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Rainwater Harvesting

Technical Report · March 2016

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BRIEF DESCRIPTION

Many U.S. Army and Department of Defense (DoD) installations are located in water-stressed locations. Rainwater harvesting is an excellent means of supplementing water for use on site if the process is permitted by state and/or local laws. Using rainwater, where appropriate, conserves potable water consumption.

Rainwater harvesting describes processes in which precipitation that falls on a site is diverted, captured, and stored for use on-site, as opposed to allowing it to run off, evaporate, or infiltrate into the soil. Depending on its intended use, the captured precipitation may require treatment. In a broad sense, rainwater harvesting can also include capture from surface water runoff; however, in the U.S., runoff is subject to surface water regulations. This document will confine discussion of rainwater harvesting to roof-top capture.



Figure 1. Picture of a rainwater rooftop collection system with an outdoor, aboveground storage tank. Notice that the gutter drainage includes a first flush diverter (the portion of pipe bypassing the storage tank).¹

Applications

Rainwater harvesting can be useful for installations with the following issues:

- Installations in areas with water stress due to drought and arid environments.
- Installations with on-site ground water wells that may require significant energy to use such as deep wells and challenging treatment.

¹ Image from Earth Times: <http://www.earthtimes.org/going-green/roof-rainwater-runoff-collection-urged-experts/1542/>

This could include groundwater, which has high solids or natural contaminants (arsenic and fluoride are common issues).

- Installations striving to increase water resilience by implementing net zero water goals.
- Areas with regulatory requirements to reduce peak flows, lessening the erosive forces of storm water runoff due to sensitive environmental receptors, such as the Chesapeake Bay area.
- Situations in which ponded surface water contributes to insect or algae problems. Capturing rainwater will reduce surface water available for ponding.

Rainwater can be harvested for a number of uses:

- Non-potable uses, such as toilet flushing, irrigation, dust control, and vehicle washing. Some of these applications may require specialized plumbing.
- Potable water uses including drinking water, food preparation, showering, and washing. These applications would likely require treatment to ensure that the water meets state and federal requirements for potable uses.

Design Notes

Rainwater Harvesting Components:

- **Rooftop collection systems** are common, taking advantage of drainage and gutter systems. Metal roofs are ideal for rainwater collection. They are easy to keep clean and maintain a high level of rainwater quality. Some roof materials, such as asphalt, may limit water uses to non-potable ones.
- **Conveyance systems** via gutters, channels, and pipe systems are used to carry collected water to storage and areas of use.
- **Storage systems** keep collected rainwater for later use. These are typically tanks, either on the surface or below ground. Open ponds may also be used, particularly for decorative effect.
- **Treatment** will be required for most potable uses and possibly for some non-potable uses. Treatment typically includes filtration to remove particulate matter in the collection and conveyance of the rainwater. Simple disinfection (chlorination, ultraviolet - UV, solar) may be required to control microbial growth in various systems, including storage systems.

- **Distribution** of water stored to its intended use may require a system of pumps, pipes, and controls.

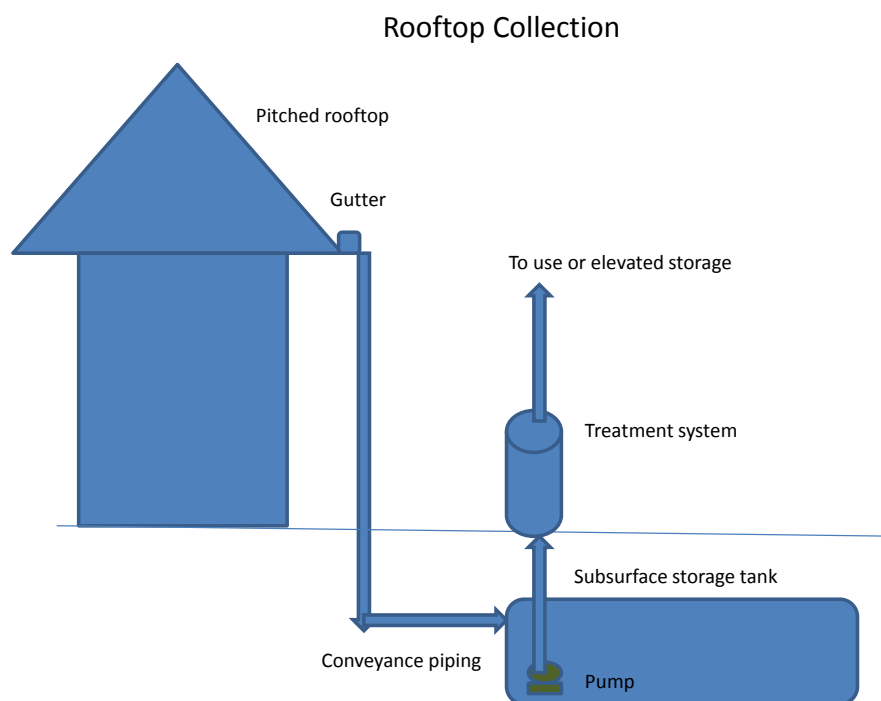


Figure 2. Elements of a rainwater harvesting system, as outlined in the section above. This system shows both rooftop collection, along with subsurface storage tank and a pump to a treatment system.

Water quality, first flush diverters:

- Rainwater is usually considered to be of high water quality, but it can contain contaminants.
- During precipitation, rain can dissolve airborne contaminants. This effect is most prominent during the early stages of rainfall.
- Roofs will accumulate sediment, plant material, animal droppings and materials, and other contaminants. The initial rainfall will have the highest concentrations of these contaminants, but as rainfall continues, these contaminants will be washed off.²

² Gould, J.E. and H.J. McPherson 1987. Bacteriological Quality of Rainwater in Roof and Groundwater Catchment Systems in Botswana, Water International, 12:135-138.

- Systems are typically designed to reject the initial runoff, which will improve the water collected and stored.³
- Overall, rooftop catchment provides much less contamination, and therefore, much higher water quality than ground surface catchment.

Water capture/sizing storage tanks:

- Storage is based on rainfall and expected usage.
- Several methods can be used, but a rule of thumb is to provide for three months of anticipated use.⁴
- A volume of 0.62 gal can be collected per square foot of collection surface (roof or impervious surface) per inch of rainfall.
- Collected Volume (gal) = 0.62 Area (ft²) x Design Rainfall event (precipitation in inches calculated from intensity for design event from hydrology intensity-duration-frequency curves. (See reference 2, Army LID Technical User Guide, for more information).
- Efficiency will vary. Rooftops are generally the best surfaces. A custom-designed metal roof can achieve close to 100% water capture, provided gutters are working efficiently. Retrofitted roofs are somewhat less efficient: 80 to 90%. Surface collection is generally less effective still. Storage vessels can become affected by algae or insect larvae. A simple solution regarding algae is to use storage vessels impervious to light. Seals and screens can limit insect access to tanks. Chemical treatments (such as low concentrations of bleach) can also be used to remove and destroy algae and insects.

Water treatment:

- The extent of treatment depends on the water's intended use. Potable use requires more intensive treatment; alternatively, use for toilet flushing may require treatment only to limit color and sediment. In

³ U.S. Army. 2013. Army Low Impact Development. Technical User Guide. Office of the Assistant Chief of Staff for Installation Management. Available on-line at: http://www.usace.army.mil/Portals/2/docs/Sustainability/Hydrology_LID/Army_LID_Technical_User_Guide_January2013.pdf

⁴ Scholze, R.J. 2010. Rainwater Harvesting for Army Installations. Public Works Technical Bulletin. PWTB 200-1-75. U.S. Army Corps of Engineers. Washington DC. Available on-line at: www.wbdg.org/ccb/ARMYCOE/PWTB/pwtb_200_1_75.pdf

contrast, water used for irrigation purposes may require simple sediment removal — perhaps even no treatment would be necessary.

- Typical systems consist of three components:
 1. Sediment removal - Settling tanks/ponds, sand filters, cyclone filters, canister filters, or cartridge filters.
 2. Organic treatment - Activated carbon filters/canisters, if needed.
 3. Disinfection - Ultraviolet or chlorination, if needed.

Regional issues:

- Rainwater harvesting can be applied to a wide range of climates.
- For hot, dry climates, the focus is on efficient collection from large, occasional events. These may use large, underground storage units to provide water between events and to reduce evaporative losses. The focus should be on maintenance of collection surface, to allow minimal waste during actual rain events.
- Wet, temperate environments may rely on first flush for cleaning collection surface. Some losses over time may be acceptable, so storage can be smaller and use outdoor storage units, which are easier to inspect and maintain, and are more common.
- Environments with frequent freezing may use underground storage.

Related Technologies

Purple Pipe, Low Impact Development

References/Useful Resources:

[1] Scholze, R.J. 2010. Rainwater Harvesting for Army Installations. Public Works Technical Bulletin. PWTB 200-1-75. U.S. Army Corps of Engineers. Washington DC. Available on-line at: www.wbdg.org/ccb/ARMYCOE/PWTB/pwtb_200_1_75.pdf

[2] U.S. Army. 2013. Army Low Impact Development. Technical User Guide. Office of the Assistant Chief of Staff for Installation Management. Available on-line at: http://www.usace.army.mil/Portals/2/docs/Sustainability/Hydrology_LID/Army_LID_Technical_User_Guide_January2013.pdf

Energy Savings

Collection and use of rainwater:

- Rainwater collection systems are typically designed to be gravity fed.
- Storage areas are typically lower elevation, so a pumping system is generally required for intended reuse.
- Since collected rainwater is generally used close to its capture, the energy needed to convey the water tends to be minimal.
- Compared to conveyance from other supplied sources of water (groundwater, conveyed surface water, shipped water), rainwater harvesting would likely have lower energy costs.

Maintenance:

- Systems are simple and tend to be robust. Monitoring and maintenance require additional effort. This includes maintenance of roofs used as collection areas, cleaning of gutters, maintenance of storage tanks and vaults, pumps and maintenance of water treatment systems (when installed).

Water Savings

How much can rainwater harvesting provide?

- A reasonable goal for an aggressive rooftop collection for a custom building could be to reduce domestic water supply by 40 to 50% for that building; this would then allow the building to meet LEED goals for sewage reduction (see reference [1]). A lower level may be expected for a retrofitted system.
- An installation could be thought of as a small city. Liaw and Chaing⁵ estimated a maximized rooftop collection approach could supply about 32% of needs. However, they also estimated a 10% goal would be reasonable from an economic standpoint.

Environmental Impacts

Army Directive 2014-02 Net Zero Installations Policy

A net zero water installation recharges as much water back into a local water supply (aquifer) as it withdraws. Rainwater harvesting projects contribute to

⁵ Liaw, C-H., and Y-C. Chaing. 2014. Framework for Assessing the Rainwater Harvesting Potential of Residential Building at a National Level as an Alternative Water Resource for Domestic Water Supply in Taiwan. *Water*. 6:3224-3246.

this goal by utilizing reclaimed water for reuse, shifting from the use of potable water as much as possible.

Reduce overall water use regardless of source; increasing use of technology that uses water more efficiently; recycling and reusing water, shifting from the use of potable water to non-potable water sources as much as possible; and minimizing interbasin transfers of any type of water, potable or non-potable.

DOD Sustainable Buildings Policy 2013

This policy applies to existing and future installations, providing minimum standards following UFC 1-200-02, High Performance and Sustainable Building Requirements dated November 2014. This UFC references the requirements under ASHRAE 189.1-2011 Section 6.4.1 of limiting landscaped water usage to 33% of baseline. It also references Section 6.5.1 of the same standard limiting potable water demand for site irrigation to 35% of baseline.

Rainwater collection has mostly positive impacts:

- Simple treatments use little to no chemicals and resources as compared to large-scale potable water systems.
- Rainwater harvesting generally has a minimal impact on the overall water balance, but larger operations may impact downstream surface water or groundwater resources where water is limited. Regulations in those environments will identify this as an issue early in the process.
- Reduce environmental impact due to decreased demand for fossil fuels needed to handle and treat potable water at central water treatment plants as well as energy needed to distribute water.

Guiding Principles

Protect and Conserve Water

Rain water harvesting can assist in several strategies used to achieve the high performance sustainable building guiding principles.

Minimize indoor water use: Rainwater reclaimed water can be used for flushing toilets which reduces a significant amount of potable water use in buildings.

Efficient Irrigation: Employ water efficient irrigation strategies. Reclaimed rainwater can be used for irrigation to reduce outdoor potable water consumption.

Alternative Water: Implement cost effective methods to utilize alternative sources of water such as harvested rainwater, treated wastewater, air handler condensate capture, gray water, and reclaimed water, to the extent permitted under local laws and regulations.

**Associated
LEED Credits
(NC 2009)**

Green Building Council LEED BD+C: Water Efficiency (WE)

WE Credit1: Water Efficient landscaping up to 4 points

- Reduce potable water use for irrigation by 50%, 2 points.
- Reduce potable water use for irrigation by 100%, additional 2 points.

WE Credit 2: Innovative Waste Water technologies 2 points

Reduce potable water use for building sewage conveyance by 50% through the use of water-conserving fixtures or non-potable water (e.g. captured rainwater, recycled gray water on-site or municipally treated wastewater).

WE Credit 3: Water Use Reduction 2-4 points

Employ strategies that in aggregate use less water than the water use baseline calculated for the building (not including irrigation):

- that result in 30% water savings, 2 points,
- that result in 35% water savings, 3 points,
- that result in 40% water savings, 4 points.

Product Images

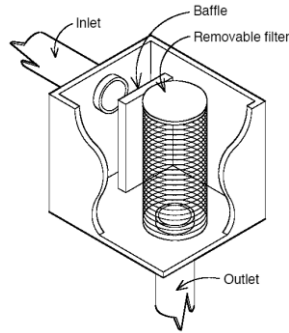


Figure 3



Figure 4



Figure 5

(Figure 3) Box roof washer

(Source: http://www.wbdg.org/ccb/ARMYCOE/PWTB/pwtb_200_1_75.pdf)

(Figure 4) Tanks Installation

(Source: <http://www.harryhelmet.com/the-pros-and-cons-of-different-rainwater-harvesting-storage-tanks/>)

(Figure 5) A simple water treatment system of canister filters for sediment and organic removal and a UV disinfection system (Source:

http://www.wbdg.org/ccb/ARMYCOE/PWTB/pwtb_200_1_75.pdf)

Components

Construction of systems:

- Construction of systems is relatively simple.
- Many of the processes (such as roof sloping, gutters, downspouts) are required for the management of rainfall on roofs and buildings normally. These can be modified to allow water collection.
- The largest component is the storage

Cost Range

Cost ranges for various components of a rainwater harvesting system can be found in pages A-39 to A-41 of "RAINWATER HARVESTING FOR ARMY INSTALLATIONS, PUBLIC WORKS TECHNICAL BULLETIN PWTB 200-1-75" 22 MARCH 2010 located at

http://www.wbdg.org/ccb/ARMYCOE/PWTB/pwtb_200_1_75.pdf

From experience at a Northwestern installation, costs varied depending on the size of the units. A system for a large barrack with two vaults of 80 m³ (20,800 gal) and 100m³ (26,000 gal) was \$132K. A large brigade-sized system with a 40 m³ (10,500 gal) vault was estimated at \$49K and a smaller, 10m³ (2,600 gal) vault system was estimated at \$30K. The determining factor is the amount of water to be stored for use.

Payback periods are variable, but are reportedly on the order of 10 to 15 years.

- A proposed rainwater harvesting project at the University of Alabama, Birmingham, featuring underground storage and use for campus irrigation, had a payback period estimated at 9.4 years.⁶
- A rainwater catchment project at Fort Bragg has an estimated Return on Investment (ROI) of 11.8 years.⁷
- Stormsaver LTD presented examples of projects with ROIs varying from 1 to 5 years. The key to short ROI projects are buildings with large roof collection areas coupled with high water usage.⁸

⁶ Li, Z. 2012. Design of an Underground Storage Tank Involving Water Collection for Water Reuse to Irrigate the Campus Green Areas of the UAB Campus. Department of Civil, Construction and Environmental Engineering. University of Alabama, Birmingham. Birmingham, AL.

⁷ J. Love, Fort Bragg Directorate of Public Works, Email Communication

⁸ Farnsworth, M. 2015. Sustainable Drainage, Case Study. <https://www.linkedin.com/pulse/sustainable-drainage-case-study-mike-farnsworth>.

Rainwater Harvesting

[SPECIFICATIONS]

Vendors State by state listing of rainwater harvesting vendors:

<http://www.harvesth2o.com/vendors.shtml>

Warranty Info Most system components are standard building items such as roof, gutter, tanks and pumps. Warranties for these items are common and may vary by vendor.

Code Restrictions If end use of harvested rainwater is for potable use, state and local plumbing codes apply.



Figure 6. Rainwater capture is integrated into the design of the building as an architectural feature. Swoop roof collect rainwater for diversion into buried cisterns for irrigation use. (Source: HDR)

RAINWATER HARVESTING AT MILITARY INSTALLATIONS

A series of literature searches were conducted in an effort to find rainwater harvesting projects associated with military installations. The search found 10 applications at five locations across the United States; Washington, Hawaii, Virginia, North Carolina, Puerto Rico):

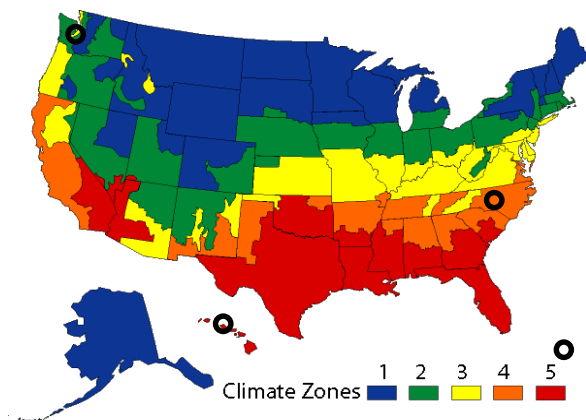


Figure 7. Location of two case studies indicated by circles.

- Barracks Renewal Project at Joint Base Lewis McCord (JBLM), near Tacoma, WA. This project is described in detail below.
- Two Battalion Headquarters Buildings and an Air Support Operations Squadron (ASOS) Weather facility at JBLM. Recovered water for each facility is collected and stored in underground vaults and used to irrigate surface water riparian strips.
- Two Regional Logistics Support Center Tactical Equipment Maintenance Facilities (RLSC TEMF) at JBLM. Recovered water is stored in a series of aboveground tanks and used for toilet flushing, irrigation, and vehicle washing. The process uses a combination of vortex filtration and a continuous ultraviolet system to treat collected water, providing sediment removal, disinfection, and color removal.
- Federal Center South 1202, the Headquarters Building for the USACE Seattle District, Seattle, WA. This project is described in detail below.
- Schofield Barracks, Oahu, HI. Rooftop recovery for irrigation.⁹
- Rooftop collection at Fort Bragg, NC.

⁹ Jenicek, E.M., L. Curvey, Y. Cruz, and R. Phillips. 2013. Water Sustainability Assessments for Four Net Zero Installations. US Army Construction Engineering Laboratory. ERDC/CERL TR-13-25

- Warrior Transition Battalion Barracks, Fort Bragg, NC. A rainwater catchment system for irrigation purposes. The economics for this system are promising compared to a potable irrigation system (the project costs would be equivalent to those of a back flow preventer and meter system). The ROI is estimated at 11.8 years, and the project is scheduled for construction in the fall of 2015.
- Fort Buchanan, PR. Proposed project to assist in meeting Net Zero Water Goals.

More detail is presented on two contrasting studies, the Barracks Renewal Project at JBLM and Federal Center South 1202.

CASE STUDY 1: Joint Base Lewis McCord (JBLM) Barracks Renewal Project

Four rainwater harvesting projects were completed between 2003 and 2005, integrated with barracks renewal construction. The projects were early adopters of the technology. The water was collected from the rooftop and directed it into a subsurface vault. The water from the vault was used for non-potable uses — toilet flushing and landscape irrigation. Over 800,000 gal storage dedicated for irrigation and just over 130,000 gal for toilet flushing.

There were a number of lessons to be learned. The toilet systems had problems with colored water and sediment in the water. Although this did not affect the performance of the toilets, it presented an unpleasant appearance to users. It was found that using higher quality, more expensive, auto-purging filters compared to manual purging filters improved the water appearance to an acceptable level. A second problem was that the system was prone to breakdowns and went through long periods of non-operation. It was found that thorough training was required for operations and maintenance personnel to keep the systems operating smoothly.

JBLM is still committed to rainwater harvesting, and has implemented different strategies based on lessons learned from the early 2000s period. The focus on these projects has been on irrigation, since toilet flushing was the most problematic aspect.



Figure 8. A concrete rainwater collection vault used in the renewal barracks project at JBLM.
(Source: USACE, Seattle District)

CASE STUDY 2: Federal Center South Building 1202

Federal Center South (Figure 9), located in Seattle, WA, serves as the Headquarters for the USACE Seattle District (NWS) and is an award-winning building that was completed in 2012. It was a project responding to the 2009 American Recovery and Reinvestment Act (ARRA), which focused on improving infrastructure and providing jobs¹⁰, and is a 4.6-acre development featuring a 209,000sf office structure. The total construction cost for the project was \$65 million and was completed on time and on budget.

¹⁰ The American Institute of Architects (AIA). 2015. Federal Center South Building 1202. AIA Top Ten. Available on-line: <http://www.aiatopten.org/node/204>



Figure 9. Federal Center South 1202, Seattle, WA. Headquarters for the USACE Seattle District. (source: USACE, Seattle District)

The project features many innovative and state-of-the-art features to promote aggressive energy performance and maximize sustainability. This includes a number of features to enhance water conservation and sustainability, including the use of rainwater harvesting.

Rainwater is collected by a rooftop runoff system as well as by a soil infiltration system and stored in a 25,000 gallon underground cistern. The collected water is used for toilet flushing and irrigation. The goal of rainwater harvesting is to collect 430,000 gallons annually. This would allow for 79% reduction of potable water needed for toilet flushing and 14% reduction of potable water for irrigation. Collected rainwater is also used for decorative water features in the building (Figure 10).



Figure 10. Decorative water feature supplied by harvested rainwater. (Source: USACE, Seattle District)

In addition to water conservation, the use of harvested rainwater contributes to the remarkably high energy efficiency of the building¹¹. The effectiveness of the rainwater harvesting system and other novel systems are maintained by periodic training of building occupants and operators via the use of email blasts and bulletins (see <http://www.facilitiesnet.com/green/article/Training-Of-Building-Occupants-Operators-Is-Critical-To-Maintaining-High-Performance--15035?source=part>). Figure 11 is a schematic of the rainfall collection system.



¹¹ Chaloeicheep, C.Q., C.F. Chatto, E. Clark. 2014. Shaped to Perform. High Performing Buildings. Fall: 18-27.

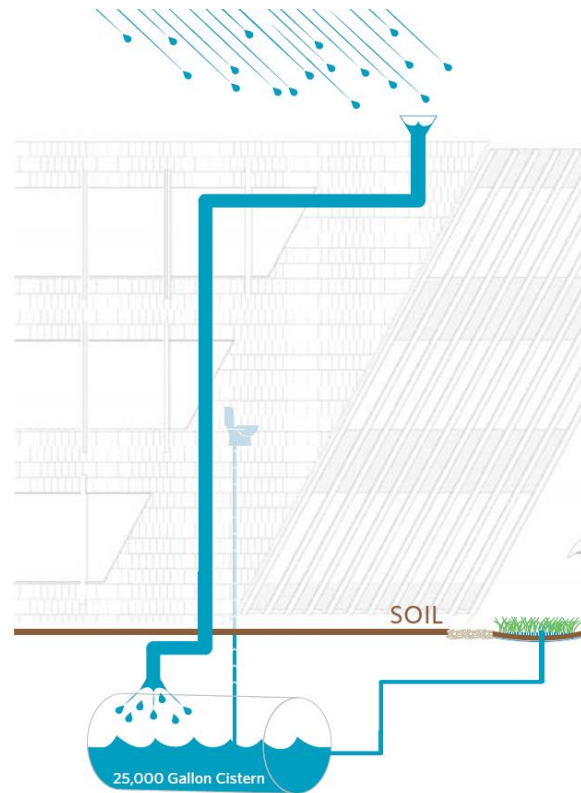


Figure 11. Schematic of the rainfall harvesting system at Federal Center South 1202 in Seattle, WA. (Source: GSA Building 1202 Sustainability Brochure)

By all indications, the Federal Center South 1202 building appears to be a remarkably engineered building, and the rainwater harvesting system is considered a success. However, a complete assessment of the performance of the rainwater harvesting project is not possible due to the relatively short period of operation, and because 2014 and 2015 have been unusually dry in the Seattle area.

Lessons

The two case studies present rainwater harvesting projects with ambitious goals of offsetting potable water use by targeting both toilet flushing and irrigation. However, the results were substantially different. The Barracks Renewal project was less successful and eventually was discontinued, while the rainwater harvesting project at Federal Center South 1202 is well conceived and is off to a highly successful start. The following are some lessons that can be gleaned from these two projects:

- The treatment protocol should be determined by the intended end use of the harvested water.
- Building users should be educated about the plan to utilize harvested rainwater; users will then be prepared for issues such as slightly discolored water.
- Provisions should be made for maintenance of the systems, including training for maintenance staff and funding for time and supplies.
- Access to the underground vaults should be included.