismic team recognized that to brew as responsibly as possible they would need to pursue an ambitious approach to maximizing water and energy efficiency. The onsite water treatment and reuse system, coupled with various clean energy initiatives, help to reduce the brewery's resource and carbon footprint.

Seismic Brewing facility in San Francisco, CA
(image courtesy of Seismic Brewing)

Producing Potable Water from Rainwater

Collecting and using rainwater can serve as a great way to conserve resources and produce drinking water. However, it is important that a rainwater harvesting system treats rainwater to remove bacteria and viruses and is maintained properly to protect public.

CASE STUDY: Producing Potable Water from Rainwater in Atlanta

Georgia Tech, located in Atlanta, Georgia, is leading the U.S. in demonstrating innovative green building design by capturing and treating rainwater for potable purposes. Rainwater at Georgia Tech's Kendeda Building for Innovative Sustainable Design is harvested from the roof, collected in a 50,000 gallon (189,270 liter) cistern, treated, and then piped throughout the building for potable water needs. The treatment includes filtration, ultraviolet disinfection, and continuous chlorination disinfection. The State of Georgia's Environmental Protection Division approved the rainwater-to-drinking system in 2020 and issued a permit that validates the system is producing safe drinking water. In addition to rainwater, the building also recycles graywater and stormwater to recharge the surrounding aquifer.

Kendeda Building for Innovative Sustainable Design in Atlanta, GA (image courtesy of Justin Chan Photography, Lord Aeck Sargent, and Miller Hull Partnership)

CASE STUDY: Using Rainwater for Beer Making in England

Manchester City, an English football club based in Manchester, England teamed up with brewers Heineken and water treatment technology company Xylem to brew a limited-edition beer from rainwater collected from the Etihad Stadium roof. The rainwater is purified from the stadium roof before providing it to Heineken's Manchester brewery to produce the beer. The beer, called Raining Champions, was also produced to raise awareness about the rising difficulties faced by many countries from environmental changes.

Producing Drinking Water from Blackwater

Water recycling includes opportunities to produce drinking water from blackwater. Appropriate treatment of blackwater for potable applications can augment existing water supplies. However, examples of collecting and treating blackwater is extremely limited in the U.S. Innovative pilots and research are underway to advance this concept from consideration to practice.

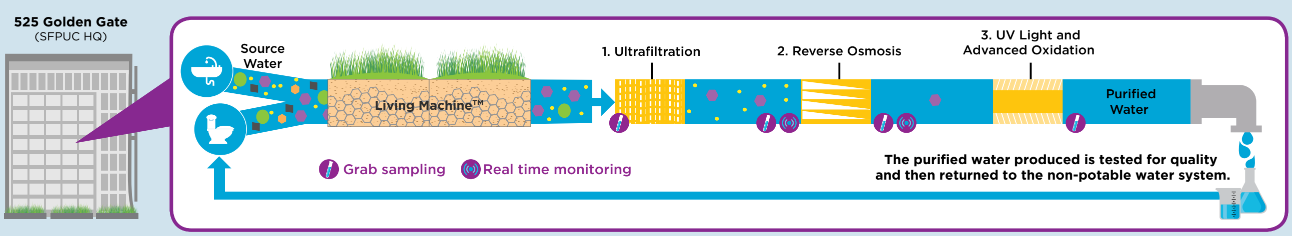
CASE STUDY: Piloting Small-Scale Purified Water in San Francisco

With an eye to the future, the SFPUC piloted one of the nation's first building-scale direct potable reuse demonstration project. Dubbed PureWaterSF, the project was aimed at better understanding the opportunities and challenges of decentralized potable reuse along with collecting data relevant for both small- and large-scale potable reuse.

The PureWaterSF treatment system train was temporarily added to a pre-existing constructed wetland system that treats blackwater for toilet flushing at the SFPUC headquarters in San Francisco. The system included ultrafiltration, reverse osmosis, and an ultraviolet advanced oxidation process to purify the effluent from the existing wetland system. The system, which was designed to have a small footprint while producing high-quality water able to meet drinking water standards, was able to treat approximately 85% of the water from the wetland system.

The PureWaterSF system was installed as a pilot project for a limited duration. The treatment and monitoring systems were designed and installed in June 2018 and the system was tested and monitored for eight months. Analytical samples were collected at every stage of the treatment train to verify the system's ability to meet drinking water standards and to document treatment performance. After analysis, all the water produced by the system was returned to the building's toilet flushing system. While the pilot project has concluded, the SFPUC currently is exploring the potential of including a permanent PureWaterSF system in its headquarters building.

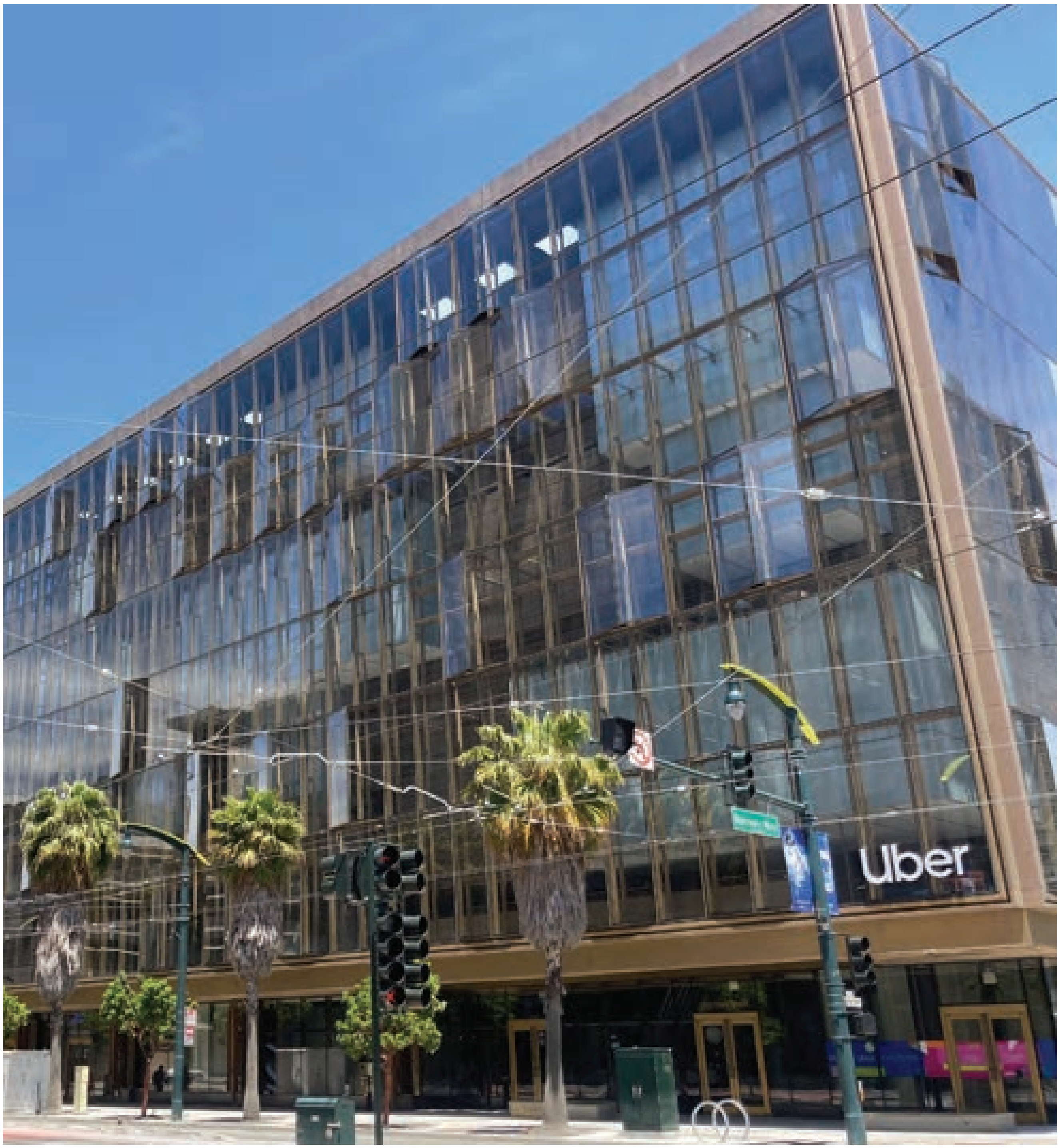
PureWaterSF Pilot Treatment System at 525 Golden Gate Avenue in San Francisco, CA



A Forward-Looking Vision for Plug and Play Systems

Reimagining our urban water systems demands collaboration and cross-cutting ideas. Looking to the future, plug and play water reuse systems are ideal, where the complexities of operating and installing these systems can be minimized. More plug and play systems can lead to increased uptake of onsite water reuse by taking advantage of modular approaches to allow for scaling up and simplifying the design of treatment systems. Consistency in policies and approaches can also pave the way to more plug and play systems and reduced burden on technology vendors and designers through more uniform standards.

Uber Headquarters in San Francisco, CA (image courtesy of HTEC)



TECHNICAL RESOURCES

PROGRAM GUIDANCE

- Onsite Non-potable Water Systems Guidance Manual
  - Guidance Manual Power Point Modules
- Making the Utility Case for Onsite Non-potable Water Systems
- Blueprint for Onsite Water Systems: A Step-by-Step Guide for Developing a Local Program to Manage Onsite Water Systems

PUBLIC HEALTH GUIDANCE

- Risk-Based Framework for the Development of Public Health Guidance for Decentralized Non-potable Water Systems

TOOLS FOR DEVELOPING REGULATIONS, ORDINANCES, AND RULES

- A Guidebook for Developing and Implementing Regulations for Onsite Non-potable Water Systems
- Model State Regulation for Onsite Non-potable Water Programs
- Model Local Ordinance for Onsite Non-potable Water Programs
- Model Program Rules for Onsite Non-potable Water Programs
- Technical Appendix: A Guidebook for Developing and Implementing Regulations for ONWS

MODELING TOOLS AND ANALYSIS

- Non-Potable Environmental and Economic Water Reuse (NEWR) Calculator
- Case Study of Energy and Greenhouse Gas Implications of Onsite Water Systems in San Francisco (see Appendix)

LOCAL, STATE, AND FEDERAL PROGRAMS

- City of Austin, TX: Onsite Water Reuse Systems Ordinance
- City and County of San Francisco, CA: Onsite Water Reuse Program
- New York City, NY: Water Conservation & Reuse Grant Pilot Program
- Colorado Department of Public Health & Environment: On-Site Wastewater Treatment Systems (see Appendix)
- California State Water Resources Control Board: Regulations for Onsite Treatment and Reuse of Non-potable Water (see Appendix)
- National Water Reuse Action Plan: Action 3.4 Develop Research and Tools to Support Onsite Non-potable Water Reuse Systems

APPENDIX

Onsite Water Treatment Systems and Innovations Projects Around the World

1 Bligh Street – Sydney, Australia

1 Bligh Street (image from ARUP on Archello)

Project Status: Completed

Project Size: 460,000 Square Feet

Alternate Water Sources:
- Blackwater

End Uses:
- Toilet Flushing
- Irrigation
- Cooling Towers

Treatment System Size: 26,500 Gallons/Day

Potable Water Use Reduction: 90%

Drivers: 6 Star Green Star

System Cost: $780,000

Annual O&M Cost: $65,000

Owner: Cbus Property, Dexus Property, and the Dexus Wholesale Fund

Project Description:

Completed in 2011, 1 Bligh Street was the first commercial high-rise building in Sydney to incorporate onsite blackwater recycling. The project was awarded the first combined private network and retailer's water recycling license in New South Wales, allowing Aquacell, the technology/system provider, to install a sewer mining system to supplement the building's blackwater supply. The sewer mining arrangement ensures that 100% of the non-potable demand within 1 Bligh Street can be met with recycled blackwater.

Drivers for Onsite Water Reuse:

The primary driver for onsite water reuse was achieving a 6-star Green Star rating for the building, the highest level for Australia's sustainability rating system for buildings. A cost benefit is achieved from operating the plant when compared to the 'business as usual' model.

Ownership Model:

Cbus Property, Dexus Propert,y and the Dexus Wholesale Fund own the building and its blackwater recycling system. Aquacell is engaged to manage the ongoing operation of the system and holds the private network and retailer licenses for the water recycling scheme. Annual audits are conducted by the Independent Pricing and Regulatory Tribunal (IPART), a branch of the New South Wales government.

Role of Public Utility in Project:

Sydney Water issued the sewer mining access agreement, which allows the water reuse system to draw additional blackwater into its treatment plant as a supplementary supply for the building's non-potable reuse. Sydney Water also entered into a trade-waste agreement with the building owners for the recycled water scheme at 1 Bligh Street, which determines the mechanism for reduction of potable water and sewer discharge fees.

Project Cost and Funding:

The total project cost $210,650,000 at the time of construction, with the water reuse system cost of approximately $780,000, and was funded by Cbus Property, Dexus Property, and the Dexus Wholesale Fund, who continue to manage the property. 1 Bligh Street was built by the construction firm Grocon and was a design collaboration between Architectus of Australia and Ingenhoven Architects of Germany.

Lessons Learned:

As this was the first major blackwater recycling scheme in Sydney, this project helped pave the way for several similar schemes in Australia and elsewhere globally.

There were significant learnings around how to integrate a sophisticated plant into the basement of a high-rise building of this size while ensuring safe access for installation, maintenance, and operation. Additional considerations included proper design and operation to provide fit-for-purpose water quality, addressing noise, odor, and incorporation of sustainable materials.

The system's continuous operation since the plant was commissioned has provided previously non-existent information, about the methodology and cost of maintaining and operating such a blackwater recycling facility, to many other projects built since.

Because there is significant regulatory oversight of this type of water recycling scheme, it was advantageous for a single organization to keep track of and manage regulatory approvals during each phase of the project's design, construction, and operation.

Reference: Colin Fisher, Aquacell (colinf@aquacell.com.au) +61 2 4721 0545

1 Bligh Street's onsite reuse system (image courtesy of Aquacell)

181 Fremont Mixed-use Tower — 181 Fremont Street

The 181 Fremont Mixed-use Tower (image courtesy of Jay Paul Company and Heller Manus Architects)

Project Status: Online

SFDPH Permit Issued: Yes

Size: 706,617 Square Feet

Alternate Water Sources:

- Graywater
- Rainwater

End Uses:

- Toilet Flushing
- Irrigation

Volume: 5,000 GPD; 1,300,000 Gallons/Year

Potable Water Use Reduction: 21%

Driver(S): Sustainability Goals, LEED Points, and Mandate (San Francisco Stormwater Management Ordinance)

System Cost: TBD

Annual O&M Cost: TBD

Owner: 181 Fremont Street LLC

Project Description:

The 70-story, 706,617 square foot, 181 Fremont Mixed-use Tower is a world-class example of modern design and sustainability in a high-rise project. The Tower, which is over 800 feet tall, features 435,000 square feet of class-A office space and 67 condominium residences on the top floors. Targeted for LEED Platinum, the development – located immediately adjacent to the future Transbay Transit Center – contains several sustainable features such as a 238-stall bike barn, a comprehensive transportation plan, regionally sourced building materials, and a comprehensive lighting design that increases access to the night sky and reduces urban sky glow.

The Tower also includes an onsite water system which captures, treats, and reuses graywater and rainwater. Graywater is collected from the condos (showers, laundry and bathroom sinks) and commercial office floors (bathroom sinks), while rainwater is captured from the roof of the building. The captured graywater is treated in an Aquacell system in the lowest basement level of the building. The self-contained treatment system is based on membrane bioreactor technology, a widely employed treatment technology for onsite systems. The system is ideal for the project because of its small footprint, tight quality controls, high yield and consistent production of high quality treated water. The onsite graywater system will provide up to 5,000 gallons per day of recycled water for toilet and urinal flushing and irrigation, saving annually up to 1.3 million gallons of potable water. Rainwater is treated in a PHOENIX Rainwater Treatment System, then combined with the treated graywater for the final stage of disinfection. The two sources utilize different process treatment trains by design, however the systems are integrated, offering a central control interface and providing the building with a single supply of highly treated recycled water.

Drivers for Non-potable Water Reuse:

From the beginning of the design stages, a primary objective of the Tower was to showcase ambitious sustainability measures in an ultra-modern design. The Tower serves as a localized example of how buildings can achieve multiple aesthetic and sustainability goals. Implementing the onsite water system also allows the Tower to obtain additional LEED points towards LEED Platinum certification. The project received an additional six Water Efficiency (WE) points and two Regional Priority (RP) points by implementing the system. Additionally, by integrating rainwater into the non-potable water system, the Tower is able to fulfill the requirements of the San Francisco Stormwater Management Ordinance. The Stormwater Management Ordinance requires projects disturbing 5,000 square feet or more of the ground surface to decrease the project's post-construction stormwater runoff rate and volume by 25% for the 2-year 24-hour design storm.

Ownership Model:

While the onsite water system is owned by 181 Fremont Street LLC, system design, permitting, installation supervision, commissioning, and operations is the responsibility of PHOENIX Process Equipment Co. (via joint-venture with Aquacell).

Project Cost: TBD

Annual Operations & Maintenance Cost: TBD

Service Costs to Residents or Tenants: TBD

Incentives provided by SFPUC:

The 181 Fremont Tower received a $250,000 grant from the SFPUC through the Onsite Water Reuse Grant Program.

References: Ben Arnold, PHOENIX/Aquacell (bena@aquacell.us)

A rendering of the treatment system at 181 Fremont Mixed-use Tower (image courtesy of PHOENIX/Aquacell)

City of Austin Permitting and Development Center – Austin, TX

City of Austin Permitting and Development Center (Image courtesy of Austin Water)

Project Status: Completed

Project Size: 260,000 Square Feet

Alternate Water Sources:
- Rainwater
- A/C Condensate
- Blackwater

End Uses:
- Toilet Flushing
- Irrigation
- Cooling Towers

Treatment System Size: 5,000 Gallons/Day

Potable Water Use Reduction:
75%; up To 1,500,000 Gallons/Year

Drivers:
- Demonstration Project
- Public Education
- Promotion of Onsite Reuse

System Cost: $1,700,000 For Blackwater Reuse System and Dual Plumbing; $625,000 for Rainwater and Condensate Reuse System

Annual O&M Cost: Tbd

Owner: City Of Austin

Project Description:

Completed in the summer of 2020, Austin's new 260,000 square foot Permitting and Development Center was designed to office all city personnel involved in planning and development processes. The building is the ideal location for the City to demonstrate and promote sustainable water management practices. Signage throughout the property is meant to educate customers and visitors about the building's innovative water reuse systems.

Blackwater from the building is treated onsite through a 5,000 gallon per day Membrane Aerated Bioreactor (MABR) and is reused for toilet and urinal flushing. The blackwater treatment system and equipment room are tucked under an outdoor pedestrian walkway. Plants growing out of one of the treatment reactors blend with the walkway's landscaping. Water from the building's rain runoff and A/C condensate is collected in two 20,000-gallon storage tanks and is reused for landscape irrigation and a circulating water feature. The two tanks are buried under the building's lawn which hosts gatherings and exercise classes.

Drivers for Onsite Water Reuse:

In 2018, the City of Austin adopted its Water Forward Plan, a long-term integrated water resources plan for the next 100 years. Water Forward recommends developing major water supply projects and incremental solutions such as demand management and reuse. The onsite water treatment and reuse systems installed at the new Permitting and Development Center were implemented in accordance with Water Forward's recommendations.

Water Forward also recommends a city ordinance to require new commercial and multifamily buildings over a threshold size to install dual plumbing and to re-use water generated onsite for indoor and outdoor non-potable purposes. The installation and operation of the reuse systems at the Permitting and Development Center provide valuable experience that is informing policy maker's development of the City's onsite reuse ordinance.

Ownership Model:

The City owns the building and reuse systems. The rainwater/condensate reuse system is operated and maintained by a third-party facility management contractor, and the blackwater reuse system is operated and maintained by Austin Water, the City's water, wastewater, and reclaimed utility. State regulations require that blackwater reuse systems are operated by a licensed wastewater treatment plant operator such as Austin Water.

Role of Public Utility in Project:

While Austin Water initiated the blackwater reuse demonstration project and owns the treatment system, the building itself and the rainwater/condensate reuse system are owned by the City's Development Services Department. Interdepartmental collaboration was key to the success of the overall project, especially since the blackwater reuse system was proposed after the building had been designed.

Project Cost and Funding:

The blackwater reuse system cost $1,700,000 which included $145,000 for dual plumbing. The project manager noted that a portion of this cost was incurred by making construction accommodations for the treatment system after the building had already been designed. The rainwater/condensate reuse system cost $625,000.

Lessons Learned:

As a first of its kind project in the City of Austin, it was critical to hold in-person meetings with city staff to explain the project and its purpose. Getting the blackwater reuse system through the City's development review process was challenging, with hang-ups at multiple stages of review and approval. As a result of this project and the expectation of more to come, the City will be requiring backflow prevention plans to be submitted earlier on in the development review process. This will facilitate fewer construction and building occupancy disruptions while ensuring adequate cross-connection prevention measures between the potable and non-potable water supplies. Early consultation with the City's backflow prevention group resulted in the incorporation of a time and water saving dye injection system that allows cross-connection testing to occur without shutting the building down to drain water lines.

Reference: Katherine Jashinski, Austin Water (Katherine.Jashinski@austintexas.gov) 512-972-0390

Onsite reuse system treatment room (image courtesy of Austin Water)

Bill Sorro Community - Affordable Housing Project — 200 6th Street

The Bill Sorro Community (image courtesty of Kennerly Architecture)

Project Status: Online

SFDPH Permit Issued: Yes

Size: 69,000 Square Feet

Alternate Water Sources:

- Rainwater

End Uses:

- Toilet Flushing

Volume: 45,000 Gallons/Year

Potable Water Use Reduction: 10%

Driver(S): Project Sustainability Goals and Mandate (San Francisco Stormwater Management Ordinance)

System Cost: $280,000 (Estimated)

Annual O&M Cost: TBD

Owner: Mercy Housing California

Project Description:

Located in the South of Market neighborhood in San Francisco, the 69,000 square-foot Bill Sorro Community, is a 100% affordable housing development. The project demolished an existing building in favor of a nine-story, 85 foot tower with 67 affordable family apartments, restaurant, retail, and community space. The project installed a 3,000 gallon cistern to collect rainwater from an 8,800 square-foot roof. The cistern is sized to hold the required average annual detention volume associated with the San Francisco Stormwater Management Ordinance design storm event. Treatment for the rainwater consists of particulate filters to remove the suspended solids and ultraviolet (UV) disinfection prior to being distributed throughout the building for toilet flushing purposes. The system offsets an estimated 45,000 gallons of potable water annually, reducing the project's potable water use by approximately 10%.

The project is also located in a designated recycled water use area under San Francisco's Recycled Water Use Ordinance, and therefore is plumbed to be ready for the eventual use of SFPUC recycled water for toilet flushing when rainwater is not available.

Drivers for Non-potable Water Reuse:

The project team installed the rainwater harvesting system to meet the requirements of the San Francisco Stormwater Management Ordinance. The Stormwater Management Ordinance requires projects disturbing 5,000 square feet or more of the ground surface to decrease the project's post-construction stormwater runoff rate and volume by 25% for the 2-year 24-hour design storm. Installing a rainwater harvesting system with a 3,000 gallon cistern enables the project to meet these requirements. Another driver for implementing the rainwater harvesting system is to meet project sustainability goals, include exceeding the San Francisco Green Building Ordinance GreenPoint Rated system for multi-family buildings.

Ownership Model:

Mercy Housing California (MHC) is the owner/developer of the Bill Sorro Community. The City and County of San Francisco owns the land under the building, so there is a ground lease for the land with the City and County of San Francisco. MHC assigned staff with the appropriate backgrounds from their maintenance team to be responsible for operating and maintaining the rainwater harvesting system. Maintenance staff are trained by the system manufacturer at the completion of the construction for continued operation and maintenance. The basic operations, inspection schedule, and routine preventative maintenance of the non-potable rainwater collection system were covered during this initial training.

Project Cost:

The total cost for the rainwater harvesting system is estimated to be approximately $280,000.

Annual Operations & Maintenance Cost: TBD

Service Costs to Residents or Tenants:

There are no service costs to the tenants for the use of the rainwater.

Reference: Sharon Christen, Mercy Housing California (schristen@mercyhousing.org)

The Bill Sorro Community (image courtesy of Kennerly Architecture)

Denver Water Administration Building – Denver, Colorado

3rd stage of wetland treatment during its construction on the roof (image courtesy of Denver Water)

Project Status: Completed

Project Size: 186,000 Square Feet

Alternate Water Sources:
- Rainwater
- Blackwater

End Uses:
- Toilet Flushing
- Irrigation

Treatment System Size: 7,000 Gallons/Day

Potable Water Use Reduction:
1.4 Million Gallons/Year

Drivers:
- Stretch Limited Water Supplies in an Arid Environment
- Eliminate Barriers for Future Water Reuse Projects in Denver
- Demonstration Project

System Cost: $1.83 Million

Annual O&M Cost: $127,000

Owner: Denver Water

Project Description:

Two sources of water will be collected and reused at Denver Water's new Administration Building. Rainwater will be collected from the roof and from the solar panels that cover a portion of the new parking garage. This water will be filtered and stored for landscape irrigation.

The second source of water is blackwater collected from all sinks, toilets, drinking fountains, and cafeteria operations in the building, diverting 100% of the water that would normally go to the sanitary sewer. This water will undergo large-object screening, aerobic and anaerobic biological treatment, three stages of wetland treatment (tidal and plug flow), cartridge filtration, ultraviolet light disinfection, and chlorination. The treatment process is designed to meet Colorado regulations for onsite non-potable reuse, with 8.5-log virus, 7.0-log protozoa, and 6.0-log bacteria removal. Purified water from this process will be used to flush toilets in the Administration Building and any excess will supplement captured rainwater for irrigation.

After basic equipment testing and commissioning by the contractor, Denver Water staff will start, optimize, and run the system.

Drivers for Onsite Water Reuse:

Denver is located in a high plains desert where its water supply (snowmelt from the Rocky Mountains) is frequently threatened by drought and a changing climate. Denver Water opened a 30 MGD non-potable reuse plant and associated distribution system in 2004; this onsite recycling project aims to demonstrate an additional way to reuse water and the future of sustainable urban water use in Colorado.

Ownership Model:

The system is owned and operated by Denver Water.

Role of Public Utility in Project:

This project was a joint effort between the public utility agency Denver Water and its design partners, Stantec and Aquanova. Denver Water staff developed a model to determine the volume of rainwater and blackwater that could be collected, the amount required to meet the entire demand for toilet flushing, and how much excess would remain for irrigation. This model was used to size storage tanks and determine the amount of landscaping that could be irrigated with non-potable water, as there is not enough supply to irrigate the entire site.

At the project's inception, toilet flushing with recycled water was not permitted in Colorado. Denver Water worked with legislators to introduce a bill in the Colorado General Assembly to change that. Staff then worked with the Colorado Department of Public Health and Environment to enact risk-based water quality standards for onsite non-potable water systems based on guidance from the National Blue Ribbon Commission for Onsite Non-potable Water Systems.

Rainwater capture at this scale is also prohibited by Colorado water law. Denver Water planners and attorneys filed, argued, and won a case in water court by promising to replace the volume of rainwater harvest with water from other sources in order to keep the Platte River whole, and to satisfy the rights of downstream water users.

2nd stage of wetland treatment in building's interior (image courtesy of Denver Water)

Denver Water hopes that the effort to legalize, permit, and demonstrate onsite non-potable water reuse at its Administration Building will pave the way for installation of onsite water reuse systems at future developments in Colorado.

Project Cost and Funding:

The total cost of the Administration Building was approximately $55 million. This includes the cost of the onsite non-potable water system, which was $1.83 million. Denver Water issued revenue bonds that included Green Bonds to pay for the building, which was part of a $204.8 million campus redevelopment.

Lessons Learned:

Denver Water needed project approval from both the City of Denver and the State's regional wastewater authority. Denver Water staff had to work with the City's policy team and the regional wastewater authority to determine which inspection responsibilities belonged to which regulating body. Significant effort was required to coordinate between the City's Water, Wastewater, and Public Works departments, especially since in Denver they exist as separate entities rather than within the same organization. And a late design alteration was required when it was discovered that the regional wastewater authority does not allow stormwater to be discharged into the sanitary sewer, even if through an emergency overflow.

Also, it was not anticipated that dual water and wastewater certifications would be required to operate the facility, which posed a challenge for staff to obtain additional certification.

The guidance developed by the National Blue Ribbon Commission and its model regulations for onsite non-potable reuse were incredibly helpful to the Colorado Department of Public Health and Environment enacting its own standards for onsite non-potable water systems. All stakeholders supported the model regulations which allowed them to be adopted quickly with minimal modification.

Reference: Jeremy Ross, Denver Water (jeremy.ross@denverwater.org), 303-628-6596

DGS Natural Resources Building – Sacramento, CA

DGS Natural Resources Building under final stage of construction (image courtesy of HTEC)

Project Status: Under Construction (Estimated Completion Late 2021)

Project Size: 838,000 Square Feet

Alternate Water Sources:

- Graywater

End Uses:

- Toilet Flushing

Treatment System Size: 6,000 Gallons/Day

Potable Water Use Reduction:
25%; 1.52 Million Gallons/Year

Drivers: Leed Platinum Certification

System Cost: $300,000 (Estimated)

Annual O&M Cost: $3,500 (Estimated)

Owner: State Of California

Project Description:

Installation is underway for a 6,000 gallon per day graywater reuse system in the State of California's Department of General Services Natural Resources Building in Sacramento, CA. The building, located on P Street in the heart of downtown Sacramento, will serve as the new Department of Natural Resources headquarters. The 20-story, 838,000 square foot tower will include a 300-seat auditorium, office space, retail space, a food court, and a childcare facility that will be able to accommodate 120 children.

The reuse system filters graywater from showers and bathroom sinks through an 800-micron prefilter before it is collected and treated in a combined collection/bioreactor tank. The membrane bioreactor is NSF-350 certified and allows the water to be transferred to a treated water storage tank without any additional chemical treatment. The treated water will be recycled for toilet and urinal flushing. System performance and maintenance will be monitored locally by the building management system, with the capability of remote monitoring via cellular connection.

Drivers for Onsite Water Reuse:

The system was implemented to help the building achieve its LEED Platinum rating by reducing the potable water demand by 25%.

Ownership Model:

The building and its internal graywater treatment system is owned by the State of California. Heat Transfer Equipment Company will either conduct the O&M services or provide the necessary training for owner operation.

Role of Public Utility:

No involvement in design or operations.

Project Cost and Funding:

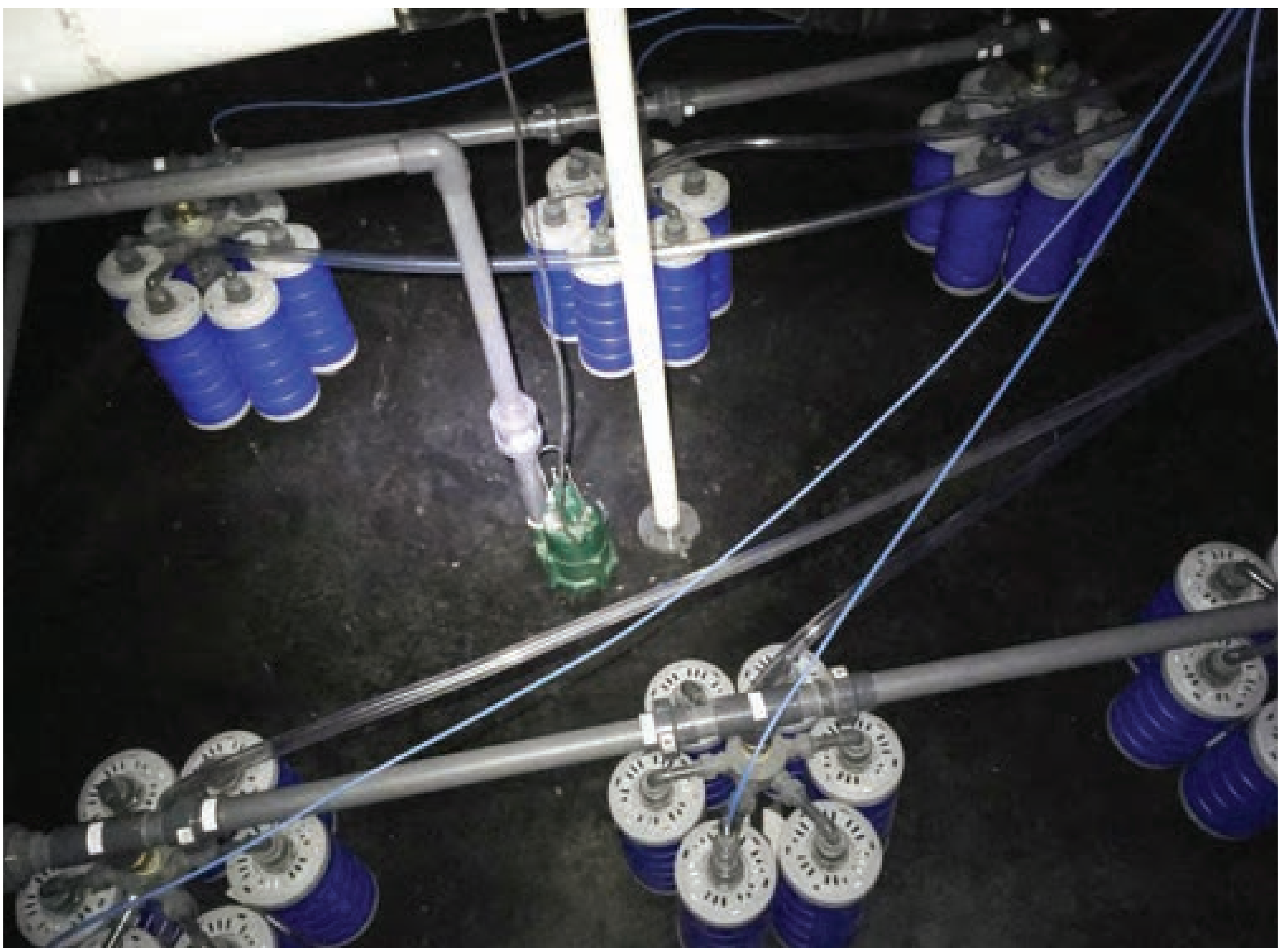
It is estimated that the graywater treatment and reuse system cost roughly $300,000, and the O&M will cost about $3,500 annually.

Lessons Learned:

It was a challenge to accurately estimate the volume of graywater flows. Over the course of project design, fixture counts and occupancy numbers were constantly being revised and updated, which caused the estimated amount of graywater supply to drastically change. As a result, the originally specified system could no longer handle the revised design conditions. Due to the necessary design update being recognized late in the project development process, additional space could not be allocated for increasing the system's treatment capacity.

Fortunately, the manufacturer was able to scale up the graywater treatment capacity within the limitations of the existing footprint so that the facility could still meet its LEED Platinum design goals of a 25% water reduction without having to allocate additional space for the increased system capacity.

Reference: Bill McCabe, Heat Transfer Equipment Company (bill@htecompany.com)



Onsite reuse system's filter cartridges (image courtesy of HTEC)

The Exploratorium — Pier 15

The Exploratorium at Pier 15 (image courtesy of Amy Snyder © Exploratorium, All rights reserved)

Project Status: Online

SFDPH Permit Issued: Yes. NPDES Permit received from Water Quality Control Board.

Size: 333,000 Square Feet

Alternate Water Sources:
- Rainwater
- Bay Water

End Uses:
- Toilet Flushing
- Heating and Cooling

Volume: Up to 2,364,000 Gallons/Year (Rainwater Harvesting System and Bay Water Heating and Cooling System)

Potable Water Use Reduction: 30% (Rainwater Harvesting System Only)

Driver(S): Project Sustainability Goals, Public Education, Leed Platinum Certification, and Mandate (San Francisco Stormwater Management Ordinance)

System Cost: Not Available

Annual O&M Cost: TBD

Owner: The Exploratorium

Project Description:

After spending 44 years at the Palace of Fine Arts, in April of 2013, the internationally renowned Exploratorium moved to its new 330,000 square feet of indoor and outdoor exhibit space on Pier 15. The LEED Platinum museum, host to over 1,000,000 visitors in its first year, houses more than 600 exhibits and experiences for guests to explore and tinker. The new location, literally on top of San Francisco Bay, is being called a twenty-first-century learning laboratory, and is equipped with oceanographic equipment, which measures the height and direction of tides, pollutants in the air, and the weather.

One of the core goals of the Exploratorium is sustainability. This goal is showcased throughout the museum, and has been validated with the building's LEED Platinum designation. A major goal the museum is working towards is to become the largest net-zero energy use museum in the United States. Water conservation is also a goal of the museum. In addition to the over 78,000 square feet of solar panels, the Exploratorium utilizes Bay water in its heating and cooling system, eliminating the need for a cooling tower, thereby saving an annual 2,000,000 gallons of water. To install the Bay water system, the Exploratorium had to obtain a National Pollutant Discharge Elimination System (NPDES) Permit from the local State of California Regional Water Quality Control Board to ensure that the system would not negatively impact the aquatic life and water quality of the Bay. The Exploratorium also has to provide annual reports to the State to show compliance with their NPDES permit requirements.

The Exploratorium also has a 38,600-gallon cistern, which captures rainwater from the roof for toilet flushing purposes. The rainwater harvesting system can save up to 364,000 gallons annually, reducing water usage by approximately 30% in a year of average rainfall. Finally, the building is equipped with high- efficiency dual-flush toilets, waterless urinals, and low-flow sensor-operated faucets— reducing water consumption by another 30%.

Drivers for Non-potable Water Reuse:

From the beginning of the design stages for the Exploratorium, two primary objectives were to have a building that demonstrated the museum's ambitious sustainability goals and served as a localized example of how buildings can be built in response to climate change. Incorporating the Bay water heating and cooling system and the rainwater harvesting system helped to achieve these objectives.

Implementing the onsite water systems also allowed the Exploratorium to obtain additional LEED points to help the project achieve LEED Platinum certification. The project received an additional six Water Efficiency (WE) points and two Regional Priority (RP) points by implementing the systems.

Finally, the rainwater harvesting system also allows the Exploratorium to fulfill the requirements of the San Francisco Stormwater Management Ordinance. The Stormwater Management Ordinance requires projects disturbing 5,000 square feet or more of the ground surface to decrease the project's post-construction stormwater runoff rate and volume by 25% for the 2-year 24-hour design storm.

Ownership Model:

The Bay water cooling and heating system and rainwater harvesting system are owned, operated, and maintained by the Exploratorium.

Project Cost:

The new Exploratorium cost $220 million to build. The specific costs for the Bay water cooling and heating system cost and the rainwater harvesting system are not available. The NPDES permit from the Regional Water Quality Control Board for the Bay water heating and cooling system cost $1,943 in 2011.

Annual Operations & Maintenance Cost: TBD

Service Costs to Residents or Tenants:

Not applicable

Reference: Jennifer Fragomeni, The Exploratorium (**jfragomeni@exploratorium.edu**)

Inside the Bay heating and cooling room at the Exploratorium (image courtesy of Amy Snyder © Exploratorium, All rights reserved)

James R. Herman Cruise Terminal — Pier 27

The James R. Herman Cruise Terminal at Pier 27 (image courtesy of San Francisco Public Works)

Project Status: Online

SFDPH Permit Issued: Yes

Size: 88,000 Square Feet

Alternate Water Sources:

- Rainwater

End Uses:

- Toilet Flushing
- Irrigation

Volume: 370,000 Gallons/Year

Potable Water Use Reduction: 50%

Driver(S): LEED Certification and Mandate (San Francisco Stormwater Management Ordinance)

System Cost: $930,000

Annual O&M Cost: $38,000

Owner: The Port of San Francisco

Project Description:

On September 18, 2014, the James R. Herman Cruise Terminal – located at Pier 27 – opened its doors for business. The approximately 88,000 square foot, two-level cruise terminal facility, is located in the heart of The City right under Telegraph Hill, with San Francisco's famous sights within walking distance. The modern terminal, designed to accommodate ships with up to 4,000 passengers, has all the functions and amenities a cruise ship might want. The terminal also includes a 2.3-acre raised plaza with grass and benches intended as a respite for visitors and residents alike.

A core objective of the James R. Herman Cruise Terminal design team was the integration of sustainable technologies in the project. The project was constructed using sustainable design practices in accord with Leadership in Energy & Environmental Design (LEED) standards. The terminal achieved LEED Silver certification due to all of its sustainable initiatives. The following are just some of the sustainable features of the terminal:

- Indoor plumbing fixtures operate 40% more efficient than existing code;
- Landscape design resulted in more than 50% irrigation reduction compared to a mid-summer baseline;
- Energy efficient building envelope, lighting, and HVAC systems reduce energy needs by more than 18% compared to a mid-summer baseline;

- Building materials composed heavily of recycled, regional, and Forest Stewardship Council certified wood; and
- A construction process which diverted more than 75% of construction waste materials from landfill.

The terminal also includes a rainwater harvesting system. Rainwater from the roof is sent to a pre-filtration system, removing larger debris, before the collected rainwater drains to a five-tank, 42,000-gal rainwater harvesting system. The five cisterns are able to capture over 75% of the annual rainfall that hits the roof surface. The captured rainwater is used for toilet flushing in the main terminal, and also for outdoor irrigation of the facility's gardens. However, before being used, the rainwater must undergo treatment. When there are toilet flushing and irrigation demands, rainwater is pumped from the cisterns through a filtration and ozone disinfection treatment system before entering dedicated plumbing lines to the toilets and irrigation zones. A digital rainwater control station houses all of the filters, treatment equipment, and controls.

The innovative rainwater harvesting system installed at the terminal saves approximately 370,000 gallons of potable water per year. The harvested rainwater covers roughly 70% of the terminal's total non-potable demand, reducing the terminals overall water use by nearly 50%.

Drivers for Non-potable Water Reuse:

Implementing the rainwater harvesting system allowed the terminal to obtain additional LEED points to help the project achieve LEED Silver certification. The project received an additional six Water Efficiency (WE) points and two Regional Priority (RP) points by implementing the systems.

Additionally, the rainwater harvesting system also allows the terminal to fulfill the requirements of the San Francisco Stormwater Management Ordinance. The Stormwater Management Ordinance requires projects disturbing 5,000 square feet or more of the ground surface to decrease the project's post-construction stormwater runoff rate and volume by 25% for the 2-year 24-hour design storm.

Ownership Model:

The rainwater harvesting system is owned by The Port of San Francisco who has hired Metro Cruise Services to operate and maintain the system.

Project Cost:

The James R. Herman Cruise Terminal cost $93 million to build. The rainwater harvesting system cost $930,000. These systems increased total construction costs by 1%.

Annual Operations & Maintenance Cost:

Maintaining the rainwater system has an annual cost of $38,000.

Service Costs to Residents or Tenants:

Not applicable

Reference: Lucas Yee, San Francisco Public Works (Lucas.Yee@sfdpw.org)

The rainwater cisterns at Pier 27 (image courtesy of San Francisco Public Works)

Market Street Place — 945 Market Street

Market Street Place (image courtesy of CRP/Cypress Market Street, LLC)

Project Status: Online

SFDPH Permit Issued: Yes

Size: 283,940 Square Feet with 91,870 Square Feet of Sub-Grade Parking.

Alternate Water Sources:
- Rainwater

End Uses:
- Toilet Flushing
- Cooling Tower Make-Up

Volume: 446,000 Gallons/Year

Potable Water Use Reduction: 12%

Driver(S): LEED Points and Mandate (San Francisco Stormwater Management Ordinance)

System Cost: TBD

Annual O&M Cost: TBD

Owner: CRP/Cypress Market Street LLC

Project Description:

The 283,940 square-foot Market Street Place, scheduled to open in 2016, is a six-level retail center with 91,870 square feet of subgrade parking located at 945 Market Street. Situated between 5th and 6th Streets, the center contains an 18,300 gallon cistern which collects rainwater from a 48,000 square-foot roof. The cistern is sized to hold the required average annual detention volume associated with the San Francisco Stormwater Management Ordinance design storm event. Treatment for the rainwater is provided by a Water Control Corporation RW-Series Skid Mounted Water Reclamation Packaged System consisting of 25 and 5 micron filtration followed by ultraviolet (UV) disinfection. After treatment and disinfection, the harvested rainwater is used for cooling tower make-up and to flush 54 toilets and 18 urinals. The system offsets an estimated 446,000 gallons of potable water annually, reducing the project's potable water use by approximately 12%.

Drivers for Non-potable Water Reuse:

The project team installed the rainwater harvesting system to obtain the LEED innovation in design credit of 40% potable water use reduction.

The project team also installed the rainwater harvesting system to meet the requirements of the San Francisco Stormwater Management Ordinance. The Stormwater Management Ordinance requires projects disturbing 5,000 square feet or more of the ground surface to decrease the project's post-construction stormwater runoff rate and volume by 25% for the 2-year 24-hour design storm. Installing a rainwater harvesting system with an 18,300 gallon cistern enables the project to meet these requirements.

Ownership Model:

The rainwater harvesting system is owned by CRP/ Cypress Market Street LLC, who will contract a building management firm for operation. The contracted building operator will operate and maintain the system.

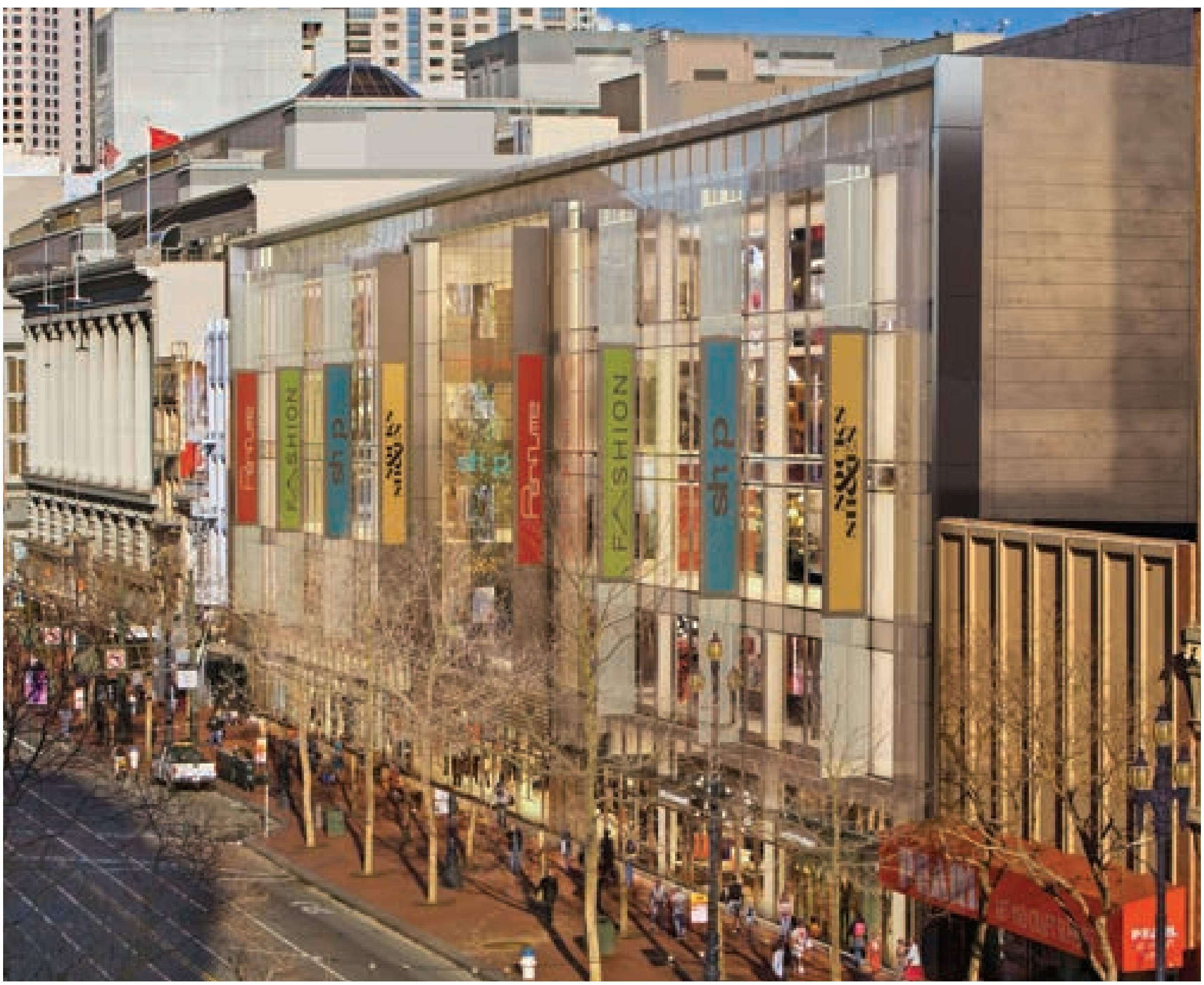
Project Cost: TBD

Annual Operations & Maintenance Cost: TBD

Service Costs to Residents or Tenants:

There are no service costs to the commercial tenants for use of the rainwater.

Reference: Phillip Alexander, Randall Lamb (PAlexander@RandallLamb.com); and Kathy Kwong, Gensler (Kathy_Kwong@Gensler.com)



Market Street Place (image courtesy of CRP/Cypress Market Street, LLC)

San Francisco Museum of Modern Art — 151 Third Street

The San Francisco Museum of Modern Art (image courtesy of Snohetta)

Project Status: Online

SFDPH Permit Issued: Yes

Size: 235,000 Square Feet

Alternate Water Source:
- Rainwater

End Uses:
- Toilet/Urinal Flushing
- Irrigation
- Cooling Tower Make-Up

Volume: 1,000 GPD; 365,000 Gallons/Year

Potable Water Use Reduction: TBD

Drivers: Sustainability Goals, Reduce Potable Water Use, and Compliance with San Francisco Stormwater Management Ordinance

System Cost: Not Available

Annual O&M Cost: Not Available

Owner: San Francisco Museum of Modern Art

Project Description:

The San Francisco Museum of Modern Art (SFMOMA) is a world-renowned modern art museum, showcasing over 33,000 pieces of modern and contemporary art. After a three year expansion project, SFMOMA opened to the public in May 2016 with nearly triple the gallery space, free public spaces, free admission for all visitors 18 and under and enhanced educational programs. In addition to the new, ultra-modern architectural design, SFMOMA incorporated sustainable elements throughout the museum such as garden terraces and a living wall. SFMOMA's commitment to sustainability is also evident through the implementation of its non-potable water reuse system. The non-potable system captures rainwater for reuse in the building. The captured water is treated by a filter assembly including a 50 micron filtration filter and a 20 micron bag type filter. After treatment, the water is disinfected and distributed for non-potable applications, which includes toilet flushing, make-up water for the cooling towers, and drip irrigation of the gardens and living wall. Overall, the system is saving 365,000 gallons of potable water annually, equating to roughly 1,000 gallons of water per day.

Drivers for Non-potable Water Reuse:

SFMOMA is building on its tradition of innovation through the implementation of the onsite water system. By harvesting rainwater, the building is offsetting a significant amount of potable water needed for toilet flushing, irrigation, and cooling tower operation. Secondly, the integration of the onsite water system enables SFMOMA's expansion project to meet the requirements of San Francisco's Stormwater Management Ordinance. The Stormwater Management Ordinance requires projects disturbing 5,000 square feet or more of ground surface to decrease their post construction stormwater runoff rate and volume by 25% for the 2-year, 24-hour design storm.

Ownership Model:

The rainwater reuse system is owned, operated, and maintained by the SFMOMA.

Project Cost:

The estimated cost of onsite water system is not available.

Annual Operations & Maintenance Cost:

The estimated annual cost to operate and maintain the onsite water system is not available.

Service Costs to Residents or Tenants:

Not Applicable

Incentives provided by SFPUC:

Not Applicable

Reference: Bob Reuter, Reuter Project Management (reuter@ix.netcom.com)

The San Francisco Museum of Modern Art's onsite water system (image courtesy of Bob Reuter)

San Francisco Permit Center at 49 South Van Ness Avenue – San Francisco, CA

Rendering of 49 South Van Ness (image courtesy of SOM)

Project Status: Completed

Project Size: 523,800 Square Feet

Alternate Water Sources:
- Rainwater
- Graywater

End Uses:
- Toilet/Urinal Flushing
- Subsurface Irrigation

Treatment System Size: 5,000 Gallons/Day

Potable Water Use Reduction:
17%; 482,000 Gallons/Year

Drivers: Non-potable Water Ordinance Compliance

System Cost: $400,000

Annual O&M Cost: $50,000

Owner: Related California

Project Description:

The new 16-story Permit Center provides office space for 1,800 city employees and is home to San Francisco's Public Works, Planning, and Building Inspections, and other city departments, consolidating all the City's permitting agencies into one space.

Graywater is collected from showers and lavatory faucets in the building and routed to a collection tank in the plant room. Rainwater is also collected from the building's rooftop, which is directed into a separate collection tank. The graywater passes through a 130-micron filter and then undergoes a biological treatment process before it enters a break tank, while rainwater is pumped directly from its collection tank into the break tank. From the break tank, the mixture of rainwater and filtered graywater is pumped through the treatment skid for further filtration, UV disinfection, and chlorine dosing to maintain a residual in the treated water storage tank. Non-potable water in the treated storage tank is used to supply the toilets, urinals, and irrigation needs. Potable water make-up will be supplied to the tank, with an air gap for backflow prevention, if the alternative water supply is too low to meet the demands.

Drivers for Onsite Water Reuse:

Based on its size, the project is required to comply with the Non-Potable Ordinance.

Ownership Model:

Related California is the owner of the water reuse system. The contract for the service and maintenance of the system has not yet been awarded.

Project Cost and Funding: The total project cost is unavailable, but the reuse system cost approximately $400,000 plus installation.

Lessons Learned:

There is immeasurable value in equipping contractors with as much knowledge as possible prior to the installation of an onsite water reuse system, and it is best to assume that contractors "don't know what they don't know" when it comes to installation. The instructional drawings and documents provided with reuse systems are detailed and can be intimidating, and contractors have always been appreciative of extra time spent explaining the installation process.

Aquacell treatment systems are manufactured to minimize the effort required to install them, saving time and money. The treatment skids are delivered to the site with the bulk of the plumbing & electrical work already completed. A pre-installation meeting with the contractor, with time spent explaining the sequence of installation, can aid the process.

Reference: David Guan, Cal Pacific Systems (David.guan@calpacificsystems.com), 415-252-8600

Onsite reuse system treatment skid at 49 South Van Ness (image courtesy of Aquacell)

San Francisco Public Utilities Commission Headquarters — 525 Golden Gate Avenue

San Francisco Public Utilities Commission Headquarters

Project Status: Online

SFDPH Permit Issued: Yes

Size: 277,500 Square Feet

Alternate Water Sources:
- Blackwater
- Rainwater

End Uses:
- Toilet Flushing
- Subsurface Irrigation

Volume:
Up to 5,000 gpd

Potable Water Use Reduction: 50%

Driver(s): LEED Points, Pilot Project, and Public Education

System Cost: $1,000,000 (Living Machine and Rainwater Harvesting System)

Annual O&M Cost: TBD

Owner: SFPUC

Project Description:

In the summer of 2012, the San Francisco Public Utilities Commission (SFPUC) completed construction of its new, 277,500 square-foot headquarters at 525 Golden Gate Avenue in San Francisco's Civic Center District. The LEED Platinum building, housing approximately 950 employees, contains two onsite water systems – a Living Machine® and a rainwater harvesting system.

The Living Machine®, treats all of the building's wastewater, up to 5,000 gallons per day, and then distributes the treated water for toilet flushing. The system reduces the building's potable water consumption by approximately 65% and provides an annual potable offset of approximately 1,500,000 gallons. The system utilizes a series of diverse ecologically engineered wetlands, located in the sidewalks surrounding the headquarters and in the building lobby, to treat the wastewater. This unique treatment process blends function and aesthetics – the wastewater is treated to San Francisco Department of Public Health (SFDPH) reuse standards while providing a high-profile pilot project for on-site water reuse.

The building also has a 25,000 gallon cistern to capture rainwater from the building's roof and children day care center's play area. The water is treated and distributed to nine irrigation zones around the building where it is used for subsurface irrigation for non-Living Machine plantings and street trees. Due to the use of water-efficient landscaping, the rainwater cistern provides more than enough non-potable water to meet all of the building's annual irrigation demands. The rainwater harvesting system provides an annual potable offset of approximately 8,000 gallons.

Drivers for Non-potable Water Reuse:

From the beginning of the planning stage for the building, the SFPUC's goal was to have a headquarters that demonstrated the agency's ambitious sustainability goals and served as an example for building smart, efficient, and sustainable buildings. As a water, wastewater, and power utility, the SFPUC recognized an opportunity to demonstrate its commitment to sustainable and innovative practices in water treatment and reuse by installing low-energy, high-profile non-potable water systems at its headquarters.

Installing the Living Machine also provided a pilot project for the San Francisco Non-potable Program, which was created by an ordinance adopted by the San Francisco Board of Supervisors in September 2012. The Living Machine became the test case for the program, providing the SFPUC, SFDPH, and San Francisco Department of Building Inspection (SFDBI) with a project for the agencies to test and demonstrate the ideal methods for installing, permitting, and regulating onsite water systems.

Implementing the onsite water systems also allowed the headquarters to obtain additional LEED points towards LEED Platinum certification. The project received an additional six Water Efficiency (WE) points and two Regional Priority (RP) points by implementing the systems.

Ownership Model:

The Living Machine and rainwater harvesting system are owned, operated, and maintained by the SFPUC. The SFPUC's lead operator for the systems is a State of California Certified Grade V Wastewater Treatment Plant Operator. The operator has received extensive training on how to operate and maintain both systems.

Project Cost:

The Living Machine, rainwater harvesting system, and their distribution piping cost approximately $1,000,000. The non-potable water systems increased the building's total construction costs of $146.5 million by less than 1%.

Annual Operations & Maintenance Cost: TBD

Service Costs to Residents or Tenants:

Not Applicable

Reference: John Scarpulla, San Francisco Public Utilities Commission (**jscarpulla@sfwater.org**)

The Living Machine at San Francisco Public Utilities Commission Headquarters

Vera Haile Senior Housing & St. Anthony's Foundation Dining Room & Social Work Center — 121/129 Golden Gate Avenue

The Vera Haile Housing and St Anthony's Foundation Dining Room and Social Work Center (image courtesy of David Wakely Photography)

Project Status: Online

SFDPH Permit Issued: Yes

Size: 110,000 Square Feet

Alternate Water Sources:

- Rainwater

End Uses:

- Toilet Flushing

Volume: 37,000 Gallons/Year

Potable Water Use Reduction: 8%

Driver(S): Mandate (San Francisco Stormwater Management Ordinance)

System Cost: $400,000

Annual O&M Cost: $2,500

Owner: Mercy Housing California (MHC) and The St. Anthony Foundation (SAF)

Project Description:

Nestled between the Civic Center and Tenderloin neighborhoods, 121 and 129 Golden Gate Avenue is a ten-story building housing Vera Haile Senior Housing and the St. Anthony's Dining Room and Social Work Center. St. Anthony's Dining Room is the only meal program in San Francisco that serves people 365 days a year. Situated on the first floor, the Dining Room serves 3,000 free meals a day and provides a place for people to socialize and find support, as more than 80% of their guests live alone. On the second floor, the building also houses St. Anthony Foundation's Social Work Center and Free Clothing Program serving the wider community. From floors three through ten, Vera Haile Senior Housing provides affordable apartments for low-income seniors ages 62 and older. There are 90 units in the building, comprised of studios and one-bedroom units that are include with full kitchens and access to internet, cable, and telephone.

This 110,000 square foot building has several sustainability measures, including a solar thermal heating system, hydronic heating system, cool roofing and high-reflectivity paving, low/no VOC sealants, and an energy efficient envelope and windows. It also has a rainwater harvesting system that will collect water from the roof into a 4,400 gallon cistern for storage. The rainwater is then treated onsite and pumped into restrooms within the Dining Room to flush toilets and urinals. With an average of 1000 Dining Room guests per day, it is estimated that demand for water in the Dining Room restrooms will match the volume of water collected in a normal wet season.

Drivers for Non-potable Water Reuse:

In order to meet the requirements of the San Francisco Stormwater Management Ordinance, the project team installed the rain harvesting system. The Stormwater Management Ordinance requires projects that disturb 5,000 square feet or more to decrease the project's post-construction stormwater runoff rate and volume by 25% for the 2-year 24-hour design storm. Installing a rainwater harvesting system with a 4,400 gallon cistern enables the project to meet these requirements.

Ownership Model:

Mercy Housing California and the St. Anthony's Foundation each own certain air rights parcels that are within the building. Mercy Housing California owns an air rights parcel that includes floors 3-10 and the part of the basement where the cistern, stormwater collection, storage , and the water treatment system are housed. St. Anthony's owns an air rights parcel that includes Floors 1-2. They stormwater distribution system is partially in both air rights parcels.

Project Cost:

The cost for the rain harvesting system is $400,000. $69 million is the total hard cost for the project ($42 million for the Vera Haile portion and $17 million for the St. Anthony's portion).

Annual Operations & Maintenance Cost:

The license and testing requirements are approximately $2,500/annually. The project is budgeting $3,500 annually for maintenance.

Service Costs to Residents or Tenants:

Not applicable.

Reference: Sharon Christen, Mercy Housing California (schristen@mercyhousing.org)

The Vera Haile Housing and St Anthony's Foundation Dining Room and Social Work Center (image courtesy of David Wakely Photography)

Whole Foods Mixed-use Development — 38 Dolores Street

38 Dolores Street (image courtesy of BAR Architects)

Project Status: Online

SFDPH Permit Issued: N/A
(A Rainwater Harvesting Project for Non-Spray Irrigation Does Not Need a Permit)

Size: 195,000 Square Feet

Alternate Water Sources:

- Rainwater

End Uses:

- Subsurface Irrigation
- Drip Irrigation

Volume: 26,000 Gallons/Year

Potable Water Use Reduction:
26% for Irrigation; 1.3% Total Project Reduction

Driver(S): Leed Points, Sustainable Sites Pilot Project Certification, and Mandate (San Francisco Stormwater Management Ordinance)

System Cost: Not Available

Annual O&M Cost: Negligible

Owner: The Prado Group (Market Dolores LLC)

Project Description:

In fall 2013, the Prado Group (Market Dolores LLC) completed construction on a new 195,000 square-foot mixed-use development containing 81 residential rental units and a 30,000 square-foot Whole Foods grocery store on the ground level. Targeted for LEED Gold, the development – located between Market Street, Dolores Street, and 14th Street – contains a 16,200 gallon cistern that collects rainwater from all rooftop surfaces (traditional roofs, green roof, and flow-through planters). The harvested rainwater is used to irrigate all landscaping within the development via subsurface and drip irrigation systems. The cistern is sized to hold the required average annual detention volume associated with the San Francisco Stormwater Management Ordinance design storm event, while also taking into consideration the project's monthly irrigation demand. The project will offset an estimated 26,000 gallons of potable water annually.

The project does not have a permit from the San Francisco Department of Public Health because rainwater systems that, at a minimum, include both a first flush diverter and a 100 micron filter, and are used for subsurface irrigation, drip irrigation, or non-spray surface irrigation, do not need one.

Drivers for Non-potable Water Reuse:

The project team installed the rainwater harvesting system to meet the requirements of the San Francisco Stormwater Management Ordinance. The Stormwater Management Ordinance requires projects disturbing 5,000 square feet or more of the ground surface to decrease the project's post-construction stormwater runoff rate and volume by 25% for the 2-year 24-hour design storm. Installing a rainwater harvesting system with a 16,200 gallon cistern enabled the project to meet these requirements.

The project also installed the rainwater harvesting system to obtain LEED points to help the project achieve LEED Gold Certification. Additionally, the project was designed and certified as a Sustainable SITES Pilot Project, which also was a driver for installing the system. Sustainable SITES certification is given to projects that use sustainable practices that enable built landscapes to support natural ecological functions by protecting existing ecosystems and regenerating ecological capacity where it has been lost.

Ownership Model:

The rainwater harvesting system is owned, operated, and maintained by the Prado Group (Market Dolores LLC), which owns the development and leases the commercial spaces and residential units to tenants.

Project Cost:

The total hard cost for the project was $48 million. The contractor did not break out the cost of the rainwater harvesting system as a discrete item.

Annual Operations & Maintenance Cost:

The cost to operate and maintain the rainwater harvesting system is negligible.

Service Costs to Residents or Tenants:

There are no service costs to the commercial or residential tenants for use of the rainwater.

Reference: Jon Yolles, The Prado Group (jyolles@pradogroup.com); Eric Girod, BKF Engineers (egirod@bkf.com)

38 Dolores Street (image courtesy of BAR Architects)

Allianz Field at Midway Development District – Saint Paul, MN

Installation of underground rainwater storage tank outside of stadium (image courtesy of the City of St. Paul)

Project Status: Completed

Project Size: 35 Acres

Alternate Water Sources:
- Rainwater

End Uses:
- Irrigation
- Toilet Flushing
- Laundry

Treatment System Size: 205,920 Gallons/Day

Potable Water Use Reduction:
- 1.3 Million Gallons/Year (Phase 1)
- Estimated 2 Million Gallons/Year at Ultimate Development

Drivers:
- Stakeholder Input
- Site Contamination
- Development Benefits
- Improve Water Quality of Mississippi River

System Cost: $2,100,000

Annual O&M Cost: $30,000 (Estimated)

Owner: City of Saint Paul

Project Description:

In collaboration with the Capitol Region Watershed District, the City of Saint Paul developed a landmark rainwater reuse system capable of recycling over 2 million gallons annually. Completed in 2019, the project is located at Allianz Field, the new stadium for the soccer team the Minnesota United FC, which is within the 35-acre Midway Development District (District).

The rainwater reuse system utilizes a 675,000-gallon underground storage tank installed just outside the stadium to collect roof runoff from the stadium, and in the future from neighboring buildings once they are built. Water is pumped from the storage tank through a treatment system called a "smart hub", which can read weather forecasts to predict rainfall and adjust water levels accordingly. The treated water is used to irrigate the entire stadium site, which includes 150,000 square feet of green public space and 200 mature trees. New development in the District will be able to connect to the system for supply of recycled water for non-potable uses such as laundry, irrigation, or restroom flushing.

More than 5 acres of new street grid were necessary to support Allianz Field as a catalytic development. Engineered tree "trenches" were deployed across the grid to collect and treat street runoff. The tree trenches had to be separated from the rainwater harvesting system because of the oils, salts, and other compounds inherent to roads. This integrated green infrastructure system doubles down on value and environmental benefit. During dry periods, 18 tree trenches that contain 60 new street trees will be nourished by drip irrigation that utilizes harvested rainwater.

Drivers for Onsite Water Reuse:

A stormwater visioning workshop was held to inform a redevelopment Master Plan for the District. A common theme that came out of the workshop included using harvested and cleansed stormwater runoff as an iconic site feature to set the District apart from other developments. Another key driver was that infiltration was restricted over much of the development area due to contamination from the historic land use, making rainwater reuse a more feasible option for stormwater management.

Another key project driver was to help spur development in the District. The centralized stormwater facility at Allianz Field eliminates the need for developers to construct individual stormwater facilities at each new building, which streamlines the construction process and gives builders greater flexibility. In exchange, developers are required to contribute funds for the ongoing operation and maintenance of the central system.

Ownership Model:

The entire system is owned by the City and operated as a public asset.

Role of Public Utility in Project:

The system was designed by a private sector development partner as part of the broader public infrastructure design and delivery agreement. The Sewer Utility Division within the City's Public Works department provided technical input regarding design of the underground vault which houses the "smart hub" treatment components. They also interfaced with the development partner for turnover and acceptance of the system. The City's Department of Safety and Inspections provided technical input regarding cistern requirements, treatment performance standards, and commissioning testing.

Project Cost and Funding:

The capital cost of the reuse system was approximately $2,100,000. The City funded the infrastructure work and established a Green Infrastructure District for the project area. The Metropolitan Council awarded a $200,000 grant to the Capitol Region Watershed District for their involvement in the project, and additional funding was provided by the Clean Water, Land and Legacy Amendment's Clean Water Fund. All future buildings in the District are required to connect and pay a "standard" stormwater connection fee at the time of development.

Lessons Learned:

The district-scale reuse system was considered a design alternate in the civil infrastructure package until district-based supplemental funding was secured. Therefore, much of the detailed design did not occur until very late in site development. Many aspects of the innovative system transcended established protocols for infrastructure testing, acceptance, and operation. The public-private partnership model, in addition to the design-build nature of the work, streamlined delivery but constrained typical owner oversight and protections. In summary, the City carried an extensive level of risk in order to capitalize on an opportunity to "move the needle" with a project of this scale and complexity.

Key takeaways were to: start earlier with detailed design rather than waiting for supplemental funding to allow more time to evaluate design considerations, create a roadmap of criteria to achieve necessary municipal approvals, and to avoid unnecessary overdesign of the treatment system.

Reference: Wes Saunders-Pearce, City of St. Paul (wes.saunders-pearce@ci.stpaul.mn.us),
(651) 266-9112

Onsite reuse system's "Smart Hub" (image courtesy of the City of St. Paul)

BedZED — London, United Kingdom

BedZED

Project Status: Construction completed in 2002

Size: Group of Buildings (3.5 acres)

Volume: Unknown

Alternate Water Sources:
- Wastewater
- Rainwater (initially used)

End Uses:
- Toilet flushing
- Irrigation

Potable Water Use Reduction: 58%

Driver: Motivated developer

Cost: Rainwater and Living Machine facilities ~US$860,000

Owner: Peabody Trust (Private, non-profit)

Role of Public Utility: Thames Water - Backup services

Project Description:

The BedZED community, completed in 2002, originally used a modified "Living Machine" design to treat wastewater on-site; however, this system is no longer operating due to the high costs of O&M. Beginning in June of 2008, BedZED again started using recycled water for toilet flushing and irrigation as part of a research study involving a use of a membrane bioreactor (MBR). Rainwater was also initially used for on-site toilet flushing after being collected from roofs; however, rainwater is no longer reused on site for anything except groundwater recharge.

Drivers for Incorporating District-Scale Utilities:

BedZED was initiated by BioRegional (One Planet Living entrepreneurial charity) to be the prototype for the One Planet Communities program, through which BioRegional works with developers to create sustainable developments and promote sustainable construction practices.

Ownership Model:

The BedZED community is owned and managed by the Peabody Trust (Peabody), one of the largest housing associations in London.The community was initiated by BioRegional and was developed in partnership with Peabody . The original Living Machine system was designed, installed, operated, and maintained by Albion Water under contract with Peabody. The MBR was originally operated by Thames Water, but is now operated by a private firm under contract with Peabody.

Role of Public Utility in Project:

Albion Water, a local private water and sewerage service company, designed, installed, operated, and maintained the initial on-site water treatment plant and associated infrastructure until the system proved to not be economically viable and was therefore taken out of service. The developer subsequently worked with a different private water utility company, Thames Water, to introduce a Wastewater Reclamation Plant to provide a non-potable supply as well as research options for wider implementation of augmenting water supplies throughout London. This plant is now operated by another private firm, under contract with Peabody, and Thames Water is no longer involved.

Project Cost and Funding:

The rainwater collection, distribution, and storage system cost US$392,137(£244,200) to construct; however, this system is not currently in use. The initial Green Water Treatment Plant (GWTP), which includes some “Living Machine” features, and distribution infrastructure cost US$468,894 (£292,000).

Rate Structure for Water and Sewer Services from Public Utility:

OFWAT, the regulator that sets Thames Water’s charging limits, established the most recent charging limits on April 1, 2012. All new and converted properties in areas served by Thames Water have to be fitted with meters and all sprinkler users and swimming pool owners are to be metered. The volume-based water charge for potable water is $4.64/CCF (122.63 pence/cubic meter) and wastewater services are $2.45/CCF (64.73 pence/cubic meter). A fixed charge per year is also billed to customers based on their pipe size (e.g., all individually metered domestic properties pay the 15mm fixed charge, which is US$44.30 (28£) for potable water and US$82.28 (52£) for wastewater). Intermediate, large, and super large volume users are charged the fixed charge, an additional tariff, as well as a higher volume charge for all use. Households that are not connected to Thames Water sewers for discharge of surface water (stormwater) get a wastewater bill reduction of US$36.39 (£23). Thames Water will consider reducing the wastewater charge if a user can prove that they return less than 90% of the potable water supplied to the public wastewater system.

BedZED Green Water System

Unmetered customers within Thames Water’s service area are charged a ‘rate per pound’ based on which local authority area they live in and the taxable value of their home. In addition, a yearly fixed charge is required for household properties: US$ 47.47 (30£) for potable water and US$ 66.46 (42£) for wastewater. Fixed charges for business customers are based on the size of their supply pipe.

For the original GWTP system, BedZED residents were charged metered unit rates for potable water, while “greenwater”[1] and sewerage were charged according to a formula based on the metered potable water consumption and the size of the property. Residents were charged for rainwater at about 90% of the rate of potable water. BedZED households saved US$167 (£104) per year per household on their water and sewerage bills as compared to average UK customers, a savings of approximately 47%.

Service Costs to Residents or Tenants:

Standing charges per household for the original GWTP system included a US$31 (£19) potable water charge and a US$61 (£38) sewerage charge.

Incentives Provided to Promote District Utilities:

Recycled water is supplied to residents at a reduced rate.

[1] "Greenwater" is a mixture of rainwater and recycled, treated wastewater.

Chase Center – San Francisco, CA

Chase Center arena (image courtesy of Chase Center)

Project Status: Completed

Project Size: 1,480,000 Square Feet

Alternate Water Sources:
- Rainwater
- Stormwater
- Graywater
- Condensate and Bleed

End Uses:
- Toilet/Urinal Flushing
- Spray Irrigation

Treatment System Size: 53,000 Gallons/Day

Potable Water Use Reduction:
34%; 3.8 Million Gallons/Year

Drivers: Stormwater Management Ordinance and Non-potable Water Ordinance Compliance

System Cost: $700,000

Annual O&M Cost: $50,000

Owner: GSW Arena LLC

Project Description:

The Chase Center arena is the Golden State Warrior's new state-of-the-art sports and entertainment complex in San Francisco's Mission Bay neighborhood. The development includes 580,000 square feet of office space in two towers adjacent to the arena, 100,000 square feet of retail space, and a 3.2-acre public plaza.

The non-potable water sources to be recycled include (1) rainwater collected from the two office towers' upper roof area and the arena roof, (2) stormwater collected from the plaza areas and the two office towers' podium roof area (3) graywater from the two office towers, and (4) condensate and bleed water from the two office towers' cooling systems. The on-site non-potable reuse applications include toilet/ urinal flushing inside the arena and two office towers, as well as irrigation demand for the towers' landscaped roof spaces.

Due to the volume of water to be recycled and the disparity between high and low flow conditions, two identical Aquacell GX100 systems were installed for this project. Each GX100 grey & rainwater recycling system is capable of processing up to 26,400 gallons per day. Having two separate skids installed allows one to operate during low-flow conditions, and two to operate during high-flow conditions. It also allows for uninterrupted operation during service & maintenance.

The system is completed and is awaiting occupancy in the office spaces (delayed due to pandemic), from which most of the graywater to be recycled will be generated. The system is anticipated to become active in late 2021.

Drivers for Onsite Water Reuse:

The rainwater reuse system is the outcome of achieving compliance with the Stormwater Management Ordinance and the City's Phase II MS4 permit. To comply with the Stormwater Management Ordinance, the arena complex was required to treat all stormwater on-site prior to discharge to the SFPUC separate storm sewer system and the Bay. The capture of graywater from the adjacent office towers and HVAC condensate was implemented to comply with the Non-Potable Ordinance.

Ownership Model:

GSW Arena LLC is the owner of the water reuse system. They have contracted with PHOENIX Process Equipment (Joint Venture Partner of Aquacell) for ongoing service & maintenance. PHOENIX Process Equipment monitors the systems operation remotely 24/7 and personnel are sent to the site regularly to calibrate instruments, perform maintenance, and collect water samples for analysis.

Project Cost and Funding:

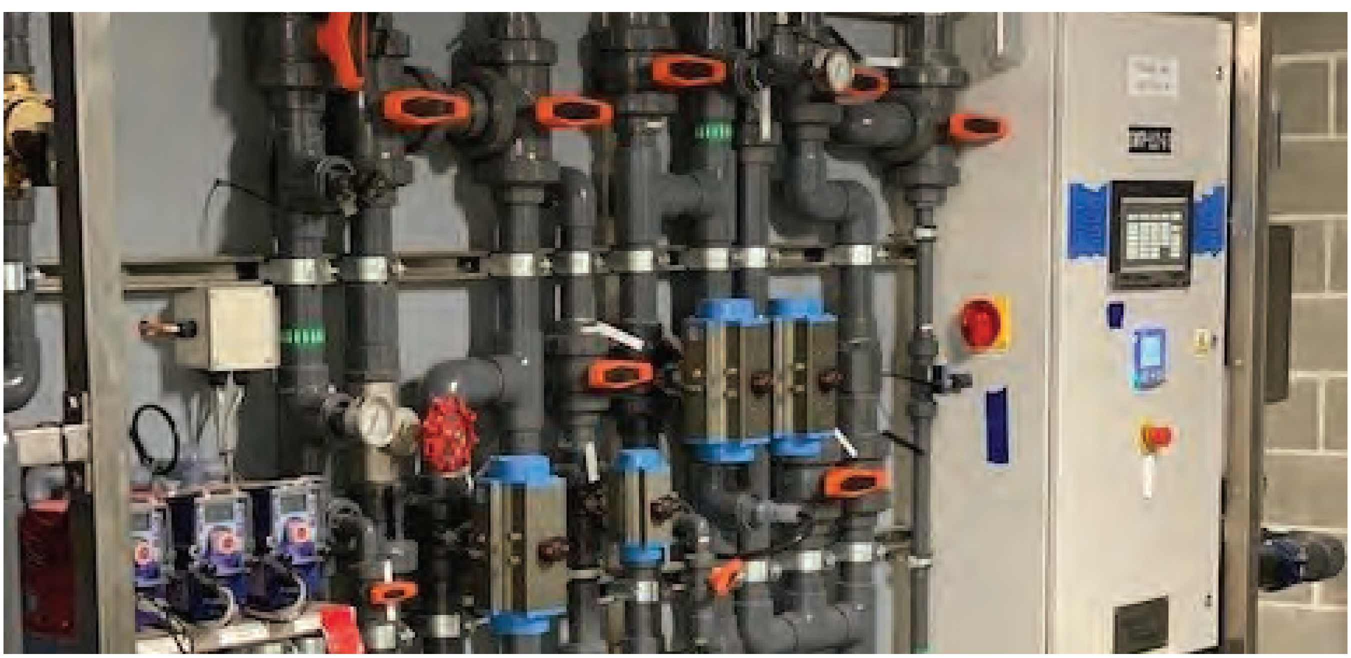
The Chase Arena cost $1.5 Billion to construct, with the water reuse system components making up approximately $700,000.

Lessons Learned:

Having a water reuse system representative present with contractors during the installation process is invaluable. The installation of the equipment, piping, and electrical conduit & wiring can be seamless if the installers have all the information they need. While this information is in the submittal package, much time, effort, and potential for confusion can be spared by talking through the installation steps with the individuals performing the work.

Taking steps to ensure that the installers can do their best work results in an optimal finished product. These systems tend to get a lot of attention since they are still a new concept to many contractors and building owners in the Bay Area. Tours of some Aquacell systems are given quite often; the installers know that their work will be on display and take pride in their work.

Reference: Neil Joson, SJ Engineers (njoson@sjengineer.com), 510-832-1505



Chase Center onsite reuse system (image courtesy of Aquacell)

Dockside Green — Victoria, Canada

Project Status: Phase 1 Built (completed December 2007, first residents moved in May 2008); two additional neighborhoods intended to be built in phases over 10 years. Construction of the wastewater treatment plant was completed in early 2008.

Size: Group of Buildings (15 acres)

Volume: 50,000 gpd; a future plant expansion can increase the capacity to 100,000 gpd

Alternate Water Sources:
- Wastewater
- Stormwater

End Uses:
- Toilet flushing
- Irrigation
- Water features

Potable Water Use Reduction: 65%

Driver: Marketability

Cost: $4 million

Owner: Windmill West Development and Three Point Properties with Vancity (Private) built the development, but the wastewater treatment plant is owned by the Dockside Green community (Private)

Role of Public Utility: City of Victoria – Backup services

Project Description:

This former industrial redevelopment site treats 100% of its sewage and the recycled effluent is used on-site for toilet flushing, irrigation, and water features. The wastewater system is currently operated by Corix Utilities, a private utility operator. The wastewater treatment plant has a capacity of 50,000 gpd and it recovers heat from wastewater. There is potential for 18,000 gallons of treated water to be available for sale off-site. A future plant expansion can increase the average daily flow to 100,000 gpd by adding additional membranes and ancillary equipment. Dockside Green also uses an on-site naturalized creek and pond system, along with underground storage, to treat and control stormwater flows, which avoids the need to connect to the municipal storm drain system.

Drivers for Incorporating District-Scale Utilities:

The decision to incorporate sustainable district-scale utilities into the project were developer and market driven. The site was heavily contaminated from industrial use, but has a desirable waterfront location. The developer bidding for the brownfield redevelopment proposed a sustainable vision for the development and the community, projecting high market demand for this type of product. The system cost more to install, but premium prices on the homes may recoup the investment. The project received a record number of LEED ND points and was recognized by the Clinton Foundation for its achievements with regard to sustainability, in large part due to the on-site water treatment and reclamation.

Ownership Model:

The system is owned by the Dockside Green community (administered by the condominium board).

Role of Public Utility in Project:

The municipal water utility has no role in the water recycling activities. All oversight and operations are provided by Corix Utilities under federal and provincial regulation. Dockside Green has its own collection system, treatment plant, and point of discharge to the harbor. Once the development achieves build out, it is contemplated that Corix may acquire the system from the Dockside Green community. Corix also operates and is a part-owner in the on-site biomass-based district energy system. The City of Victoria provides emergency backup to the system which is metered, but not billed at this time.

Project Cost and Funding:

The wastewater treatment plant cost $4 million to construct. Most of the capital for the project (75%) was provided by Canada's largest credit union, Vancity, which became a co-developer of the project in a partnership called Dockside Green Limited. A key early contributor to the project's success was the city's willingness to allow the developers to defer payment for the land, which freed up enough cash for quick construction of the project's infrastructure without significant bridge financing.

The Federation of Canadian Municipalities provided $350,000 to support the development of innovative infrastructure, including part of the costs associated with developing and obtaining approval for the unprecedented wastewater treatment system.

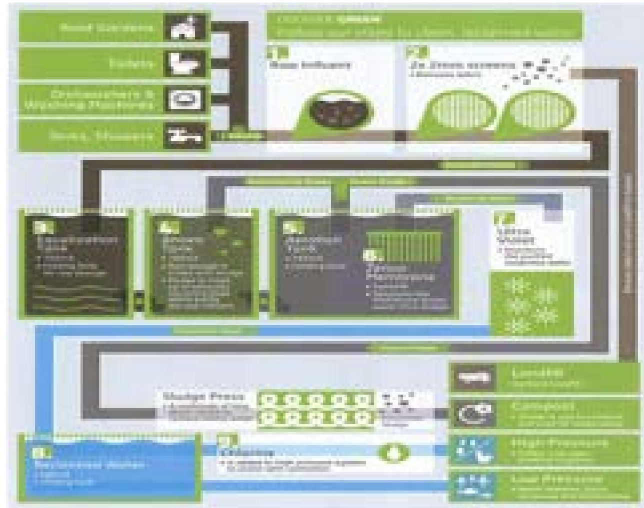
Rate Structure for Water and Sewer Services from Public Utility:

The City of Victoria charges a service charge every 4 months based on the size of service connection (e.g., ¾" for $36.63). Potable water is billed at a rate of $3.25/CCF. The sewer rate is $1.92/CCF and is based on metered water consumption. In addition, there is a Capital Regional District (CRD) sewer charge of $1.57/CCF.

Residents of Dockside Green are not charged for the use of recycled water (no metering) and there are no sewage charges paid to the City of Victoria.

Service Costs to Residents or Tenants:

Residents of Dockside Green pay for the wastewater treatment system based on the square footage of their unit in the form of strata fees.[5] This charge covers maintenance, operational, capital, and contingency costs of the system. Residents are charged at a rate of 2 cents per square foot of their unit, per month (e.g., a 600 square foot unit would be charge $12/month).



Dockside Green—Steps to Clean, Reclaimed Water

Incentives Provided to Promote District Utilities:

Through negotiations with the developer, concessions were provided on sewer development charges and sewer usage fees. The City does not bill residents for the sewage component charge of the water bill; they are only charged for potable water at the metered rate. Development cost charges (DCC's)[6] for sewage were waved for the developer.

Reference: Eric van Roon, Vice President and COO, Corix Utilities (eric.vanroon@corix.com; 604.697.6712)

5 "Strata fees" is a Canadian term, roughly equivalent to homeowners' association fees.

6 Development cost charges (DCC's) are monies that municipalities and regional districts collect from land developers to offset that portion of the costs related to these services that are incurred as a direct result of this new development.

Energy Center San Francisco-BART Foundation Drainage Project — Powell Street BART Station

caption

Project Status: Online

SFDPH Permit Issued: Not Applicable

Size: Not Applicable

Alternate Water Sources:

- Foundation Drainage

End Uses:

- Steam Heating in Downtown San Francisco Steam Loop

Volume: 30 Million Gallons/Year

Potable Water Use Reduction: 30%

Drivers: Reduce Potable Water Use and Sustainability Goals

Onsite Water System Cost: $3.5 Million

Annual O&M Cost Of Onsite Water System: $200,000

Owner: Energy Center San Francisco

Project Description:

Beneath the crowds of people that visit Union Square every day, there is an under-utilized water source that flows directly under Powell Street BART station. Energy Center San Francisco (ECSF), owned by Clearway Energy, and BART have partnered on a unique project to bring that underground resource to the surface.

ECSF, formerly known as NRG, is the district steam heating system operator in San Francisco. 24/7/365 days a year, ECSF provides steam for heating, hot water and process steam to hotels and buildings in downtown San Francisco. Driven by their commitment to the sustainable use of energy and water, ECSF has partnered with BART on a project to reclaim foundation drainage at the Powell Street BART station, and redirect it to their District Energy Plant located nearby on Jessie Street for use in the district steam loop.

To maintain the structural integrity of its transportation system, BART captures foundation drainage from the Powell Street BART station in a large cistern and pumps it to SFPUC's sewer system. Recognizing an opportunity, ECSF approached BART to divert that water instead for use in the district steam loop.

ECSF first worked with BART to replace and upgrade the aging sump pumps at Powell BART station that were used to pump the foundation drainage to the sewer system. Next, a new pipeline roughly 1,000 feet long was constructed to transport the foundation drainage to the nearby plant located at 460 Jessie Street. From there, ECSF installed an onsite water treatment system to treat the foundation drainage to a quality that is suitable for use in a district steam heating system. The onsite water treatment system includes a raw water collection tank with a coarse strainer, microfiltration (MF), and closed circuit reverse osmosis (CCRO). The water also undergoes softening to remove minerals that interfere with the process of steam production. This treatment system is unique in that the CCRO allows for 80-90% recovery of the treated water, as compared to 75% recovery from traditional RO systems.

Commissioning of the project began in September 2018. Currently, ECSF is operating the onsite water treatment system and will continue to monitor its integration with the district steam heating system. In total, ECSF is reducing their overall potable water use by 30 million gallons each year.

Drivers for Non-potable Water Reuse:

ECSF's innovative approach began with identifying foundation drainage as a resource rather than a nuisance to be discharged to the sewer. By tapping into this constant flow of groundwater, ECSF can reduce their overall water consumption by 30%. Their commitment to sustainability pushes them to continue investigating ways to use less potable water in their operations. Similarly, BART is dedicated to achieving its sustainability goals of reducing its impact on energy and water use. Through this joint effort, both BART and ECSF are demonstrating outstanding leadership and modeling the path for successful public-private partnerships in San Francisco.

Ownership Model:

The project is owned, operated, and maintained by ECSF. BART has agreed to grant ECSF access to use the foundation drainage.

Project Cost:

$3,500,000

Annual Operations & Maintenance Cost:

$200,000

Service Costs to Residents or Tenants:

Not Applicable

Incentives provided by SFPUC:

The SFPUC is providing a $500,000 grant to ECSF as part of the Onsite Water Reuse Grant Program. The project meets the grant criteria by offsetting at least 3 million gallons of potable water annually.

Reference: Gordon Judd, Clearway Energy (**gordon.judd@clearwayenergy.com**)

caption

London Olympics — London, UK

London Olympic Stadium Site

Photo Courtesy of AECOM

Project Status: Built/planned

Size: Area (618 acres)

Volume: up to 150,000 gpd

Alternate Water Sources:
- Wastewater
- Rainwater

End Uses:
- Toilet flushing
- Irrigation
- Cooling water

Potable Water Use Reduction: 20% for residential development; 40% reduction for Olympic park use [58% reduction achieved to date]

Driver: Marketability and Water Conservation

Cost: Old Ford Water Recycling Plant US$11.2 million (£7 million)

Owner: Olympic Park Legacy Company (Public)

Role of Public Utility: Thames Water - Built, owns, and operates the recycled water treatment plant

Project Description:

The 2012 London Summer Olympics infrastructure has been built; legacy development is still in the planning stage. The non-potable network currently extends three-quarters of the way around the Olympic Park and can be extended into planned housing developments once the Olympic Park landscape has been established and if the treatment plant proves technically and commercially viable.

Recycled wastewater is currently used at the Olympic venues for toilet flushing, irrigation, and to provide cooling water. The Aquatics Centre has an independent water recycling system that uses the pools' filter backwash water. The source of sewage for the recycled water system is the main sewer line running from homes in north London, not from the Olympic venues or athlete's village. Roofs and gardens in legacy housing developments are proposed to be irrigated by water from rainwater harvesting.

Drivers for Incorporating District-Scale Utilities:

At the core of London's bid to host the 2012 Olympics was a pledge to achieve an outstanding example of sustainable development. The 'London Plan', 'The Mayor's draft water strategy', planning authorities and Building Regulations all have requirements to conserve water. Large-scale non-potable water reuse was needed to meet the Olympic Delivery Authority (ODA)'s[7] established 40% potable water use reduction target. In addition, London is a water stressed area.[8]

London Olympics Old Ford RWP Process Map

Ownership Model:

The ODA and Thames Water, a large public utility in the UK, partnered on the project; previous to Thames Water agreeing to partner, ODA had ruled out wastewater reuse because of risk and cost constraints. Thames Water managed construction of the treatment plant (Old Ford Water Recycling Plant (WRP)) and ODA managed construction of the pipe network.

Role of Public Utility in Project:

Thames Water developed the recycled water treatment plant under a seven-year build-own-operate contract with the Olympic Park Legacy Company. The Legacy Company will seek to work with Thames Water to supply the non-potable water network to monitor the technical and commercial viability of the Old Ford WRP. After 7 years, Thames Water will examine operational costs, conduct cost-effectiveness studies, and review the operational process of the technology to decide whether or not they want to upgrade it, close the plant down, or switch to a different type of treatment.

The non-potable water distribution network distributes recycled wastewater from the Old Ford WRP around the Park to end-use customers. The interface for connections to end-use customers is at metered connection pits, which are located outside the customer's premises and provided the delineation of ownership. Thames Water owns the non-potable water distribution network up to the revenue meter (under the terms of a self-lay agreement with the ODA) and the customer owns the pipework downstream of the revenue meter (similar to the standard potable water arrangement).

Project Cost and Funding:

ODA and Thames Water partnered on funding the project, with Thames Water investing approximately US$8 million (£5 million). The total cost of the Old Ford WRP was US$11.2 million (£7 million). The ODA is funded by the Department for Culture, Media and Sport, the Greater London Authority, and the Olympic Lottery Distributor.

The initial system was sized to meeting the non-potable water requirements of the Park only (not the

London Olympic Stadium Site

Park's long-term legacy community) in order to optimize the infrastructure without the consequences of an oversized network. The additional requirements of implementing a system that could meet the long-term legacy community, when added to the uncertain timeframe and size of future developments, were considered unacceptable to Thames Water who would need to adopt the network and operate the Water Recycling Plant after the Games.

Rate Structure for Water and Sewer Services from Public Utility:

See previous discussion of Thames Water water and sewer pricing presented for the BedZED case study.

Service Costs to Residents or Tenants:

Unknown.

Incentives Provided to Promote District Utilities:

Information currently unavailable.

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7 The ODA is the public sector body responsible for developing and building the new venues and infrastructure for London 2012, and their use afterwards.

8 Thames Water, London's main water supplier, recognized this in their Water Resources Management Plan, identifying London's limited access to new fresh water supplies to support its expanding population.

Mission Rock at Third and Mission Rock Street – San Francisco, CA

Rendering of Mission Rock (image courtesy of Mission Rock Partners)

Project Status: Design

Project Size: 2.7 Million Square Feet

Alternate Water Sources:
- Blackwater

End Uses:
- Cooling Tower Make-Up
- Toilet/Urinal Flushing
- Irrigation

Treatment System Size:
Blackwater Treated: 64,000 Gallons/Day
Non-potable Water Produced: 43,000 Gallons/Day

Potable Water Use Reduction:
17%; 11.8 Million Gallons/Year

Drivers:
- The Eco-District Program
- Model Sustainable Development
- Non-potable Water Ordinance Compliance

System Cost: $8.4 Million (Estimated)

Annual O&M Cost: Not Available

Owner: Mission Rock Utilities, Inc.

Project Description:

Mission Rock will be a new mixed-used neighborhood spread over 28 acres, including parks, open space, residential, commercial, and retail. The Blackwater Treatment Plant, located on the ground floor of the Parcel B office building, is an advanced water recycling facility treating a portion of the blackwater from the Mission Rock development to meet the non-potable water needs of Mission Rock buildings, as well as the project open space. The blackwater consists of wastewater collected from the development's toilets, showers, and sinks. The primary non-potable water needs of the site will be irrigation and toilet flushing, along with cooling tower makeup water. Total blackwater inflow at the facility will be approximately 64,000 gallons per day, with a maximum design capacity of approximately 43,000 gallons of recycled non-potable water per day.

Drivers for Onsite Water Reuse:

The Blackwater Treatment Plant is being implemented to comply with San Francisco's Non-potable Water Ordinance. Additionally, the Mission Rock project is participating in the San Francisco Eco-District program. Eco-Districts are neighborhood scale public-private partnerships that strengthen the economy and reduce environmental impacts while creating a stronger sense of place and community. The Mission Rock development is looking to maximize this potential to deliver a sustainable, low-carbon neighborhood. To strengthen the project's commitment to sustainability, the Port and SWL 337 included a Sustainability Strategy as a component of their Disposition and Development Agreement. Mission Rock's Sustainability Strategy provides a comprehensive approach to achieve Mission Rock's goal of becoming a model for sustainable development in the city. Multiple sustainable site strategies have been evaluated to inform the targets and strategies included in the Sustainability Strategy. Important performance goals related to the District utilities include meeting 100% of building energy demands with renewable energy, reducing green-house gas emissions by 50% from the average development in San Francisco, and meeting 100% of non-potable water demands with non-potable sources.

Ownership Model:

Mission Rock Utilities, Inc. (MRU) will be structured as a mission-based utility business formed for the exclusive purpose of serving the Mission Rock site. The non-stock corporation will enter into long-term utility service agreements to secure revenue bond or construction financing. Energy and water rates will be cost-based and will include provisions for recovery of all capital and operational costs. MRU will have a board of directors appointed by the Developer and Owner's Master Association that will approve annual budgets and each system's rates.

MRU will consist of a Board of Directors with third-party operations and management teams. The daily business activities of MRU will be managed by Ever-Green Energy, through a Management Services Agreement. Daily operation and maintenance of the district energy and blackwater recycling systems are anticipated to be provided by two separate entities under contract with MRU. Tishman Speyer Properties personnel, likely engineering staff serving the broader Mission Rock project, will operate and manage both utility systems. A Contract Blackwater Recycling System Operations Firm will provide process operations and membrane maintenance functions for the blackwater recycling system and will serve as the Treatment System Manager.

Project Cost and Funding:

The Blackwater Treatment Plant is planned to be financed through 100% debt-financing, based on long-term utility service agreements that will require each property at Mission Rock to be a customer of the utility systems. The blackwater recycling system will be financed in phases with the initial financing expected to be funded over several years through exempt facility, private activity tax-exempt revenue bonds and taxable revenue bonds. Future Mission Rock public financing sources may contribute to paying down the financing.

Lessons Learned:

The biggest lessons learned are the institutional challenges of implementing a district scale non-potable water system, which were found to be greater than the technical challenges. Implementing the first district-scale blackwater plant in San Francisco has presented a number of technical, administrative and policy obstacles. From an administrative perspective, one challenge the team is working through with SFPUC is how billing will occur. As all buildings on the project will be impacted by the recycled water and potable water use of the other Mission Rock buildings, MRU will act as the invoicing agent for all potable water and recycled water use. SFPUC will invoice MRU directly for water and sewer services, and MRU will charge individual buildings based on metered water usage. This will enable proper allocation of water and sewer charges to each building, as well as any excess water use fees, if applicable.

The project may set an exciting new precedent for the city to consider building more distributed district scale plants in other areas, particularly in and near Mission Bay and in the southeast waterfront area where they could be connected to the purple pipe system that already exists in the streets.

Reference: Steven Minden,
Tishman Speyer & Mission Rock Partners
(sminden@tishmanspeyer.com), 213-458-1272

Moscone Center Expansion Project — 747 Howard Street

Moscone Convention Center (image courtesy of Skidmore, Owings & Merrill LLP with Mark Cavagnero Associates, 2016. All rights reserved.)

Project Status: Online

SFDPH Permit Issued: Yes

Size: 1.5 Million Square Feet

Alternate Water Sources:
- Rainwater
- Foundation Drainage
- Steam Condensate

End Uses:
- Toilet/Urinal Flushing
- Irrigation around Moscone Center and The Yerba Buena Gardens
- Street Cleaning

Volume: 15 Million Gallons/Year

Potable Water Use Reduction: Meets 100% of Onsite Non-Potable Demands & Provides Offsite Potable Water Demand Offset

Drivers: LEED Certification, Compliance with San Francisco Mayoral Executive Directive 14-01, and Compliance with San Francisco's Stormwater Management Ordinance

Onsite Water System Cost: $2.5 Million

Annual O&M Cost Of Onsite Water System: TBD

Owner: Convention Facilities Department

Project Description:

City and County of San Francisco's Convention Facilities Department, in conjunction with San Francisco Public Works and the San Francisco Tourism Improvement District Management Corporation (SFTID), have partnered to develop the $500 million expansion to Moscone Convention Center. The project has a contiguous exhibition space of more than 500,000 square feet, three new ballrooms, more than 80 state-of-the-art new flexible meeting rooms, more than 20,000 square feet of secure outdoor spaces and more than 8,000 square feet of new public open space.

Aiming for LEED Platinum certification, the expanded convention center has several sustainable features, such as the largest rooftop solar array in San Francisco, zero-emissions electricity, and daylight harvesting to offset electrical lighting. The building is one of the most compact, efficient and sustainable convention centers in the U.S., with the lowest carbon footprint per visitor and one of the lowest energy consumption rates per visitor in the world. The building also has net-positive water usage, meaning that the project intends to export more non-potable water offsite than the amount of potable water consumed onsite.

As part of the expansion, the project showcases a district-scale onsite water system that harvests, treats, and reuses rainwater from the new building's roof, foundation drainage from the existing building, and steam condensate from the new building's heating system. The rainwater, foundation drainage, and steam condensate are collected in a 70,000-gallon tank where it undergoes multi-step filtration and UV disinfection. After treatment, the water is distributed for use in Moscone Center's toilets and urinals, the irrigation systems around Moscone Center and Yerba Buena Gardens, and a street cleaning truck fill station that provides treated water for Public Works street cleaning trucks to use throughout the City. A district-scale onsite water system is optimal for Moscone Center and its neighbors due to the large demand for non-potable water in the area and the availability of a significant amount of foundation drainage. Overall, the onsite water system offsets more than 15 million gallons of potable water annually and helps the Moscone Center expansion export more water than the facility consumes.

Drivers for Non-potable Water Reuse:

The project team recognizes that reclaiming and reusing water is the right thing to do, particularly in a state with a history of drought. Other drivers include:

- The LEED Platinum certification target.
- San Francisco Mayor Ed Lee's Executive Directive 14-01, which requires San Francisco City and County agencies to develop alternative local water sources. Prior to the Directive, San Francisco Public Works implemented a strategy for an onsite water system to take advantage of local water resources for reuse.
- San Francisco's Stormwater Management Ordinance that requires projects disturbing 5,000 square feet or more of ground surface to decrease their post construction stormwater runoff rate and volume by 25% for the 2-year, 24-hour design storm.

Ownership Model:

The rainwater, foundation drainage, and steam condensate treatment and reuse system project is owned, operated, and maintained by San Francisco Conventions Facilities Department.

Onsite Water System Project Cost:

The estimated cost of the system is $2.5 million.

Annual Operations & Maintenance Cost of Onsite Water System: TBD

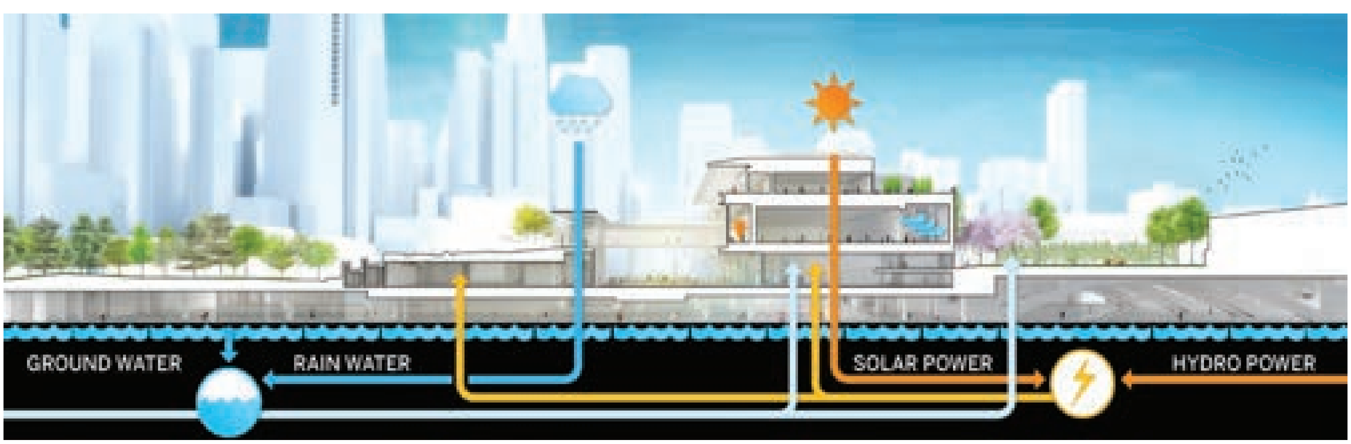
Service Costs to Residents or Tenants:

Not Applicable

Incentives provided by SFPUC:

The Moscone Center Expansion projectreceived a $500,000 grant from the SFPUC through the Onsite Water Reuse Grant Program.

Reference: Steve Basic, The Moscone Center (sbasic@moscone.com)



Moscone Convention Center is planning to implement an onsite water system (image courtesy of Skidmore, Owings & Merrill LLP with Mark Cavagnero Associates, 2016. All rights reserved.)

Nye Sustainable Suburb – Aarhus, Denmark

Homes surrounding Nye's central lake/storage reservoir (image courtesy of Aarhus Vand)

Project Status: Under Construction

Project Size: 42 Acres

Alternate Water Sources:
- Rainwater

End Uses:
- Toilet Flushing
- Laundry

Treatment System Size: Not Available

Potable Water Use Reduction: 40%;
10-13 Gal/Person/Day; up to 800,000 Gallons/Year

Drivers: Sustainability Goals, Conserving Groundwater Resources, Localized Stormwater Management

System Cost: $1.4 Million (Estimated)

Annual O&M Cost: TBD
(Estimated $42,000/Year)

Owner: Aarhus Vand A/S, Denmark

Project Description:

The construction of Nye, a new suburb of Aarhus, Denmark, is a city-driven initiative to meet Aarhus's increasing housing demand with a water-wise urban district that will make sustainable living more effortless for its citizens. Nye is designed to be resilient to the anticipated effects of climate change by incorporating blue/green structures that will also serve as natural amenities for residents and increase biodiversity. The private developer, local water utility Aarhus Vand, and Aarhus municipality collaborated to build a pilot rainwater harvesting system that will be the first of its kind in Denmark. Rainwater from roofs, roads, and open areas are to be collected and conveyed through a network of trenches and ponds to a central lake, which will serve as a storage reservoir. A central treatment plant will pump recycled water through a secondary pipe network to meet the non-potable demands of the community's households, such as toilet flushing and laundry.

The Nye suburb is still under construction, but its first inhabitants moved in during 2018 and the water re-use system will be ready to go online in 2021. Meter data from the first 50 households shows that non-potable water use accounts for approximately 40% of the total household water use, which confirms the expected potable water use reduction. By the time the entire development is completed, it will be able to house approximately 15,000 people.

The close collaboration between the private developer, Taekker Group; the consultant engineer, COWI; the City of Aarhus; and the water utility Aarhus Vand has resulted in a radical new approach to sustainable urban development and master planning residential areas for rainwater harvesting.

Drivers for Non-potable Water Reuse:

The main objectives are to fully manage stormwater runoff, to protect Nye from flooding from the 100-year stormwater event, and to conserve the region's groundwater, which the city of Aarhus depends on for its drinking water supply. Additionally, Nye is designed to meet a number of the UN's 17 Sustainable Development Goals (SDGs), specifically those defined by SDG 6: Clean Water and Sanitation; SDG 9: Industry, Innovation, and Infrastructure; SDG 11: Sustainable Cities and Communities; and SDG 13: Climate Action.

Ownership Model:

The water utility Aarhus Vand will own the water infrastructure.

Project Cost and Funding:

Estimated cost of the Treatment Facility and Pipe System is $1,400,000 USD.

Role of Public Utility in Project:

Motivated by maintaining a sustainable dependence on local groundwater resources to supply Aarhus with water as the city continues to grow, the utility Aarhus Vand worked closely with the municipality and the private developer to design and develop Nye with a rainwater harvesting system to reduce its potable water demand by 40%. As the owner of Nye's water treatment plant, Aarhus Vand will charge residents the same rate for the local non-potable water service as they are charged for their potable water service.

References: Mariann Brun, Project Manager, Aarhus Vand (mariann.brun@aarhusvand.dk);
Pia Jacobsen, Head of Development – Operation Division, Aarhus Vand (pia.jacobsen@aarhusvand.dk)

Schematic of the central treatment plant (image courtesy of Aarhus Vand)

Sydney Olympics — Sydney, Australia

Sydney Olympics Site

Sydney Olympics Urban Water Reuse

Project Status: WRAMS became operational in July 2000; new developments are built and planned (Master Plan completion estimated in 2030)

Size: Area (1,581 acres)

Volume: up to 1.8 million gallons per day (MGD)

Alternate Water Sources:
- Wastewater
- Stormwater

End Uses:
- Toilet flushing
- Irrigation
- Water features

Potable Water Use Reduction: 50%

Driver: Marketability and Mandate (redevelopment)

Cost: US$16.6 million

Owner: Sydney Olympic Park Authority (Public)

Role of Public Utility: Sydney Water Corporation – source of raw sewage, backup services, and billing administration

Project Description:

As part of the Sydney Summer Olympics in 2000, the Water Reclamation and Management Scheme (WRAMS) was developed and includes a water reclamation plant, a water treatment plant, stormwater collection, clean water storage, and recycled water delivery systems. The water treatment plant, which treats a combination of secondary effluent and stormwater, has a maximum capacity of 1.8 MGD. The Water Reclamation Plant supplies various non-potable uses within the park, as well as in the suburb of Newington. Three on-site water quality control ponds at the Sydney Olympic Park also collect stormwater runoff, which is then either re-used for irrigation, used in the production of recycled water, or overflows into local creeks and wetlands.

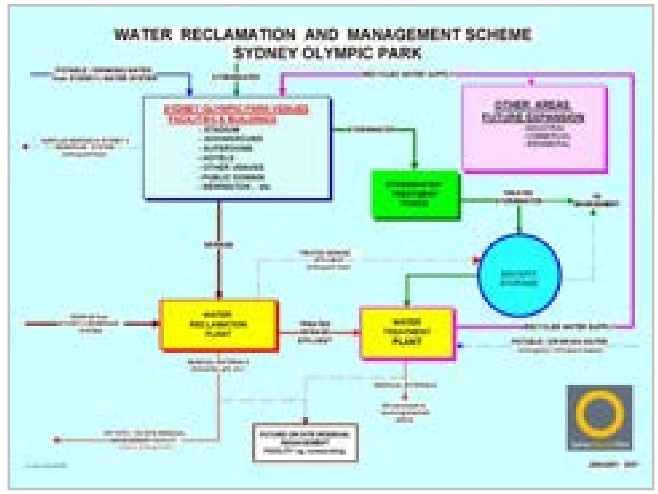
Drivers for Incorporating District-Scale Utilities:

The Sydney Olympic Park Master Plan (2002) requires all new developments to connect to WRAMS.

Ownership Model:

WRAMS was developed and is owned by the Sydney Olympic Park Authority (SOPA) and is operated by a third party contractor (Kilpatrick Green, a.k.a. United KG). The implementation process included a competitive public tender process for design, construction, and operation. Currently SOPA has a 25 year operating agreement in place with United KG, who

Sydney Olympics Integrated Water Cycle



Sydney Olympics Water Reclamation and Management Scheme

also designed and built the treatment plants and stormwater reservoir. For the purpose of WRAMS, SOPA is a Water Supply Authority under the New South Wales (NSW) Government's Water Management Act of 2000 and is responsible for managing the scheme including compliance with regulatory and statutory Authorities. The NSW Minister for Planning is the consent authority for all development within Sydney Olympic Park.

Role of Public Utility in Project:

WRAMS sources its sewage supply from Sydney Water Corporation's (SWC) sewage network utilizing the concept of sewer mining. SWC and SOPA jointly developed a formal sewer mining agreement in 2000 to enable SOPA to source sewage from SWC's sewer system. Infrequent surplus sewage is sent to Sydney's sewage system and SWC also provides potable water.

In addition, meter reading and customer billing functions, recycled water pipeline maintenance, plumbing inspections and certifications have been outsourced and are being performed by SWC on behalf of SOPA.

Project Cost and Funding:

WRAMS at Sydney Olympic Park had a capital cost of US$16.6 million (Australian $15.88 million). Actual costs of WRAMS operation (excluding capital investment) is on the order of US$6/CCF (Australian $2.00 per kilolitre (kL)).

Rate Structure for Water and Sewer Services from Public Utility:

SWC charges homes, apartments, dual occupancies, and mixed use development water users with a meter at a rate of US$6.33/CCF (Australian $2.13/kL) for potable water and a fixed charge of US$146.40 (Australian $138.77) each quarter for wastewater (prices apply from July 1, 2012 to June 30, 2013 and are set by IPART). The Independent Pricing and Regulatory Tribunal of NSW (IPART) is a government agency that determines the maximum water, wastewater, and stormwater prices that declared water utilities can charge. A fixed water service charge each quarter is set at US$35.64 (Australian $33.78) if you have your own meter, US$18.76 (Australian $17.78) if you share a meter. If you don't have a meter, you pay US$136.76 (Australian $129.63).

Residents of Homebush Bay (which is a Sydney suburb that include Sydney Olympic Park) who have recycled water pay a fixed charge each quarter to SWC for their connection of US$9.36 (Australian $8.87) (July-September quarters) and US$9.24 (Australian $8.76) (October-June quarters). The recycled water price is set at US$0.45/CFF (Australian 15 cents/kL) below Sydney's drinking water price of US$5.89 (Australian $1.98/kL). This recycled water price does not reflect its true cost or value. SWC collects the service charge and per kiloliter charges for SOPA.

Service Costs to Residents or Tenants:

A small connection charge is applicable on a quarterly basis.

Incentives Provided to Promote District Utilities:

Discounted water rates.

Uber Mission Bay at 1455 and 1515 Third Street – San Francisco, CA

Uber Headquarters (image courtesy of HTEC)

Project Status: Completed

Project Size:
1455 Third St: 182,530 Square Feet
1515 Third St: 223,680 Square Feet

Alternate Water Sources:
- Rainwater
- Graywater

End Uses:
- Toilet Flushing
- Irrigation

Treatment System Size:
1,200 Gallons/Day (Graywater)

Potable Water Use Reduction: 22%;
Graywater - 219,000 Gallons/Year,
Rainwater - 474,500 Gallons/Year

Drivers: Non-Potable Water Ordinance (Article 12C Compliance)

System Cost: $500,000 (Estimated)

Annual O&M Cost:
$23,000 Est. – Operation/Maintenance
$35,000 Est. – Article 12C Testing
$23,000 Est. – Treatment System Manager

Owner: Uber Technologies

Project Description:

The new San Francisco headquarters for Uber Technologies is comprised of two buildings: an 11-story building at 1455 Third St, and a 6-story building at 1515 Third St. Rainwater and graywater are collected from both buildings and treated at a facility within 1515 Third St before distribution to end use. This is the first district scale system to be permitted under Article 12C.

Storage tanks at 1455 Third St collect the building's rainwater and graywater in separate tanks. The collected rainwater and graywater are transferred to the storage tanks at 1515 Third St, where they undergo separate treatment processes before being combined in a treated water storage tank. The treated water is then used to meet the irrigation and toilet flushing demands of both buildings.

Rainwater is treated using an 800-micro prefilter, 30-micron sediment filter, and an 186mJ/cm2 UV disinfection tower with a combined collection volume of 24,000 gallons for both buildings. Graywater is treated using an 800-micron prefilter, NSF-350 certified membrane bioreactor, and an 186mJ/cm2 UV disinfection tower with a combined average treatment capacity of 1,200 gallons per day. Keeping the sources of influent in separate treatment trains reduces the size and cost of the overall system while still meeting or exceeding Article 12C log reduction targets.

Treated water residual disinfection per the Article 12C requirement is accomplished by an on-site sodium hypochlorite generator. The generator uses table salt to create an environmentally benign concentration of sodium hypochlorite and peroxide. This allows the facility to reduce the environmental and health hazards associated with the transportation, storage, and handling of highly concentrated sodium hypochlorite. A side stream recirculation loop is continuously monitored to maintain the required level of residual disinfection.

Drivers for Onsite Water Reuse:

This project falls under SFPUC's Article 12C requirement for an onsite non-potable water system to treat and reuse available graywater and rainwater for toilet flushing and irrigation.

Ownership Model:

Uber Technologies owns the building and the water reuse system. System designer Heat Transfer Equipment Company (HTEC) is contracted for operations and maintenance, and third-party affiliates will provide lab analysis and the treatment system manager role.

Lessons Learned:

As with the launch of any new regulatory policy, uncertainty around implementation and compliance led to several project-specific challenges along the way. The manufacturer had to seek clarification from the SFPUC and its third-party consultants on multiple occasions regarding Article 12C and its supporting documents to fully understand how to comply with the regulation. This iterative process allowed both the manufacturer and the SFPUC to more fully understand how projects can move forward under this new regulatory framework. The manufacturer was able to submit an approved treatment train that became the basis of design for future Article 12C projects.

It was important for HTEC to be able to pivot with changing site conditions during the COVID shutdown, and to be able to support the installation contractors understand the system, a type of system they had no prior experience with. HTEC spent many more hours on site than originally anticipated to assist with installation hurdles. This helped HTEC develop more comprehensive installation guides for plumbing and electrical that have benefited more recent system installations since. It is not yet clear how to navigate a conditional startup of the system during the buildings' limited initial occupancy, requiring further coordination with the Department of Public Health.

Reference: Bill McCabe, Heat Transfer Equipment Company (bill@htecompany.com)

Onsite reuse system at Uber HQ (image courtesy of HTEC)

UConn Reclaimed Water Program — Storrs, CT

UConn Central Utilities Plant

Project Status: Under construction (anticipated to be operational in early 2013)

Size: Campus (3,000 acres)

Volume: up to 1 MGD

Alternate Water Sources:
- Wastewater
- Rainwater

End Uses:
- Feedwater for the Central Utilities Plant (boiler and cooling tower water)
- Irrigation (future)

Potable Water Use Reduction: 20%

Driver: Water resources

Cost: $20 - 26 million

Owner: UCONN (Private)

Role of Public Utility: NA

Project Description:

A water reclamation facility is being constructed to treat wastewater which will be blended with captured rainwater for redistribution on-site to satisfy campus non-potable water demands (cogeneration power plant and irrigation). Recycled water is being developed for non-potable uses due to a lack of additional water supplies in the area. There is also potential for future system expansion to supply non-potable water to the adjacent Town of Mansfield (total system capacity up to 1 MGD).

Drivers for Incorporating District-Scale Utilities:

The University of Connecticut (UConn, the University) anticipated increasing potable water needs on campus due to growing population. This need could not be met by the limited capacity of UConn's existing water sources, two permitted groundwater supplies, and there was a lack of additional conventional water supplies available. This need for a new source of water, along with the University's focus on sustainability, prompted the decision to implement a recycled water program.


UConn Microfiltration


UConn Water Reclamation

Ownership Model:
The University owns and operates the water system which serves the campus; therefore they are the owner, operator, and consumer of the district water system. UConn also provides water to more than 100 users across parts of Mansfield, including Town Hall, E.O. Smith High School, and the emerging downtown Storrs Center.

Role of Public Utility in Project:
NA

Project Cost and Funding:
The project will cost between $20 and $26 million. The University water system is funded through operating and capital funds. Operating funds are taken from the Facilities Operations budget which is generated from tuition. Capital funds include funding from the "UConn 2000 Program" and "21st Century UConn Initiative" are used for particular water-related projects, including the water reclamation facility. The University water system is also partially funded by water revenues from its off-campus customers.

Rate Structure for Water and Sewer Services from Public Utility:
The University does not bill any on-campus users for water, but historically utilized a declining block structure[2] for off-campus commercial customers and a flat rate for unmetered residential customers. This policy did not encourage conservation, so a uniform rate structure[3] was adopted for commercial and metered residential customers in 2006. The change was made in part to encourage conservation. An inclining block pricing structure[4] may be considered in the future if necessary to reduce wasteful consumption and encourage maximum conservation.

Although on-campus users are not billed for water, on-campus meters are recorded continuously and reviewed on a daily basis, while off-campus meters are read quarterly. Meter reading of on-campus users serves an important function with regard to leak detection. Metered residential and commercial customers are charged at a uniform rate of $3.05/CCF.

Service Costs to Residents or Tenants:
The basic service fee for off-campus customers ($100 per year) covers meter reading, billing expenses, and administrative costs related to overseeing the customer metering program.

Incentives Provided to Promote District Utilities:
None currently, as the system will only serve the campus initially. In the future, the University may develop incentives to spur buy-in from off-campus customers.

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[2] With a declining block structure, water is priced in blocks of consumption with a decrease in unit price as the user enters a larger consumption block.

[3] Uniform rates are based on the assumption that every unit of water is of equal value; the unit price of water is constant.

[4] With an inclining block pricing structure, water becomes more expensive as consumption increases; the unit priceincreases as the user enters increasing volume blocks.

UN Plaza Foundation Drainage Project — Market Street

UN Plaza (image courtesy of Taylor Nokhoudian)

Project Status: Construction Completed In 2020

SFDPH Permit Issued: No

Size: N/A

Alternate Water Sources:

- Foundation Drainage

End Uses:

- Irrigation
- Street Sweeping
- Make-Up Water in UN Plaza Fountain

Volume: 14,500 GPD; 5,292,500 Gallons/Year

Potable Water Use Reduction: TBD

Driver(S): Reduce Potable Water Use and Comply with Executive Directive 14-01

System Cost: $3,000,000

Annual O&M Cost: TBD

Owner: San Francisco Public Works

Project Description:

The UN Plaza is located along Market Street between 7th and 8th Streets in San Francisco's Civic Center neighborhood. The Plaza, which is publicly owned and maintained by San Francisco Public Works, was built in 1975 as part of the Market Street Reconstruction Project which coincided with the construction of the Bay Area Rapid Transit (BART) stations along Market Street. The majority of the Civic Center neighborhood was built over an underground branch of Hayes Creek. As a result, San Francisco Public Works encountered foundation drainage issues caused by the construction of a deep vault below the UN Plaza Fountain. Public Works recognized foundation drainage as a valuable alternate water source and historically pumped the water at UN Plaza to a truckfill station used for street cleaning on Market Street. However, that operation was abandoned over thirty years ago. Now, Public Works plans to restart water reuse operations underneath the UN Plaza Fountain and take back the under-utilized resource.

Per San Francisco Mayor Ed Lee's Executive Directive 14-01, San Francisco City and County Agencies are working to develop alternative local water sources. Following the intent of the Directive, Public Works and SFPUC began discussing the possibility of implementing an innovative Foundation Drainage Reuse Project at UN Plaza. The project will recycle foundation drainage underneath the UN Plaza fountain for beneficial purposes such as irrigation, street sweeping, and use in the Plaza Fountain.

To treat the foundation drainage for reuse, the project will use multiple step media filtration coupled with disinfection. The treated water will be stored in a 15,000 gallon tank that will be located in the existing UN Plaza Fountain reservoir. The onsite water system is projected to provide 14,500 gallons of recycled water per day and 5,292,500 gallons annually.

Drivers for Non-potable Water Reuse:

A primary objective for Public Works is to reduce potable water use. Municipal street sweeping operations in the Civic Center and Tenderloin neighborhoods require multiple truck fills each day, using up to 6,000 gallons per day. Additionally, irrigation around the UN Plaza, City Hall, Civic Center Plaza, Asian Art Museum, and Main Library use up to 37,000 gallons per day, most of which could be met using this non-potable water supply. Lastly, the UN Plaza Fountain loses 50 gallons per week due to evaporation and the non-potable water supply will help offset this water demand. Implementing the onsite water system allows Public Works to utilize foundation drainage as a resource to offset their potable water needs in the UN Plaza area.

Ownership Model:

The proposed foundation drainage treatment and reuse system project is owned, operated, and maintained by San Francisco Public Works.

Project Cost:

The estimated cost for the onsite water system is $3,000,000.

Annual Operations & Maintenance Cost: TBD

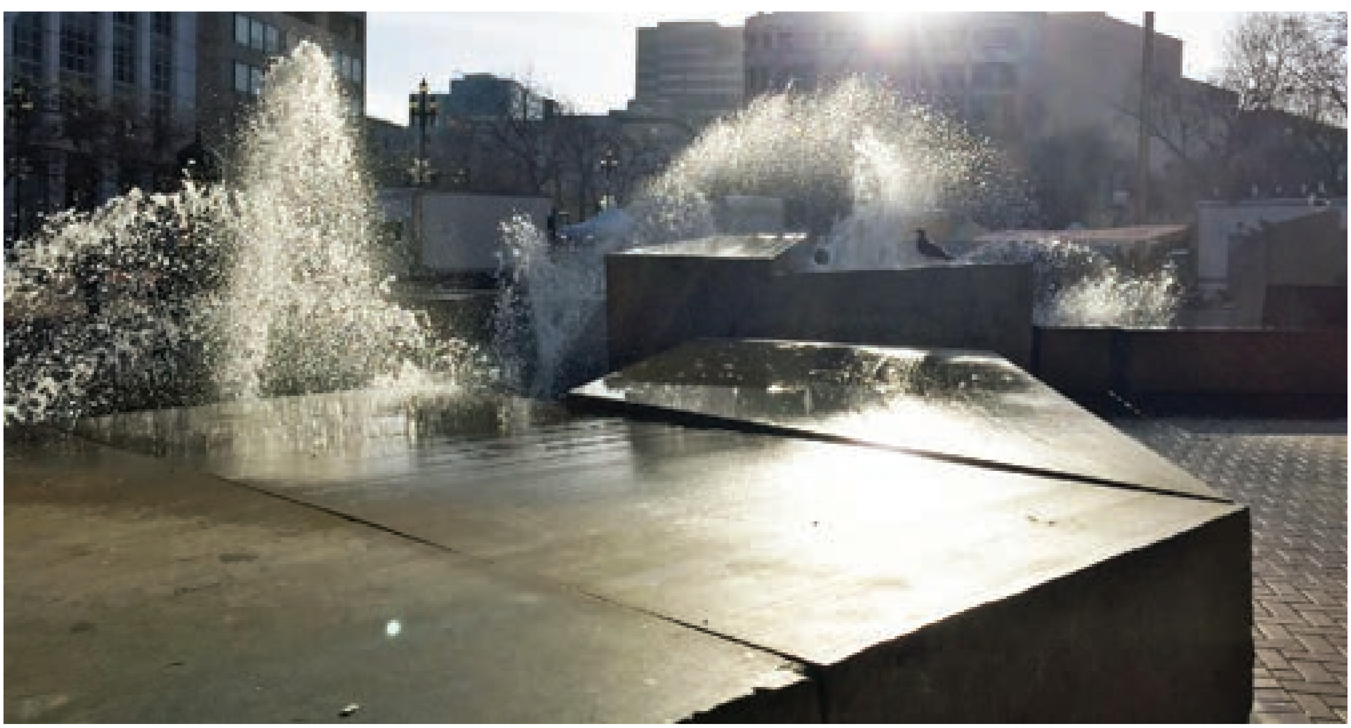
Service Costs to Residents or Tenants:

Not Applicable

Incentives provided by SFPUC:

The UN Plaza Foundation Drainage Reuse project received a $500,000 grant from the SFPUC through the Onsite Water Reuse Grant Program.

Reference: Raymond Lui, San Francisco Public Works (Raymond.Lui@sfdpw.org)



UN Plaza Fountain (image courtesy of Taylor Nokhoudian)

The WaterHub® at Emory University – Atlanta, Georgia

Exterior of the WaterHub greenhouse at Emory University (image courtesy of Sustainable Water)

Project Status: Completed

Project Size: 7,800 Square Feet
(3,500 Greenhouse/Building,
3,000 Outdoor Hydroponics)

Alternate Water Sources:
- Blackwater

End Uses:
- Boiler Makeup
- Cooling Tower Makeup
- Toilet Flushing

Treatment System Size: 440,000 Gallons/Day

Potable Water Use Reduction: 40%

Drivers: Drought, Aging Infrastructure, EPA Consent Decrees, Rising Water & Sewer Rates, Conserving Community Water Resources

System Cost: Not Available

Annual O&M Cost: Not Available

Owner: Third-Party Investor

Project Description:

Since it was commissioned in May 2015, the WaterHub at Emory University has provided over 350 million gallons of recycled water to the campus and is designed to reduce the campus's total water demand by 40%. Wastewater is mined directly from the municipally owned sewer system on campus, and reclaimed water is provided to campus HVAC/utility systems (makeup for central chiller and steam plants). The treatment process is housed in a greenhouse to allow for the integration of technology and nature deploying a hydroponic moving bed biofilm reactor (MBBR) treatment train. The greenhouse also serves as a gathering place for a student led docent program providing 3 tours per week and a central facility for the Living, Learning Laboratory for the campus. While the WaterHub currently serves five central utility plants through a reclaimed water distribution network of 4,400 linear feet, the non-potable service will expand to as many as five other campus-owned utility systems over the next few years, including the University Hospital.

In addition to servicing campus utilities, the WaterHub is connected to a residential dormitory delivering it with non-potable water for toilet flushing. Emory

University plans to connect the WaterHub® to dormitories coming online in the future that are designed to accepted non-potable water.

Drivers for Onsite Water Reuse:

In the last decade, Atlanta has witnessed numerous water-related stresses, including severe drought. The EPA mandated consent decrees to resolve critical water infrastructure failures and an extended political dispute over water rights in the so-called "Tri-State Water Wars". As a result of these challenges, Emory University set out to explore ways to minimize its impact on community water resources and the environment with a more strategic and impactful water management solution: campus-wide water reclamation and reuse.

Ownership Model:

Through a Water Processing Agreement (WPA), Sustainable Water designed, built, commissioned, and continues to oversee operations of the WaterHub on behalf of the university. Under a services agreement, a third-party operator hired by the investor takes responsibility for the ongoing operations, maintenance, and compliance. This model eliminates development and operational risk for the client while delivering long-term water utility savings through a guaranteed discounted rate structure.

Role of Public Utility in Project:

Dekalb County was instrumental in the permitting and final approval processes of this project. With Dekalb County working towards the federally mandated infrastructure improvements to meet their consent decrees, they welcomed the sewer flow reductions that would result from the treatment and beneficial reuse across Emory University's campus.

Project Cost and Funding:

The project was funded through a Water Processing Agreement with no capital or operating costs borne by Emory University and guaranteed savings accruing over the life of the project.

Lessons Learned:

- Engage with academic stakeholders early and do not under estimate the value these stakeholders have in a campus utility / facilities design process.
- Never under estimate public interest in local sustainability initiatives and plan for interactive tours.
- Plan for the future. Design for the next 30 years of development, demand, and hydraulic constraints.

Reference: Bob Salvatelli, Sustainable Water (bob.salvatelli@sustainablewater.com)
(973) 632-8560

Interior of the greenhouse (image courtesy of Sustainable Water)

The WaterHub® At Philip Morris USA – Richmond, Virginia

The WaterHub's greenhouse, administrative building, and reclaimed water storage tank (image courtesy of Sustainable Water)

Project Status: Completed

Project Size: 8,200 Square Feet

Alternate Water Sources:

- Blackwater

End Uses:

- Cooling Tower Makeup
- Open-Air Chiller Makeup

Treatment System Size: 650,000 Gallons/Day

Potable Water Use Reduction: 40%

Drivers: Operational Resiliency, Corporate Sustainability, Conserving Community Water Resources, Relieving Strain on Municipal Infrastructure

System Cost: Not Available

Annual O&M Cost: Not Available

Owner: Third-Party Investor

Project Description:

Located on the site of a former coal-fired power plant, the WaterHub at Philip Morris USA (PMUSA) is a symbol of an industrial park's turn to green infrastructure. The WaterHub, which began operation in 2019, can produce 650,000 gallons per day while also serving as the primary water supply for a district-energy system with 27,000 tons of refrigeration capacity. The WaterHub is expected to decrease total potable water use for the industrial park by approximately 40% and decrease total wastewater discharge by up to 70%. Moreover, the system is designed to reduce risk of manufacturing center downtime by providing a redundant source of makeup for critical utility (cooling tower makeup and open-aired chillers) operations.

The full project scope includes approximately 6,000 linear feet of water conveyance and distribution piping in addition to 150,000 gallons of clean water storage. The facility contains a full-service water testing laboratory, operator offices, and a conference room for staff and guests. System operations are highly automated, leveraging cloud-based state-of-the-art SCADA and 24-hour remote monitoring capabilities.

Drivers for Onsite Water Reuse:

Like many cities in the United States, the City of Richmond has a combined sewer system, which is prone to overflows during even minimal rain events. Combined sewer overflow (CSO) events have been a significant source of pollution to the James River Watershed and the larger Chesapeake Bay Watershed. The City, working with the Department of Environmental Quality to meet the goals set in its Watershed Action Plan, welcomed the sewer flow and discharge reductions that the WaterHub would achieve by diverting for treatment and reuse across the industrial campus. Altria, the parent company of PMUSA, was also looking for an opportunity to provide industry leadership in water sustainability by conserving community water resources, relieving the strain on local municipal infrastructure, and insulating their operational viability, all of which is accomplished by the WaterHub system.

Ownership Model:

Through a Water Processing Agreement (WPA), Sustainable Water designed, built, and operates the WaterHub at PMUSA. Under a services agreement, Sustainable Water takes responsibility for all permitting, compliance, and maintenance matters through the life of the contract. This development model eliminates development and operational risk for the Client while delivering long-term water utility savings through a guaranteed discounted rate structure.

Role of Public Utility in Project:

The City of Richmond was instrumental in the permitting and final approval processes of the project.

Project Cost and Funding:

The project was funded through a WPA with no capital or operating costs borne by Philip Morris USA and guaranteed savings accruing over the life of the project.

Lessons Learned:

A key learning was that industrial clients such as Philip Morris USA tend to have higher variability of influent concentrations, especially after cleaning processes are conducted during semi-annual maintenance protocols. Another lesson was to plan ahead for the possible expansion of the water reuse system's distribution components.

Reference: Bob Salvatelli, Director of Business Development at Sustainable Water (bob.salvatelli@sustainablewater.com) (973) 632-8560

The onsite reuse system's mechanical room (image courtesy of Sustainable Water)

Anchor Brewing Company – San Francisco, CA

Anchor Brewing Company

Project Status: Completed

Project Size: Not Available

Alternate Water Sources:
- Brewery Process Water

End Uses:
- Tank and Bottle Rinses
- Packaging
- Clean-in-Place
- Facility Washdown

Treatment System Size: 10,000 Gallons/Day

Potable Water Use Reduction: 68%; (Capacity to Recycle up to 20,000,000 Gallons/Year)

Drivers: Sustainability Goals

System Cost: $5,290,000

Annual O&M Cost: Not Available

Owner: Anchor Brewing Company

Project Description:

Anchor Brewing Company, America's first craft brewery, is the first brewery in San Francisco to install a brewery process water recycling system.

With help from Cambrian's wastewater reuse technology, Anchor installed a water recycling system that captures and treats process water from rinsing bottles and cleaning equipment for reuse in similar applications. Anchor's process water recycling system will have the capacity to save 20 million gallons of water per year. This reduction in wastewater will reduce Anchor's water usage footprint by 68%.

Cambrian's wastewater reuse technology treats brewery process water to meet San Francisco's guidelines for brewery process water recycling.

The project was implemented through Cambrian's 20 year water-purchase agreement (WEPA), under which Cambrian invested into the plant and sells clean water back to Anchor brewing as a service, reducing long term stress of keeping up with ever changing regulations.

Drivers for Onsite Water Reuse:

Anchor Brewing Company was driven by its commitment to sustainability. Onsite water recycling helps Anchor reduce its potable water consumption by over 60%. The system is also providing ongoing cost savings by reducing the brewery's annual wastewater fees. Additionally, with the water reuse system, Anchor is achieving environmental benefits such as reducing carbon emissions. By treating water at the source, it reduces the need for pumping and trucking water. Overall, the system is reducing the brewery's overall carbon footprint by over 90 metric tons per year.

Ownership Model:

Cambrian owns the onsite water reuse system. Cambrian and Anchor entered into a Water Energy Purchase Agreement (WEPA) which, removed any cost barriers for Anchor to successfully implement their water recycling system. The Cambrian WEPA is an innovative approach to partnering with customers so breweries such as Anchor only pay for the gallons of water treated instead of the construction and ongoing operational maintenance of the technology.

Role of Public Utility in Project:

The San Francisco Public Utilities Commission (SFPUC) developed brewery process water reuse guidance, including pathogen and chemical control strategies for process water to be reused for tank and bottle rinses, floor wash down, boiler feed water, and as a source water for the beer. The SFPUC guidance includes requirements for source water characterization, source control, treatment, and ongoing monitoring to ensure the water is safe for these uses. Following the SFPUC's guidance, the project received a $1,000,000 grant from the SFPUC through the Onsite Water Reuse Grant Program.

Reference: Michelle Keefer, Cambrian (**mkeefer@cambrianinnovation.com**)

Anchor Brewing Company's brewery process water recycling system

Bullitt Center – Seattle, WA

The Bullitt Center (photo by Nic Lehoux)

Project Status: Completed

Project Size: 50,000 Square Feet

Alternate Water Sources:
- Rainwater

End Uses:
- Potable Drinking Water

Treatment System Size: 1,700 Gallons/Day

Potable Water Use Reduction:
100%; 125,000 Gallons/Day

Drivers:
To Achieve Living Building Certification in Alignment with the Bullitt Foundation's Environmental Mission, and to Lower Barriers for Constructing More Sustainable Buildings in the Future

System Cost: Not Available

Annual O&M Cost: $60,000

Owner: The Bullitt Foundation

Project Description:

The Bullitt Center has a fully operational rainwater-to-potable water system in a dense urban setting in Seattle. The building was designed, built, and operated to demonstrate what is possible, attempting to do everything right from the perspective of regenerative design, and the water system is a key component of the project. The sustainable water features at the Bullitt Center consist of three elements: the rainwater harvesting system designed to achieve "net-zero" water use and provide potable water for all building uses (including drinking water), a vacuum flush toilet system to reduce water use and wastewater production, and a graywater system to complete the hydrologic cycle by infiltrating treated water for groundwater recharge.

Rainwater is captured at the 7,000-sf roof and routed to a 56,000-gallon concrete cistern in the basement. The rainwater is sent through a vortex filter, which removes large particulates, followed by ultra-filtration in three ceramic filters with the finest removing viruses. Following this, the rainwater is also passed under ultraviolet light and through activated charcoal and a small amount of chlorine is added. Treated water is stored in two 500-gallon day-use tanks.

Graywater from sinks and showers drains into a 500-gallon storage tank in the basement of the building and then pumped up to a constructed wetland at the third-floor green roof for treatment. The graywater is circulated through a series of drip lines to allow plants to absorb nutrients, and then is released into bio-swales along the edge of the site where the water filters down through 20 feet of gravel before it reaches the water table.

Drivers for Onsite Water Reuse:

The primary driver of the building's rainwater-to-potable water system was the Bullitt Foundation's mission of safeguarding the natural environment and promoting responsible human activities and sustainable communities in the Pacific Northwest. To demonstrate this, the project pursued the ambitious "Living Building Challenge" certification that required, among other performance imperatives, that all water demands be met with onsite sources and all be treated and managed onsite.

Ownership Model:

The Bullitt Foundation owns the water system and manages the Bullitt Center. The Foundation has contracted with Water & Wastewater Services Herndon to manage the water system, performing the day-to-day operational tasks such as preventative maintenance, water quality monitoring, cross connection control, and field engineering. The operator needs special certifications as required by state regulation.

Role of Public Utility in Project:

The project required a formal agreement from the Seattle Public Utilities (SPU) to allow the formation of a new Group A public water system within its retail service area. The Bullitt Center maintains two connections to SPU service, for the fire sprinkler system and for emergency domestic supply. Prior to final approval of the water system the SPU provided potable water through the emergency domestic connection.

Project Cost and Funding:

The overall cost to construct the Bullitt Center was $28.5 million, and the estimated cost of annual O&M is $60,000.

Lessons Learned:

It was important to research and understand the relevant rules and regulations before developing the Center's water system plan because regulations, guidance, and enforcement vary by state and jurisdiction. The Washington State Department of Health (WSDOH) oversees implementation of the overarching EPA regulations and additional State regulations. It was necessary to develop a water system plan with qualified engineers and architects for WSDOH's review and approval in advance of construction.

At the Bullitt Center, the building engineer can release water stored in the rainwater cistern in advance of a storm so it can capture stormwater while it is raining and mitigate peak flows into the combined sewer. If this strategy could be implemented at scale across a system of cisterns controlled by the stormwater authority, the potential stormwater management benefits are significant.

A major challenge was that WSDOH requires National Sanitation Foundation (NSF) certification or testing to NSF standards for every part of the system that contacts rainwater before it reaches the cistern, including the solar array on the roof. If possible, finding system components that already have NSF approval would save the time and money required to test components to ensure that they meet NSF standards.

The Bullitt Center team explored the possibility of delivering safe drinking water without chlorine, but found that it is required by the federal Safe Drinking Water Act without exception, and regulatory authorities cannot grant waivers to its use.

Reference: Salley Anderson, Bullitt Foundation (sanderson@bullitt.org)

Additional Information: https://bullittcenter.org/2018/11/01/rainwater-to-potable-water-system-is-live/

Onsite reuse system (image from Gray & Osborne Inc., Consulting Engineer's Bullitt Center Water Treatment System Engineering Report)

Lubhu Fecal Sludge Treatment Plant – Lubhu, Nepal

A view of the treatment plant's prefabricated modules (photo courtesy of ENPHO)

Project Status: Completed

Project Size: 3,229 Square Feet

Alternate Water Sources:
- Blackwater

End Uses:
- Irrigation
- Soil Amendments
- Biogas

Treatment System Size: 226 Gallons/Day

Potable Water Use Reduction: 50%

Drivers:
- Public Health (Manage Sewage)
- Pilot Demonstration Project to Demonstrate the First Prefabricated FSTP Modules in Nepal for Fecal Sludge Treatment
- Optimum Resource Recovery: Reuse of All Possible End Products Closing the Sanitation Loop

System Cost: USD $70,000

Annual O&M Cost: USD $2,320

Owner: Nepalhilfe Beilngries, Kathmandu

Project Description:

The 3,229 square foot Fecal Sludge Treatment Plant (FSTP) located in Lubhu, Nepal was built by the Environment and Public Health Organization (ENPHO) in collaboration with Mahalaxmi Municipality, BORDA, the CDD Society, and Nepalhilfe Beilngries. The FSTP piloted the use of prefabricated modules for construction, and is designed for resource recovery, with a treatment process that generates water suitable for irrigation, transforms bio-solids into soil fertilizers, and captures biogas that can be used for cooking. As the first of its kind in Nepal, the FSTP provides a model for how waste can be transformed into valuable resources.

Drivers for Onsite Water Reuse:

The primary objective of the project was to safeguard the health of people residing in relief camps built during emergency response to a devastating earthquake on April 25th, 2015. Ten such camps were built in Lubhu, situated in Mahalaxmi Municipality of Kathmandu Valley, Nepal. These camps were provided with on-site sanitation systems to improve sanitation conditions and safeguard the health of the people residing in the camps. But as time passed the emergency latrines filled up and overflowed with fecal sludge, posing a public health risk. Without a fecal sludge treatment plant in Kathmandu Valley, the unsafe disposal of the fecal sludge was inevitable.

Additionally, this project was intended to showcase a successful model of resource recovery from fecal sludge. The Nepalhilfe Beilngries' orphanage, which operates a small farm adjacent to the FSTP, utilizes recovered water for crop irrigation and treated bio-solids for soil fertilizer.

Ownership Model:

The FSTP is owned, operated, and maintained by Nepalhilfe Beilngries, Kathmandu, with technical support of the ENPHO and other administrative support of Mahalaxmi Municipality. Nepalhilfe Beilngries has appointed a caretaker of the facility who was trained in O&M, a sanitation safety plan, personal hygiene and safety measures, and end-product reuse.

Role of Public Utility in Project:

The private companies that provide fecal sludge emptying and transport services pay a tipping fee for desludging into the plant. ENPHO regularly provides technical support and Mahalaxmi Municipality provides administrative assistance.

Project Cost and Funding:

The total project cost $70,000 and was implemented with the financial support from the CDD Society.

Lessons Learned:

The most typical challenges for treatment plants in Nepal are land acquisition and successful O&M. A key lesson from this project was that resource recovery can be sufficient incentive for people and the community to resolve land issues and operate the plant effectively.

The land where the FSTP was sited was originally intended to farm a year-round supply of food for the orphanage. However, water scarcity and the expense of fertilizers made it impossible to farm the land year-round as planned by Nepalhilfe Beilngries. Since one of the provisional designs of the FSTP was to recover water and bio-solids for farming, Nepalhilfe Beilngries agreed to provide the land for the plant.

The simplicity of the FSTP's design allows for proper and regular O&M in the absence of highly trained labor. Because the treatment plant requires fecal sludge as the core feeding material to operate, it is critically important to the continued operation of the plant that the people desludging the latrines have adequate incentive to do so. Engaging all stakeholders was key to the project's success.

Reference: Rajendra Shrestha, Environment and Public Health Organization (ENPHO) (rajendra.shrestha@enpho.org) (977-1- 5244641, 5244051)

The orphanage farm utilizes recycled water for irrigation and treated bio-solids for soil fertilizer (photo courtesy of ENPHO)

Mazda Stadium – Hiroshima, Japan

The baseball field's rainwater fed sprinkler irrigation system (photo source: www.city.hiroshima.lg.jp/site/gesuido/2638.html)

Project Status: Completed

Project Size: 3 Acres (Size of Baseball Field)

Alternate Water Sources:
- Rainwater

End Uses:
- Toilet Flushing
- Water Feature
- Irrigation

Treatment System Size: Not Available

Potable Water Use Reduction:
1,630,000 Gallons/Year (Measured In 2019)

Drivers:
- Water Use Cost Savings
- Flood Control Measures

System Cost: $2,040,000

Annual O&M Cost: $13,900 for Disinfection and Water Feature O&M

Owner: Hiroshima City

Project Description:

The Mazda Zoom-Zoom Stadium, home to the baseball team the Toyo Carp in Hiroshima, Japan, underwent a massive renovation to incorporate an onsite regional stormwater project which includes a rainwater reuse system. Completed in 2019, the renovation installed a subsurface reservoir below the baseball field to collect stormwater runoff from the stadium and surrounding area, managing a total drainage area of 128 acres. As a multi-purpose water reuse effort, the project won the "Circulation Michi Sewerage Award" from the Water Division of the Ministry of Land, Infrastructure, Transport and Tourism. About 7% of the reservoir (264,000 gallons) is segmented for the rainwater reuse system, while the other 3.5 million gallons of storage capacity prevent stormwater from inundating the sewer system, most critically preventing flooding of the nearby Hiroshima Station, which has an underground plaza and passageways.

The rainwater treatment system disinfects the runoff with chlorine and passes it through a filtration system before it is re-used for the baseball field's sprinkler irrigation, for the stadium's toilet flushing, and for a circulating water feature outside the stadium called the "Amaoto no Komichi". The "Amaoto No Komichi" has educational signage about sustainable stormwater management, is designed for children to play in, and is lit up at night.

Drivers for Onsite Water Reuse:

A key driver for the rainwater reuse system was to reduce the stadium's water charge.

Ownership Model:

The stadium is owned by Hiroshima City. The O&M of the rainwater reuse system is outsourced to Hiroshima Toyo Carp Co., LTD.

Role of Public Utility in Project:

The Sewerage Bureau of the Hiroshima City Government took a strong initiative to install the stormwater reservoir under the baseball stadium because there is such limited space for large scale stormwater control measures in the densely urban area. Without these measures in place, heavy rainfall over 0.78 in/hr exceeds the drainage capacity of the sewer and would result in flood damages.

Project Cost and Funding:

The total project cost was $2,040,000, half of which was subsidized by the Japanese National Government, while half was paid for by municipal bonds and the allocation of local tax funds.

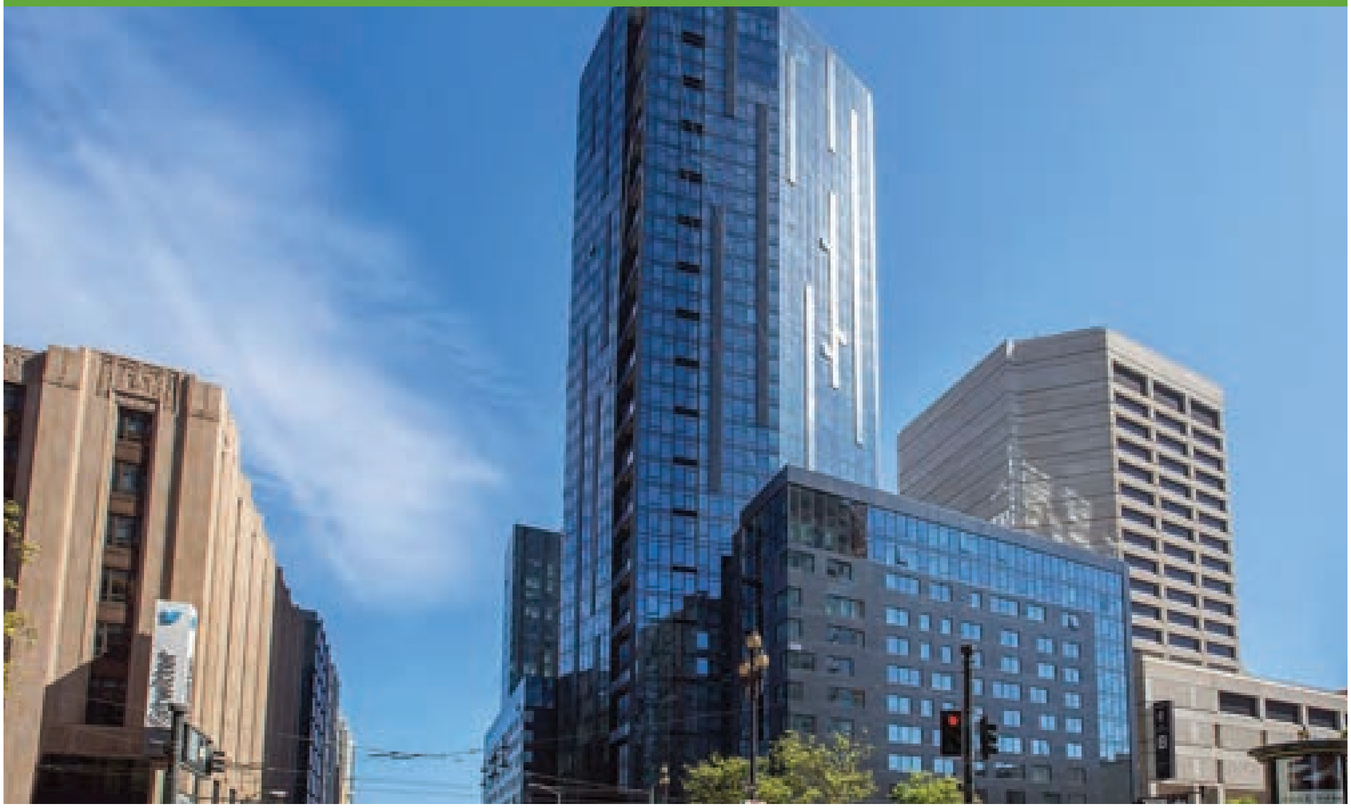
Lessons Learned:

When there is a series of games with full stadiums of spectators, the supply from the water reuse system cannot meet the toilet flushing demand.

Reference: Hiroshima City Government, Sewerage Bureau, Facility Management Department, Planning and Management Section (g-keikaku@city.hiroshima.lg.jp)

The circulating playground water feature "Amaoto No Komichi" (photo source: www.city.hiroshima.lg.jp/site/gesuido/2638.html)

NEMA – San Francisco, CA



NEMA apartment complex (image courtesy of Epic Cleantec)

Project Status: Completed

Project Size:
Deployed at a 754-Unit Residential Building

Alternate Water Sources:

- Blackwater

End Uses: Nutrient Recovery to Produce High-Quality Sterile Soil Amendment

Treatment System Size: 3,000 Gallons/Day

Potable Water Use Reduction:
Not Applicable (No Water Reuse)

Drivers: Cost-Savings, Developer's Sustainability Goals, Developer's Desire to Prepare for Future Article 12C Projects

System Cost: Not Available

Annual O&M Cost: Not Available

Owner: Nema

Project Description:

NEMA is a 754-unit residential community and apartment complex consisting of a 24-story tower and a 37-story tower connected by a podium, located across the street from one another in downtown San Francisco. The high-rise complex was constructed for sustainable self-sufficiency, achieving LEED Silver Certification. To further its commitment to sustainability, NEMA installed a distributed Epic Cleantec solids handling system - designed to capture, process, recover, and reuse solid waste from the building's wastewater collection system.

The proprietary Epic Cleantec wastewater system enables a more circular model of resource use by recovering value from solid waste, like compost. The NEMA system consists of an initial, ultra-fine screening process to remove solids from the wastewater, and a proprietary chemistry to sterilize the solids and process them into a reusable form. The solids recovery system is designed to function with both 'greywater' and 'blackwater' influent sources. At NEMA, the solids filtered from the wastewater are collected in a self-contained, odor-proof, temperature-controlled cabinet. Twice a week, the recovered organics are taken off-site and processed through a proprietary sterilization system, where they are then converted into high-quality soil amendments that can be used to create renewable soil blends. This product can be used in a wide range of applications, varying from bulk amendment in public parks to bagged products for distribution and sale in nursery and gardening stores.

Drivers for Onsite Water Reuse:

NEMA, and Epic, have furthered the goal of water sustainability – institutionalizing a proprietary wastewater solids system that moves the building, and the city, one step closer to a zero-waste future for the building's occupants and San Francisco residents in general.

Ownership Model:

Epic Cleantec was responsible for the operation and maintenance of the system for the duration of the pilot.

Project Cost and Funding: Not available

Lessons Learned:

The Epic system can significantly reduce a project's ongoing sewer charges, minimizes energy and waste loading to the downstream wastewater treatment facility, and creates a high-quality sterile soil amendment that can be used to create renewable soil blends for the benefit of households and public agencies. Deployment of this technology throughout San Francisco could catalyze downstream wastewater treatment plants to undergo significant reductions in system service and operational maintenance programs.

As demonstrated through this project, Epic Cleantec views wastewater as a resource recovery opportunity, not as waste. The screening system is a next-generation management technique for biosolids and wastewater treatment that saves money for building owners and creates a more circular, resilient economy for the future of San Francisco.

Reference: Eric Hough, Chief Commercial Officer - Epic Cleantec (eric@epiccleantec.com)

Tour of solids processing operation (image courtesy of Epic Cleantec)

PureWater SF – San Francisco, CA

Project Status: Completed

Project Size: 277,500 Square Feet

Alternate Water Sources:
- Blackwater
- Rainwater

End Uses: Testing and Analysis for Potential Potable Reuse Applications

Treatment System Size: 45-50% Recovery; 4,000 Gallons/Day

Potable Water Use Reduction: Research project did not provide a potable offset; however, 1:1 potable water use reduction would be anticipated with implementation

Drivers:
- Test Treatment Process Reliability
- Staff and Public Engagement
- Operator Training
- Support State and National Research

System Cost: $1.2 Million (Includes Operation And Maintenance Cost)

Owner: San Francisco Public Utilities Commission (Project & Site), The United States Bureau Reclamation (Equipment), and The Water Research Foundation (Analytical Data/Report)

SFPUC Headquarters

Project Description:

PureWaterSF was a building-scale Direct Potable Reuse (DPR) research and demonstration project aimed at better understanding the opportunities and challenges of decentralized potable reuse along with collecting data relevant for both small- and large-scale potable reuse.

The PureWaterSF treatment system train was temporarily added to a pre-existing constructed wetland system that treats blackwater and rainwater for toilet flushing at the office headquarters building of the San Francisco Public Utilities Commission (SFPUC) in downtown San Francisco. The PureWaterSF advanced water treatment (AWT) system included ultrafiltration, reverse osmosis, and an ultraviolet advanced oxidation process (UF/RO/UV AOP) to purify the tertiary recycled water effluent from the existing wetland system. The AWT train, which was designed to have a small footprint while producing high-quality water able to meet drinking water standards, was able to treat approximately 85% of the water from the wetland system. During operation, the system was online from Monday through Friday, 24 hours a day.

This research project was completed in two distinct phases. First, the treatment and monitoring system was designed and installed in June of 2018 and the system was tested and monitored for eight months through February 2019. During the second phase from June through October 2019, analytical samples of the wastewater were periodically collected at every stage of the treatment train for lab analysis of water quality parameters to verify the system's ability to meet drinking water standards and to document treatment performance. After analysis, all the water produced by the AWT was recombined with the brine and returned to the building's toilet flushing system.

Drivers for Onsite Water Reuse:

With two combined wastewater/stormwater treatment plants but no drinking water treatment plant within the City and County of San Francisco, the SFPUC is very interested in understanding and exploring the potential for DPR as a future water supply. The location and scale of this initial research project were selected for high visibility, to support project goals, and to allow for more direct management of project staff. It was advantageous to collect wastewater from a such small sewershed, which has greater variation in wastewater strength and quality, so that the treatment system's ability to handle variation could be more easily observed and the reliability of its process tested. It also provided an opportunity to train operators onsite, and to contribute to statewide data that will inform the development of DPR regulations that are to be conceived by 2023.

Ownership Model:

Designing the AWT, purchasing and installing the equipment included in the system, and testing the online monitoring system were completed by the SFPUC and its consultant with financial support from the United States Bureau of Reclamation (USBR). The second phase of the project, which included the water quality testing and analysis, was conducted with funding support from the Water Research Foundation. Each funding partner owns components of the project based on the terms of its grant agreement with the SFPUC.

Role of Public Utility in Project:

The SFPUC hosted the project at its headquarters, provided funding, day-to-day oversight and coordination, and was directly involved in every aspect of the project. SFPUC operators received training to operate the system and helped with troubleshooting over the course of the research. SFPUC staff worked closely with the consultant team and conducted regular staff tours and public outreach.

Project Cost and Funding:

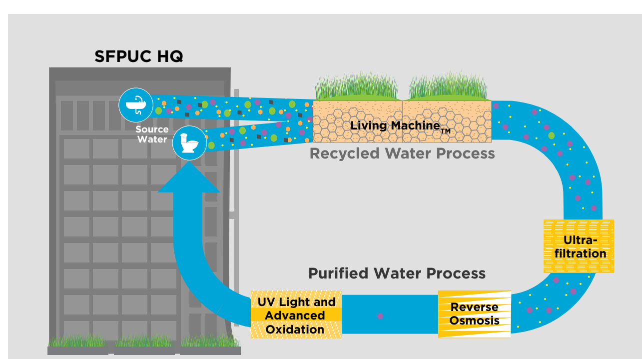
USBR provided grant funding of $200,000 toward the purchase and installation of AWT equipment. WRF provided a grant of $200,000 for water quality testing and data analysis. The SFPUC provided in-kind staff time and funds totaling $800,000 toward completion of the project.

Lessons Learned:

The AWT system consistently provided high quality water, as did PureWaterSF at the building scale. Consistent influent water quality, critical control point monitoring, and the ability to divert off-specification water were all important design objectives. PureWaterSF did experience greater variability in pathogen concentrations and some chemical spikes compared to larger-scale potable reuse projects, though it was still within the range of what is generally observed within centralized municipal wastewater. Given the sensitivity of a small sewershed to chemical inputs, additional barriers would likely be required for pathogen reduction.

Operations and maintenance (O&M) considerations in potable reuse projects include operational needs, source control, operator skills, and accuracy of online monitors. While potable reuse systems are not generally designed for intermittent operations, PureWaterSF only operated during the workweek. Long weekends required particularly careful preparation to preserve the AWT equipment, especially the RO membranes. Source control can be customized based on the size and nature of the sewershed. Although much of the AWT processes are automated, it was important to have highly skilled operators for frequent calibration, chemical batching and troubleshooting. For small-scale operations, it may be most efficient to manage networks of facilities at one central location. Finally, online monitors need to be highly sensitive at very low concentrations, especially for small scale decentralized systems, so it is important to test and identify the most appropriate online monitoring systems. Continuous online monitoring is a critical part of a well-designed potable reuse system.

Reference: Manisha Kothari, SFPUC (mkothari@sfwater.org)



Schematic of treatment system

Seismic Brewing Company – Santa Rosa, CA

Seismic Brewing facility (image courtesy of Seismic Brewing)

Project Status: Completed

Project Size: 15,000 Square Feet

Alternate Water Sources:

- Industrial Process Water

End Uses:

- Boiler Feed
- Tank Cleaning
- Motor/Gearbox Cooling
- Facility Washdown

Treatment System Size: 8,000 Gallons/Day

Potable Water Use Reduction: 50%; 300,000 Gallons/Year (In 2020; Expected to Increase to 500,000 Gallons in 2021 and Continue to Grow with Brewery)

Drivers: Sustainability Goals

System Cost: Not Available

Annual O&M Cost: Not Available

Owner: Seismic Brewing Company

Project Description:

Seismic Brewing's water treatment and reuse system was installed in 2016 as the brewery completed construction. The system treats wastewater from the brewing process so it can be reused onsite, helping to reduce the brewery's potable water demand. In the brewing industry, the average water consumption is 7 gallons of potable water per every gallon of beer brewed, whereas at Seismic it is now just 2.7 gallons of potable water per every gallon of beer brewed. Treated wastewater is reused for non-potable processes such as facility washdown, boiler feed, cooling motor gearboxes, and tank cleaning.

In developing the brewing facilities, Seismic pursued a holistic water treatment approach and undertook groundbreaking efforts to reduce water consumption. A majority of the equipment was provided by Cambrian Innovation, Toray Industries, ClearBlu Environmental, and Water Works Inc, with the engineering integration and operation of these components done by the brewery itself. The system incorporated Cambrian's EcoVolt Mini, a system specifically designed for small and midsize food and beverage producers. The Ecovolt is a highly automated system able to provide advanced wastewater treatment. To polish the water after filtration, it undergoes a high-recovery reverse osmosis process and UV disinfection. Other key components of the water treatment system are a primary screening unit for solids removal, an equalization tank, and a "headworks" unit, which is effectively the system's control room.

An additional benefit of the onsite treatment and reuse of the brewery's wastewater is the avoidance of additional City sewer fees for industrial process water treatment.

Drivers for Onsite Water Reuse:

Seismic Brewing was founded with sustainability, including water conservation, as a core principle. The Seismic team recognized that to brew as responsibly as possible they would need to pursue an ambitious approach to maximizing water and energy efficiency. The onsite water treatment and reuse system, coupled with various clean energy initiatives, help to reduce the brewery's resource and carbon footprint.

Ownership Model:

Seismic Brewing Company is the sole owner and operator of its water treatment and reuse system.

Role of Public Utility in Project:

The public utility encouraged the project's efforts but didn't play a significant role in the development of the reuse system. By avoiding the one-time connection and demand fees that would normally be paid by a larger water customer, Seismic was able to greatly offset the cost of the system.

Lessons Learned:

Breweries are excellent applications for water reuse systems due to high water demand and numerous suitable uses for non-potable water. With that said, most craft breweries have a very high barrier for entry into on-site water treatment and/or reuse. Cost and complexity of these systems are still very high for most small breweries, but it is slowly becoming more approachable. The system at Seismic Brewing will hopefully serve as a test case and successful example for other small craft breweries to follow, especially given the increasing drought conditions in California.

Reference: Andy Hooper, Seismic Brewing Company (ahooper@seismicbrewingco.com)

Treatment system RO skid (image courtesy of Seismic Brewing)

The New School – New York City

The New School's University Center (image courtesy of NSU)

Project Status: Completed

Project Size: 375,000 Square Feet

Alternate Water Sources:
- Blackwater
- Graywater
- Rainwater

End Uses:
- Toilet Flushing
- Cooling Tower Make-Up
- Irrigation
- Laundry

Treatment System Size: 40,000 Gallons/Day

Potable Water Use Reduction: 74%

Drivers: Education, Sustainability Goals, ROI in Cost Savings, LEED Certification

System Cost: Not Available

Annual O&M Cost: Not Available

Owner: The New School

Project Description:

Working with Natural Systems Utilities (NSU), the New School installed water conservation fixtures and an on-site water treatment and recycling system during the construction of its University Center. Located on 5th Avenue, the University Center stands 16-stories, and was opened to the public in 2014. Its water systems were designed to reduce water use by 74% and reduce discharge into the combined sewer by 89%. All of the building's wastewater is collected and treated at the University Center including water from toilets, sinks, showers, laundry, etc. Stormwater is also included as a source of reclaimed water after it is detained by the vegetated green roofs. The University Center contains one of the largest operating in-building water recycling systems in New York City with a treatment capacity of 40,000 gallons per day, and it is one of the first buildings approved to reuse treated water for laundry. Other uses include toilet flushing, irrigation of the green roof, cooling tower make-up, and sidewalk maintenance. The University Center is LEED Gold certified and achieved every point in LEED's water efficiency category.

The water recycling system consists of a membrane bioreactor followed by a multiple barrier approach for disinfection. The bioreactor is an activated sludge system with membranes that have an effective pore size of 0.4 microns. The disinfection system consists of an ozone generation and contacting system, used for oxidation and color removal, followed by an ultraviolet light system for additional disinfection. Finished water in the storage tank is circulated through the ozone and UV systems to maintain the level of disinfection. Surplus raw wastewater and residual biosolids are discharged to the city sewer system. Automatic potable water fill valves at the water storage tanks ensure an uninterrupted supply of water. In this way, there is a backup system to provide water service in case the recycling system is out of service for maintenance or repair. A computerized system automates control of the entire process.

Drivers for Onsite Water Reuse:

Many communities worldwide are approaching, or have already reached, the limits of their available water supplies. Water demand exceeds sustainable supply in many areas and the current practices of diversion, consumption, use, and disposal are depletive and destructive. The New School University adopted a “water fit for purpose” strategy to address this challenge where all sources of water were considered and all opportunities to reduce water use were identified.

Ownership Model:

The system is owned by The New School and NSU designed, built, and has operated and maintained the system since construction was completed.

Role of Public Utility in Project:

New York City played an integral role in this water reuse system’s permitting and approval process. The onsite system is backed up by public infrastructure, which allows the discharge of biosolids into the city sewer. This is mutually beneficial because it eliminates the need for pumping and hauling while the system’s aerobically active biomass provides in-pipe treatment and organics to the City’s sewage system during dry weather conditions.

Project Cost and Funding:

The project was privately funded, and qualifies for the Comprehensive Water Reuse Program rates which reduce water and sewer fees from the City of New York by 25%.

Lessons Learned:

- Previous installations paved the way for laundry to be added as an approved use for non-potable water, ultimately leading to a higher percent reduction in water use and sewer contribution.
- Getting involved early in a project is key to being successful. This will allow for the system to be optimally located reducing the need for pumping, improving access to equipment, and reducing risk while improving reliability.
- Continuous improvements on headworks and influent screenings greatly improves the system’s longevity and reduces life cycle cost of downstream equipment.
- Reverse osmosis can be added as a sidestream for cooling tower reuse where source water conductivity is high.

Reference: Phil Skalaski, The Durst Organization (PSalaski@durst.org), (212) 257-6600

The onsite reuse system’s control panel (image courtesy of NSU)

The Solaire – New York City, NY

The Solaire residential tower (image courtesy of NSU)

Project Status: Completed

Project Size: 383,000 Square Feet

Alternate Water Sources:
- Blackwater
- Graywater
- Rainwater

End Uses:
- Toilet Flushing
- Cooling Tower Make-Up
- Irrigation

Treatment System Size: 25,000 Gallons/Day

Potable Water Use Reduction:
%50; 9 Million Gallons/Year

Drivers: Battery Park City Authority Green Initiatives, Sustainability/LEED Certification, Anticipated Future Cost Savings

System Cost: Not Available

Annual O&M Cost: Not Available

Owner: Albanese Organization

Project Description:

Completed in 2003, The Solaire was the country's first environmentally advanced residential high-rise tower, and the first new development to be completed in lower Manhattan following September 11th, 2001. Standing 27-stories tall, the luxury apartment building is located by the waterfront of the Hudson River in Battery Park City. The building is LEED Platinum certified, and features naturally harvested building materials, a landscaped roof terrace with herb gardens, photovoltaic panels built into the façade, electric vehicle charging stations, and a wastewater treatment and reuse system.

The project's developer, The Albanese Organization, partnered with Natural System's Utilities (NSU) to design and construct Solaire's wastewater reuse system. The system features a membrane bioreactor with ultraviolet and ozone disinfection. Treated water is reused for flushing toilets in the 293 apartment units, for cooling tower make-up, and for irrigation of the green roof and adjoining teardrop park. Over the years the system has been upgraded to reduce energy consumption, utilize online biological monitoring, and a thermal energy recovery system has been installed to achieve net zero energy water reuse.

Drivers for Onsite Water Reuse:

Inspired by New York's first "green" commercial high rise at 4 Times Square, the Battery Park City Authority (BPCA) assembled a multidisciplinary team to set environmental standards for residential development in Battery Park City. Motivated by sustainability goals, Albanese proposed this onsite water reuse system which exceeded the BPCA's requirements set forth in its environmental standards for water conservation and reuse. With rising water and sewer rates, and incentives such as the comprehensive water reuse program provided through NYCDEP, the system has begun to pay for itself.

Ownership Model:

The water reuse system is owned by Albanese Organization and NSU designed, built, and has provided operation and maintenance services since 2003.

Role of Public Utility in Project:

New York City played an integral role in this water reuse system's permitting and approval process. When the reuse system was first proposed, it was not allowed according to city code, so the BPCA staff had to reach out to the utility commissioners to advocate for the project's approval. The onsite system is connected to public infrastructure so that biosolids can be discharged to the sewer. This eliminates the need for pumping and hauling, while the City's sewer system benefits from Solaire's aerobically active biomass that provides in-pipe treatment and organics to the city sewage system during dry weather conditions.

Project Cost and Funding:

The Solaire building's total construction cost was $91.5 million. Initially, the Albanese Organization setup a venture partnership with Northwest Mutual to finance the project through a combination of debt and equity investment, however the September 11th attack in 2001 directly impacted the development site and the project's financing agreements with lenders. Albanese was the first developer to apply for and receive tax-exempt Liberty Bonds that were approved by U.S. Congress through the New York State Housing Finance Agency to aid redevelopment after the attack. Albanese estimates that its investment in environmental features added 14.5% to the project's overall costs, though some of this investment is recovered by cost savings from improved efficiencies and an environmental premium on its apartment units' rent prices. Because the onsite water treatment system reduces the building's burden on public water infrastructure, it saves somewhere between $50,000-$100,000, and these cost savings are anticipated to grow with increasing water and sewer rates.

Lessons Learned:

- Increase of overall reuse percentage by working closely with cooling tower consultants to improve water quality and ultimately allow for 100% reclaimed water to be used as cooling tower makeup.
- Reduction in energy by improving blower operations.
- Reduction of chemical consumption by eliminating the need for chlorination while implementing other forms of disinfection such as UV and Ozone.
- Incorporation of online biological monitoring
- Implementation of a patented heat recovery system designed to extract sensible heat from treated effluent and pre-heat the domestic hot water. This has resulted in a net energy neutral operation reducing the buildings overall carbon footprint. It also increases cooling tower efficiency by reducing the temperature of the make-up water. (NSU Patent # US9719704B2)

Reference: Miroslav Salon, Albanese Organization (msalon@verdesian.com), (212) 528-2200

The green roof reduces runoff, insulates the building, and is irrigated by the onsite reuse system (image courtesy of NSU)

Vashantek and Tarabo Urban Decentralized Wastewater Collection and Treatment Systems – Dhaka Slums, Bangladesh

Vashantek community post installation (image courtesy of Water1st International)

Project Status: Completed

Project Size: Collection and Treatment System for 575 Households

Alternate Water Sources:
- Raw Sewer (Blackwater) from Community Toilets

End Uses:
- Treated Discharge to Environment (No Direct Reuse)

Treatment System Size: Anaerobic Upflow Filter Design Flow 850 Gallons/Day. Empty Bed Contact Time Estimated 9 Days

Drivers: To Improve Living Conditions with a Gravity Flow Collection System Designed for Low Capital Costs, Easy Installation, and Local O&M

System Cost: USD $31,800

Annual O&M Cost: USD $480 (Estimated)

Project Description:

The non-profit Dushtha Shasthya Kendra, which works to reduce poverty across Bangladesh, teamed up with Water 1st International and the local government to finance and build two decentralized wastewater treatment systems (DEWATS) with small anaerobic upflow wastewater treatment plants in the slum communities of Vashantek and Tarbo in Dhaka, the capital city of Bangladesh. These wastewater systems demonstrate remarkable progress in a city where 80% of the 18 million inhabitants are disconnected from any kind of wastewater collection system.

These wastewater treatment systems provided a vast improvement to the quality of life for the 640 residents of Vashantek and the 1,750 residents of Tarabo. Prior to the systems being put in place, the discharge of untreated sewage to local areas and water bodies was hazardous to human and environmental health and caused a foul smell. The systems require no pumping or energy inputs and are providing significant treatment with over 40% reduction in COD, 50% reduction in phosphorous, and over 80% reduction of TSS.

Drivers For Onsite Water Reuse:

The improvement in the local area living conditions is striking when compared to pre-installation conditions. The sewage smell is noticeably absent! During a February 2018 site assessment, when explaining why they continued to maintain the collection system, community members were emphatic that the improvement in community living conditions was nothing short of miraculous.

Ownership Model:

The DEWATS systems are governed and maintained by the local community. Ongoing baseline water quality data is monitored to determine the filter replacement schedule.

Role of Local Government:

Support to facilitate the construction and operation.

Tarabo anaerobic treatment at work (image courtesy of Water 1st)

Project Cost and Funding:

The $31,800 project was funded by Water 1st International, a Seattle based non-profit that works to implement clean water supply and sanitation services to the world's most vulnerable communities.

Lessons Learned:

While the treatment portion of these wastewater systems is certainly interesting and appears to be working, the heart of this project is the successful implementation of a piped wastewater collection system in one of the most challenging settings on the planet and continued operation of this system by the poorest of the poor. Success here is determined by the drastic improvement in local living conditions, continued maintenance and governance of the system by the local community, the resiliency of the system to recover from the monsoon conditions (collection and treatment), and the fact that ongoing baseline water quality data is being collected and is used to determine filter replacement.

The Vashantek and Tarabo experiences provide a proof of concept for DEWATS using locally based management as a viable and implementable approach to addressing the health, livability and environmental issues surrounding the current crisis of untreated and unmanaged human fecal waste in urban areas of the developing world. This approach allows for implementation based on a wide variation in funding. The DEWATS allows future incorporation of the facilities into larger solutions and for staged treatment options. The DEWATS concept is compatible with potential reuse options or incorporation of future toilet modifications.

Reference: Steve Deem, Water 1st International (stevedeem@water1st.org)

California's Onsite Non-potable Water Reuse Regulations

Authors: Brian Bernados & Sherly Rosilela, California State Water Resources Control Board Division of Drinking Water

Until recently, California public health officials lacked the pertinent information needed for a credible risk assessment addressing toilet flushing with treated graywater. Within the last decade, there has been growing interest in expanding the use of graywater from outside subterranean landscape irrigation to indoor uses. California public health officials knew this would require more water treatment but were not sure how much more. When the California Department of Public Health (CDPH) was consulted and reviewed the portions of the 2010 California Plumbing Code (CPC) addressing graywater, it was recognized that there were many unknowns, such as water quality and required treatment standards. At the time, the only regulatory recommendation CDPH could make was to follow the existing California Code of Regulation (CCR) Title 22, Section 60301.230 criteria for disinfected tertiary recycled water, which are the criteria for water reclamation of domestic wastewater. While it was recognized that this did not explicitly address graywater, there was no other standard available at the time.

In this vacuum, the NSF/ANSI standard 350 Onsite Water Reuse was developed in an attempt to provide a manufacturer standard analogous to an Underwriters Laboratories (UL) Listing. The standard established material, design, construction, and initial filtration unit performance requirements for onsite residential and commercial water reuse treatment system. The NSF/ANSI standard 350 did not specify an ongoing performance standards. The NSF/ANSI standard 350 was referred to in the next version (2013) of the CPC for certain graywater applications. The NSF/ANSI standard 350 committee process was conducted without the involvement from California public health officials at CDPH. As a result, while NSF Standard 350 includes requirement for filtration device, it does not address the important process of disinfection and inactivation of pathogens. Thus, NSF Standard 350 does not entirely provide public health protection, nor coincide with the disinfected tertiary recycled water standard in the CCR Water Recycling Criteria of Title 22. Nationwide, addressing the inconsistencies between device standards and public health protective standards for indoor use of graywater continued to be a source of confusion for regulators and practitioners.

In 2014, the administration of the Drinking Water Program in CDPH was transferred to the State Water Resources Control Board (SWRCB). Acknowledging the need for a uniform standard that is protective of public health and the evolving knowledge field of onsite non-potable water systems, California public health officials (now a part of the SWRCB) joined the National Blue Ribbon Commission for Onsite Non-potable Water System in 2016. The commission is comprised of representatives from municipalities, public health agencies, water utilities, and national organizations for innovative water solutions.

The major accomplishment of the NBRC was the collaboration between government public health officials and water utilities to agree on a nationwide standard. The NBRC published its Model State Regulation incorporating recommendations of the 2017 expert panel publication "Risk Based Framework for the Development of Public Health Guidance for Decentralized Non-Potable Water Systems" (2017 Risk Based Framework). This valuable report with its science-based risk assessment provides the basis for protection of public health for indoor use of various source waters, including graywater. The Model State Regulation includes a table specifying Log Removal Targets (LRTs) for pathogens for various source waters and end uses.

As recycled water continues to gain recognition as a valuable water resource, the push for uniform standard in decentralized (onsite) scale continues to gain the California public, stakeholder, and legislature support. California Senate Bill 966, effective January 1, 2019, directed the SWRCB to adopt regulations for risk-based water quality standards for the onsite treatment and reuse of non-potable water for non-potable end uses in multifamily residential, commercial, and mixed-use buildings. The regulations must include, among many other things, risk-based log reduction targets for the removal of pathogens such as enteric viruses, parasitic protozoa, and enteric bacteria for non-potable water sources, including graywater, and non-potable ends uses, including toilet flushing. SWRCB Division of Drinking Water (DDW) staff is leading the rulemaking effort. The statutes direct SWRCB to adopt the regulations by December 1, 2022. By December 1, 2023, the Department of Housing and Community Development, in consultation with the SWRCB, is required to adopt any necessary corresponding building standards to support the risk-based water quality standards established by the SWRCB.

The SWRCB DDW staff finds that the 2017 Risk Based Framework help addresses the need for a credible and scientifically based risk assessment addressing toilet flushing with treated graywater. The SWRCB DDW will be utilizing the 2017 Risk Based Framework and the NBRC's Model State Regulation as a starting point to inform the development of the regulations for onsite treatment and reuse of non-potable water.

Enabling Water Reuse in Colorado

Author: Bret Icenogle, Colorado Department of Public Health and Environment

Colorado's long history of water supply challenges have resulted in regulations and policies that drive conservation and water reuse. The challenges are rooted in historical water diversions, frequent droughts, and threats of more recurrent and severe periods of insufficient supply due to climate change. According to the Colorado Water Plan, Colorado predicts a 500,000 acre foot shortfall of water supply and the doubling of the state's population by 2050. Water reuse, or reclaimed water, can be one tool to help mitigate this shortfall.

This state did not regulate water reuse until 2000 when the Water Quality Control Commission (commission) adopted Reclaimed Water Control Regulation 84 to allow for landscape irrigation with non-potable reclaimed water. The Colorado Department of Public Health and Environment (the department) oversees this regulation. The regulation included three reclaimed water categories based on the potential exposure level: Category 1 is minimal exposure, Category 2 is restricted exposure, and Category 3 is unrestricted exposure. Each category has corresponding water quality standards, minimum treatment requirements, and best management practices. The water quality standards can be *E. coli* plus turbidity or total suspended solids. Landscape irrigation was the only use allowed for reclaimed water when the commission first adopted Regulation 84. Over 20 years, the commission has adopted 17 new uses for reclaimed water, using the landscape irrigation as a base for developing standards. These reclaimed water uses fit within one or more of the three categories.

Prior to 2017, adding new approved uses of reclaimed water was based on potential exposure paths to reclaimed water and *deduced* health risks. While the department and commission considered environmental and health based risks, there was (and still is) limited information so they relied on sparse data sets and generally accepted practices for items like pathogen concentration and exposure dose. This approached shifted in 2017 based on two key factors. First, the Colorado legislature and two progressive water leaders within Colorado expressed their desire to expand the adopted reclaimed uses to include toilet and urinal flushing from localized (decentralized) and centralized sources. Second, the Water Environment & Reuse Foundation (WE&RF) published the *Risk-Based Framework for the Development of Public Health Guidance for Decentralized Non-Potable Water Systems* that provided the foundational framework necessary for the adoption of indoor toilet and urinal flushing. The commission ultimately incorporated log reduction targets (LRTs) and other aspects from this publication into Regulation 84 because this science-based approach was more protective of public health. This marked the shift toward implementing fit for purpose treatment goals based on specific source water characteristics and microbial risk assessment models.

The state has benefited from incorporating the LRTs into Colorado's regulatory framework. First and foremost, the LRTs enable the safe expansion of uses because, as with any approved use, the risks and costs of potential disease outbreaks and the associated negative setbacks must be considerably low. In addition, the adoption of LRTs has shifted the program toward establishing fit for purpose public health targets while giving time to work through challenges in advance of widespread pressures to implement indoor toilet and urinal flushing with reclaimed water. This approach has also allowed the department time to coordinate among its implementing agencies, including the Colorado Plumbing Board, and Colorado Water Conservation Board, prior to widespread adoption.

With clear benefits of early adoption, progressive systems have pushed forward and installed localized reclaimed water systems prior to the department finalizing any supporting policy and guidance work for the adopted LRTs. For example, one of the most popular mountain peaks visited in Colorado, Pikes Peak (visitor center elevation is at 14,115 feet), traditionally paid to haul potable water up the mountain and wastewater down to a municipal wastewater treatment plant. The adoption of localized systems allows the system to treat wastewater from the restrooms and cafeteria for toilet flushing reuse, thereby reducing hauling costs. Additionally, Colorado's largest potable water provider has installed a localized system in their administration building for toilet flushing reuse and is also exhibiting the treatment system to educate the public, promote water efficiency and reuse, and to set an example for future development.

These early adoptions have not come without challenges however. Systems have experienced long review times since the regulation is new and the department has not developed policies or guidance yet. Without these policies or guidance, and given the complexities of each reuse system, multiple coordinated agency reviews and approvals is needed. The state has also experienced challenges with implementation prior to fully developing the framework needed to support the regulation. A prime example is the adaption of existing systems into the revised LRT frameworks. Prior to 2017, Colorado identified all reclaimed water systems as centralized but the new regulation differentiates between centralized and localized systems. Colorado's localized systems are akin to decentralized non-potable water systems as defined by the WE&RF report. In Regulation 84, these two systems are defined as follows:

- Localized system - a domestic wastewater treatment works that receives domestic wastewater from a single building, multiple buildings within a single property or area bounded by dedicated streets or ways, or a district designated by a City or County for treatment to produce reclaimed water for beneficial use where the source water does not have meaningful inputs from industrial or other diluting sources.
- Centralized system - a domestic wastewater treatment works that receives domestic wastewater from a diverse service area for treatment to produce reclaimed water for beneficial use where the service area has meaningful inputs from industrial or other diluting sources.

Colorado has existing reclaimed systems currently classified as centralized systems that may actually represent localized systems because they do not have meaningful inputs from industrial or other diluting sources. Now, Colorado is evaluating how to best classify systems (centralized versus localized) and potentially transition existing systems to more stringent treatment requirements.

Furthermore, Colorado is contending with the practical implementation of the risks and LRTs defined by the WE&RF report. For example, the WE&RF publication does not account for LRT reductions based on mitigating risk through best management practices but Colorado's existing reclaimed water categories include exposure categories and best management practices. Similarly, the WE&RF report does not address all the approved reclaimed water uses in Colorado. Colorado has to classify existing uses, such as reclaimed water for fire protection, within the adopted framework. Finally, while the WE&RF report defines LRTs, minimal studies and documentation exist on how to credit log reductions to common wastewater and drinking water treatment processes for virus, protozoa, and bacteria based on various sources of wastewater. Even so, the Department recognizes that resources have been developed more recently to assist with pathogen reduction crediting. These publications are useful to the state and will help the department continue advancing reuse using a risk based approach by relying on the latest research.

Energy and Greenhouse Gas Implications of Hybrid Centralized and Decentralized Reuse Systems in San Francisco, CA

Authors: Kara L Nelson[1], Olga Kavvada[2], Arpad Horvath[1]

One of the most compelling reasons to pursue decentralized reuse is to collect and produce recycled water in close proximity to where it will be reused, thus avoiding the large conveyance costs needed to transport wastewater and recycled water over large distances and elevations. While all reuse systems aim to conserve water, it is also important to consider the implications of design decisions on cost, energy use, and greenhouse gas emissions. As wastewater treatment systems are typically characterized by economies of scale, whereas pipe networks are typically characterized by dis-economies of scale, factors like population size, density, and topography can have a large influence on these parameters for decentralized reuse systems (Figure 1). In addition, if a centralized wastewater collection and treatment system already exist, the environmental performance of new decentralized infrastructure must be compared to that of the existing system.

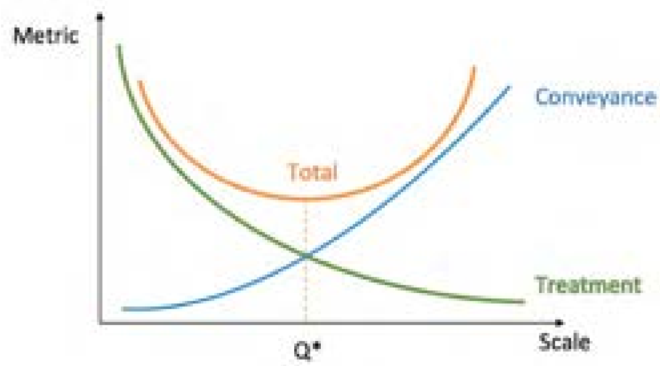


Figure 1. The optimum scale (flow rate, or number of people served) for decentralized reuse depends on the economies-of-scale of the treatment system and the diseconomies-of-scale of the piped conveyance system. Metrics of interest include unit energy, greenhouse gas emissions, and economic cost.

In this case study, we explore such trade-offs for San Francisco, CA, which was chosen because it is a global leader in promoting hybrid decentralized/centralized reuse systems. Two related modeling studies were conducted: (1) a comparison of centralized and decentralized systems for providing non-potable recycled water at different locations in the city (Kavvada et al 2016); and (2) an analysis of the impact of decentralized system size and location (Kavvada et al 2018). The modeling framework combined life cycle assessment and geospatial analysis to account for the distances (modeled on the existing road network) and changes in elevation over which wastewater and recycled water must be transported. In both studies, we assumed that the

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decentralized tertiary treatment employs a membrane bioreactor (MBR) that was used to produced non-potable water for toilet flushing and landscape irrigation.

For the first study, we compared the unit energy to provide non-potable recycled water (kWh/m^3) from a centralized system and a decentralized system. For the centralized system, the unit energy accounts only for the additional infrastructure needed to provide the non-potable water, which included tertiary treatment at the centralized plant and the pipes and pumping needed to transport the recycled water back to the building where the recycled water would be used.   In other words, the existing infrastructure already in place for wastewater management (e.g., sewer system, secondary treatment) is not included. For the decentralized system, the unit energy accounts for the new infrastructure required to treat the wastewater to tertiary standards in a new decentralized system, and the pipes and pumping needed to transport the recycled water to the nearest buildings depending on the system scale. The facility size (proportional to the number of people served) was varied, to explore the influence of system scale. Importantly, the analysis accounts for the existing population density and topography in San Francisco.

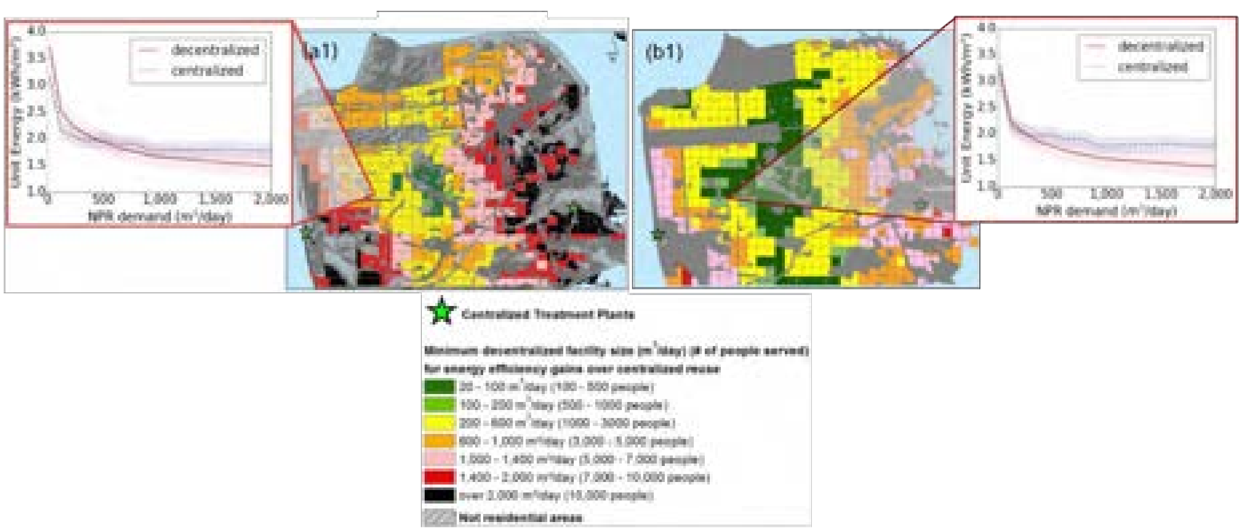

Figure 2. Minimum facility size for each grid cell for decentralized reuse to be more efficient than a centralized reuse scenario. The shading in the grid cells reports the life cycle energy intensity for (a1) treatment with an MBR based on energy intensity information reported in the literature; and (b1) a future scenario in which the MBR treatment has gained 20% energy efficiency. [Adapted from Kavvada et al. 2016]

In Figure 2(a1), the results are presented for the minimum facility size at which the decentralized system has lower unit energy than the centralized system. As expected, decentralized systems offer the greatest advantage at locations that are at the furthest distance, and highest elevations from the existing centralized treatment plants. However, a powerful insight from the modeling is that lower population densities resulted in higher unit energy for decentralized systems due to the diseconomy-of-scale for MBR treatment. If the efficiency of the MBR treatment increased (20% more efficient), the benefit of decentralized reuse would increase accordingly and more areas would benefit from smaller decentralized systems (Figure 2(b1)). For centralized reuse, the impact of system size depended on whether the pipes for distributing the recycled water were designed as dedicated pipes for each grid cell (shown in Figure 2), or as a connected network, which would require building a large purple pipe system to serve an entire section of the city. The analysis was conducted for both types of centralized networks and also unit GHG emissions ($kgCO_2e/m^3$), which tracked closely with unit energy.

The second study was motivated to better understand the impacts of system size (scale) for decentralized reuse, and provide guidance on the optimum size and energy performance that could be achieved. Again, this analysis accounted for population density and topography. In the NE corner of the city, the optimum system scale was several thousand people, because the high building density can support a reuse system that serves a few high-rise buildings without having to transport water very far (Figure 3a). At that scale, the unit energy was between 1.3 and 2 kWh/m^3 (Figure 3b). In parts of the city with lower population density and greater elevation changes, the optimum system scale was smaller (several hundred people), but the unit energy is higher by a factor of 2-3x.

The optimization tool used for these calculations is open source and available for others to modify[3]. The interface currently allows users to choose the building location in San Francisco for which the analysis is conducted, and to select the optimization parameter of interest; in addition to energy, the model can calculate the unit GHG emissions ($kgCO_2e/m^3$), which tracks closely with energy, and economic cost (USD/m^3).

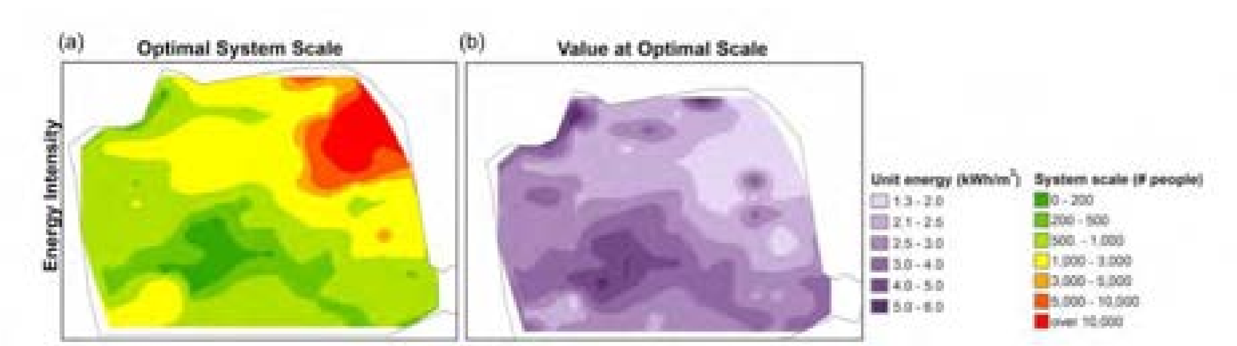

Figure 3. Decentralized reuse as a function of location. (a) optimum scale (# of people served) and (b) energy intensity (kWh/m[3]) at the optimum system scale [Adapted from Kavvada et al. 2018].

From these studies, we demonstrated that under the right conditions decentralized reuse systems have the potential to provide non-potable recycled water with unit energy and greenhouse gas emissions that are lower than centralized reuse systems. Because decentralized systems can be built in a piecewise fashion, their flexibility can be attractive compared to the high level of coordination and disruption required to plan and install a large

[3] https://water-reuse-map.herokuapp.com/

centralized non-potable reuse system. However, if not designed carefully, decentralized reuse systems have the potential to require significantly higher unit energy, which could make it more difficult for cities to achieve greenhouse gas reduction goals. Larger decentralized reuse systems, that serve large multi-story buildings or district-scale systems that connect multiple buildings, can benefit from the economies of scale that occur from treatment. This research also highlights that the development of innovative treatment technologies that have low energy demand even at small scales would make smaller systems more attractive from a sustainability perspective. Alternatively, energy recovery or generation could be incorporated into decentralized systems, such as thermal energy recovery.

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