Rainwater Management Solutions
www.rainwatermanagement.com
2550 Shenandoah Ave NW
Roanoke, VA 27014
540-375-6750

Water Harvest Systems Technical Study

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Lessons Learned and Recommendations

Written By: Rainwater Management Solutions
Performed For: U.S. General Services Administration's National Capital Region
GSA Contact: Russell Clark, russell.clark@gsa.gov

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I. Introduction

Rainwater Management Solutions was contracted to assess existing water harvesting systems within GSA's National Capital Region's facility portfolio. These systems included those that harvest rainwater, those that collect groundwater and one system that recycles greywater.

The purpose of the study was to:

1. Understand best practices and industry trends around the design and installation of systems to share with future project teams considering or planning on designing and installing new systems.
2. Provide information regarding system design and performance for future project teams so that best practices, national standards, and codes are met and that the systems are not needlessly complex.
3. Assess the current performance/operational condition status of the region's various water harvesting systems so facility managers may make needed repairs or perform needed maintenance according to scopes and cost estimates provided.
4. Describe the overall keys to success for water harvesting systems. Understand how the systems should integrate into the overall building design to meet assessable demands and should not be installed to merely meet building design criteria requirements.
5. Understand how to determine if future systems make the most economical sense along with environmental viability and profitability.

II. Industry Best Practices and Trends

The following is a list of current industry best practices and trends that should be considered for existing and proposed rainwater harvesting systems. Incorporating these suggestions into the system design will increase a system's economic and environmental viability and improve the likelihood that the system will consistently function as intended. These best practices and trends inform the specific recommendations provided below.

1. ***<u>Use rainwater harvesting to expand the total available supply.</u>***
   As water supplies and treatment capabilities continue to be strained in many urban areas, rainwater harvesting can provide a scalable, cost-effective option to meet increasing demand, particularly when developed in partnership between building owners and water providers.

2. ***<u>Keep design as simple as possible while also meeting performance objectives.</u>***
   Simple designs are easier to install, maintain and repair. Rainwater harvesting systems are scalable. One or two standard or "stock" designs can be created that will cover most potential scenarios and simply have their components sized to work with the available harvested water, an appropriately sized storage system, and the end use demand.

3. ***Maximize water quality entering the storage tank to minimize post-storage treatment requirements.***
   One of the benefits of a rainwater harvesting system is the high initial quality of the water. Protecting this water quality is both environmentally and economically less expensive than relying on extensive post-storage treatment. A well-engineered pre-tank filtration system is critical to this success. It should meet the filtration requirements of American Society of Plumbing Engineers (ASPE) Standard 63 and the International Code Council's ICC 805-2018 rainwater harvesting code.

4. ***Integrate rainwater harvesting systems into stormwater management.***
   A rainwater harvesting system automatically reduces runoff volume from a site. With increased emphasis on volume reduction in stormwater management, rainwater harvesting systems in the stormwater management plan as a viable stormwater management option may prove key to developing the most cost-effective solution, especially when potable water cost savings are included.

5. ***Use harvested rainwater for more than irrigation.***
   Year-round demand leads to more cost-effective rainwater harvesting systems. The safe finished water quality needed for spray irrigation is minimally different from that needed for indoor non-potable uses, while the additional water-saving potential is high. Because of this, indoor use of harvesting rainwater should be considered on every project.

6. ***Use innovative partnerships to better match supply and demand.***
   Efficient rainwater harvesting systems may require looking beyond a single building with options like combined storage or use of rainwater harvested from one building to supply another.

7. ***Monitor performance and function remotely and in real-time.***
   Frequent monitoring of rainwater harvesting systems improves performance and reliability. This monitoring should be made as user-friendly as possible by including remote monitoring options connected to the building automation system which should also have secured connectivity to the world wide web so that information regarding the performance of multiple systems can be centrally tracked and compared.

8. ***Flush systems that have been unused for an extended period before using the system to remove stagnant water.***
   Based on our experience, water quality tends to deteriorate with stagnation in the plumbing system. Any system, regardless of water source, should be flushed after periods of low use.

III. Recommendations Regarding System Design and Performance

1. ***Training requirements for designers and engineers.***
   The design team should have personnel that are knowledgeable about the design and integration of rainwater harvesting systems into the overall stormwater management plan. Successful completion of third-party certification by ASSE as a rainwater harvesting system designer based on the American Society of Plumbing Engineers (ASPE) Standard 63 for rainwater harvesting systems should be a requirement as well as completion of several systems that have been successfully commissioned and have been in operation for at least two years.

2. ***Certification requirements for system manufacturers and integrators.***
   Like the designers and engineers, the system manufacturer and integrator should have staff that maintain ASSE certification for rainwater harvesting systems not only for design but installation and inspection as well. Further, they should be able to document at least five (5) similar systems that are currently in operation. All electrical and control equipment should be manufactured in an Underwriters Laboratory approved facility.

3. ***Establish frequent, involuntary water demands.***
   To maximize the economic and environmental value of a system, the designated uses for harvested rainwater should be carefully considered. Systems that are used to fulfill mandatory water demands, such as toilet flushing, cooling tower makeup, or select industrial uses, will be used more frequently and be better maintained, as the water demand must be met to ensure proper functioning of the building, equipment, or industrial process. Discretionary water demands, such as irrigation of well-established lawn/shrubs/wooded areas, or vehicle washing are easy to forgo, or conduct with alternative sources of water, thereby undermining the utilization of the system and making it easier to abandon or inadequately maintain. Designated water uses should also be frequent, such that harvested water is extracted on a regular basis. This maximizes the capture of rainwater runoff, as there is room available in the storage tank due to previous extractions, prevents the stagnation of water within the system, maximizes operational/maintenance staff awareness of system functions, and increases the economic benefit of replacing potable water with harvested rainwater. Many of the buildings examined in this report use harvested rainwater for toilet flushing, which is an excellent example of a frequent, involuntary demand.

4. ***Always include some form of pre-tank filtration.***
   Filtering rainwater runoff before it enters the storage tank is essential to ensure optimal water quality and maximize the longevity of system components. Pre-tank filtration does not need to be complex; however, the dirtier the initial collection surface, the more robust this system component should be. While appropriate initial filtration adds to the initial cost of the system and is another maintenance touch point, the use of these filters will

decrease the maintenance of downstream treatment equipment and reduce the potential for system failure. If a system is collecting rainwater from a metal roof with no overhanging trees or vegetation, a simple horizontal LineAr filter can be used which should only require the rinsing of its stainless-steel filter element twice a year. Alternatively, when runoff is collected from a walking/driving surface, or from a roof with substantial overhanging vegetation, a larger vertical, vortex filter may be most appropriate to ensure all particulate matter larger than 280-micron is removed from the water prior to discharge into the storage tank. The frequent fouling of the post-tank treatment filters at Saint Elizabeth Campus Center Building East, West, and West addition is evidence of the need for pre-tank filtration.

5. ***Built-in indicators of performance/failure*.**
   Oftentimes, a system is not maintained or repaired simply because the operating staff are not aware that it is not functioning properly. Thus, every system should be designed such that there are clear indicators of system performance and function which make it obvious when parts or the entire system is not operating as intended. Examples include pressure gauges before and after filters that would indicate a drop in water pressure due to clogged filters, or lights that indicate when bulbs or filters need to be replaced. Having this information viewable both at the system and on the building automation system allows for rapid identification of issues and necessary corrective steps. The logging of the amount of harvested water and backup water used by the system will also assist in determining the true return on investment that the system(s) provides. It should be noted that visual inspections of the systems, at least weekly, should continue as they allow for the maintenance personnel to identify issues that are not tracked by the automated control system, and inspection also maintains a positive level of familiarity with the system.

6. ***All uses of harvested water with probable human contact should be disinfected.***
   Due to the potential presence of bacteria and pathogens in harvested rainwater, disinfection should be included in any system for which the designated water use(s) present the possibility of contact with humans. Regardless of the initial water source, water used for spray irrigation in an area with frequent public access, such as facilities near The Mall in Washington, D.C., should be disinfected to prevent possible spread of pathogens. The treatment sequence should include not only mechanical filtration, but also a method of inactivating bacteria and pathogens. The use of ultraviolet light is the most efficient and effective method of accomplishing this, though ozone and chlorine are options as well (though care should be taken to minimize the generation of by-products via the interaction of chlorine with organic matter in the harvested water). Ultraviolet light disinfection requires the least maintenance with most systems only requiring the changing of the unit's bulb once a year with a material cost of typically under $200 for systems with flow rates under 100 gallons per minute.

7. ***Consider alternatives to in-tank disinfection.***
   Point-of-use (POU) disinfection is preferable to recirculation/in-tank treatment. By disinfecting water as it exits the storage tank (either directly to the building distribution system or prior to a day tank), disinfection dosing can be more precise and accurate and is not jeopardized by inflows of rainwater during a rain event. This ensures that all water within the distribution system has received adequate levels of disinfection. For example, a recirculating treatment system could easily allow the delivery of untreated water to the end use, particularly when water is used shortly after a rainfall event. This scenario of untreated water being delivered to the end use could not occur with a point-of-use treatment method.

8. ***Automated shut down for treatment failure*.**
   Human health can be jeopardized when the treatment components of a system, such as ozone injection systems, chlorine injection or ultraviolet bulbs are not functioning properly where potential human contact is an issue. Thus, it is imperative that systems contain a built-in, automated kill switch that ceases operation of the system when there is a treatment failure. The continued operation of the rainwater harvesting system at the Switzer Building, despite the failure of the ozone treatment system, demonstrates the necessity of this feature.

9. ***Operations guidance/manual*.**
   The staff dedicated to operating and maintaining a rainwater harvesting system could arguably be considered the weakest link in terms of ensuring proper system function and performance. This is not due to negligence, but instead due to a lack of knowledge. Based on the system information that was compiled by GSA for this review, no comprehensive Operating and Maintenance (O&M) Packages could be located. While there were some videos of training created when the systems were initially commissioned. These were not readily available to the maintenance teams. One solution, in addition to an electronic copy that should be passed to the maintenance team when the system is brought online, would be a hard copy of the complete O&M being placed in a lockable box permanently attached to the skid. The requirement of this manual and the box should be noted in the written specification for the water harvesting system. Start up, shut down and sequence of operations information as well as replacement part information should be accessible on the system's controller under a dedicated tab. The system manufacturer should also be required to maintain a copy of the O&M electronically for a minimum of 5 years in case a replacement copy is needed. The manual should include a schematic that identifies each component of the system and explains its function. Thorough explanations should be provided regarding system performance indicators and how to tell if various aspects of the system are not working as designed. In addition, a sequence of operations for startup, shut down, normal operation and emergency procedures must be included. Finally, a check sheet for daily or weekly observation of the system along with quarterly and yearly system reviews should be included as well. Contents outline and sign out sheet should be

required with the documents that are securely housed on the treatment skid. This manual should work in tandem with a maintenance/troubleshooting guide (see section V) to allow staff members to thoroughly assess, troubleshoot, maintain, and repair any aspect of the system.

10. ***Carefully consider collecting water from green roofs.***
While not prohibited, collecting runoff/leachate from green roofs can be problematic in several ways. Green roofs may produce runoff/leachate that contain significant amounts of sediment and nutrients, which should be removed prior to the storage tank to maintain optimal water quality and prolong the lifespan of system components. While green roof growing media used on shallow bed, extensive green roof systems, is typically only 4-8% organic content they also more easily collect and hold organic material that travels through the air than a roof constructed of an impermeable material. Matting and other materials utilized during the initial establishment of the green roof may also be an issue as they are designed to degrade over time and can cause obstructions to the roof drains as well as the water harvesting system. Because of the characteristics of green roof runoff/leachate, the complexity and robustness of the pre-tank filtration components will be greater than that of a system collecting cleaner water (e.g., from an impervious roof surface). The higher concentrations of organic matter in this water may be problematic for systems utilizing chlorination as a means of disinfection due to the generation of potentially carcinogenic by-products formed from interactions between the organic matter and chlorine. Great care should be taken when considering collection of water from green roofs to ensure that the system can consistently operate as intended, provide water of appropriate quality, and avoid the production of chlorine byproducts. While systems collecting rainwater from green roofs can be successful, collection from a green roof does add complications to the design and maintenance.

IV. Recommendations Regarding System Installation

1. ***General Contractor must be aware that successful system installation will require coordination on their part.***
Depending on the location of the pre-filter(s) and cistern tank(s) the civil and plumbing contractors may be actively involved in the installation of the water harvesting system. Further, if the tank is made of poured in place concrete, there will need to be coordination with the concrete contractor so that sleeves are properly placed. Controls and electrical contractors must also be part of the collaboration to ensure connectivity issues do not arise between the water harvesting system and the building automation system and that appropriately sized power feeds are brought to the correct locations.

2. ***Ensure scope of work properly aligns with contractor's skill set***
Some rainwater harvesting systems have pre-filter(s) and cistern tank(s) that are located outside the footprint of the building. This may mean that the installation of these

components may fall to the civil contractor. As a result, the civil contractor may be faced with installation of pumps and control devices in the tank(s) that are not typically part of their scope of work. It should strongly be considered to have the plumbing contractor be responsible for all pumping and controls equipment for the water harvesting system.

3. ***Training requirements for contractors installing water harvesting systems.***
Both plumbing and civil contractors should have personnel on site that have successfully passed the ASSE training program for the installation of rainwater harvesting systems. This third-party certification requires documentation of a minimum number of previous system installations by the card holder. This certification is based on the American Rainwater Harvesting Systems Association (ARCSA)/ASPE Standard 63 for rainwater harvesting systems and is complemented by ARCSA's rainwater harvesting system design and installation manual and addenda.

4. ***Manufacturer Installation Certifications.***
Contractors must provide documentation of their certification or ability to install or erect specialty equipment so there will be no issues with enforcement of warranty terms. This includes, but is not limited to, below ground fiberglass tanks, above ground steel tanks with liners, ozone treatment systems.

5. ***System Startup and Training***.
The general contractor should coordinate start up and training of the water harvesting system as multiple trades are involved in the installation of the system. All trades and their associated manufacturer's representatives should be present for system startup and training.

V. Recommendations Regarding System Operation and Maintenance

1. ***A stated imperative that the system must reliably operate at its designed level of performance.***
The onus should be placed on the building operations contractor to ensure that the system is functioning to its designed level of performance. If the system requires repairs beyond routine maintenance and service, then the government entity responsible for overall upkeep of the facility should be contacted so a corrective action plan can be created and executed.

2. ***Training requirements for maintenance team.***
Members of the maintenance team should have successfully passed and maintained accreditation under the ASSE training program for rainwater harvesting system inspections. It is strongly recommended that at least some team members should also maintain the installers certification as well.

3. ***Clear assignment of responsibility for maintaining and troubleshooting the system to specific maintenance staff/supervisor/service contract.***

   While rainwater harvesting systems should be designed with commonly available plumbing and mechanical components and easy-to-maintain specialty rainwater harvesting components, the systems are often unfamiliar to most maintenance staff. This lack of familiarity can lead to neglected maintenance and hesitancy about repairs. The maintenance responsibility for the rainwater harvesting system should be clearly assigned to specific individuals in the maintenance staff. Assigning responsibility to multiple individuals allows continuity if one individual is unavailable or leaves his/her employment. Simply having a general maintenance staff team responsible for building systems is not adequate with respect to rainwater harvesting systems; oftentimes these systems get overlooked as part of the regular maintenance program due to their complexity and lack of documentation/guidance. For example, at one facility, staff were told in training that the pre-tank vortex filter should be cleaned yearly; however, upon a site investigation the filter has not been serviced in over a year. Despite knowing what maintenance tasks to perform, the lack of designated individuals responsible for performing that task resulted in it being overlooked. Having a contractor that is experienced and certified in maintaining rainwater harvesting systems inspect the system yearly and provide any work that is above the scope of the maintenance team is one way that it can be assured that a system will not go offline for more than a year without problems being addressed.

4. ***A custom maintenance and troubleshooting guide.***
   The maintenance guide, specific to each system, should include a schedule of recommended maintenance on all components along with a summary of required weekly, monthly, quarterly, and yearly maintenance. In addition, each system should include a troubleshooting guide that identifies potential system problems such as discolored water or low water pressure and a systematic, logical approach to identifying the source of the problem and a suggested remedy. Numerous systems assessed as part of this project did not have a maintenance plan developed or accessible to staff. Most of these systems are not fully operating as intended. Contrarily, the rainwater harvesting system serving one department's headquarters building has operation and maintenance documents on-site, and the system is fully operational. The need for a thorough maintenance and troubleshooting guide is evident based on the document review, interviews with maintenance staff and onsite assessments. In multiple situations, staff was not provided with the information on how to reset the alarm after changing the U.V. light. At another facility, the staff manually switched the system to the domestic water bypass because they did not know how to restore the system to operational status. Their decision was appropriate, but if the information had been available to them, the system could have still been in operation. As previously stated, with the onus of system operation being clearly placed with an entity and specific individuals, and maintenance information readily accessible, a situation like this can be prevented.

5. ***<u>A low water use plan</u>*** *(to prevent water stagnation).*
   The dramatic changes in the prevalence of remote work due to the Covid-19 pandemic have demonstrated the need to consider how buildings function through extended periods of low or no occupancy. For plumbing systems, regardless of the water source, this leads to stagnation in the pipes which can increase the likelihood of deteriorated water quality. Each building should have a plan for flushing the plumbing system or recirculating water to the main rainwater storage tank after long periods of reduced or low occupancy. In addition, if rainwater harvesting systems are designed with intermediate treated water tanks (often called day tanks), water from these tanks should be periodically cycled back to the main storage tank during low-occupancy periods. For example, low occupancy conditions which result in low system demand can result in diminished system performance and perhaps even damage; when water is not cycling through the treatment unit regularly, the U.V. light can overheat causing premature failure of the disinfection system.

6. ***<u>Record keeping as part of maintenance to document performance and identify problems.</u>***
   Every time maintenance is performed on the rainwater harvesting system, it should be documented on a maintenance log along with simple notes. This can be a powerful tool to identify problems, such as a change in water quality requiring more frequent changes of the post-tank filters. This also enables proper accounting of the maintenance costs of the rainwater harvesting system. If adequate records are maintained situations such as post-tank filtration units clogging too frequently, signifying that pre-tank filtration should be added to achieve acceptable water quality and system performance could be discovered and funds allocated for this type of upgrade. Without tracking of this type of information staff may simply change the filter bags more frequently which is an inefficient use of their time that could have been avoided.

7. ***<u>Establish performance metric(s) to help identify problems</u>*****.**
   Monitoring a simple performance metric, such as weekly or monthly volume of water used from the rainwater harvesting system, can also help identify problems early. While a decrease in the use of rainwater may be due to lower demand or low rainfall, a decrease in rainwater use not easily explained by either of these causes indicates a problem in the system and should trigger troubleshooting. Some of the systems assessed have not operated in over 3 years. Others were found to be non-operational, though it is unknown exactly how long they have not functioned as intended. With established performance metrics, problems with system performance and function can be detected early and remedied, thus avoiding prolonged periods of time when the system is not being used.

VI. Overall Keys to Success

1. ***The rainwater harvesting system must be considered an essential building system.***
   While including a system bypass is often a reasonable design solution to allow for building operation in the case of pump failure or similar, running the system in the bypass should be seen as analogous to running the building off a back-up generator—a safeguard to allow operation during disruptions, not a viable option for long-term operations. When the rainwater harvesting system is viewed as an auxiliary system, allowing the system to remain offline and inoperable is easy and can reduce the incentive to make even simple repairs. This is evident when a system is taken offline when inadequate water flow and pressure led the maintenance staff to modify the building plumbing such that the rainwater harvesting system could be completely bypassed. Had the system been seen as an essential part of the building system, changes would have been made that remedied the flow/pressure problem while still utilizing rainwater as the primary water source for flushing toilets.

2. ***The water demand should be large enough to make the system economically & environmentally viable.***
   This requires a consistent, year-round water demand for which harvested rainwater is the default option. For example, a rainwater harvesting system that requires operators to manually switch to harvested rainwater or select a harvested rainwater tap is likely to be underused. In addition, systems designed solely for irrigation are generally not economically viable in temperate areas such as the Washington D.C. metro area. As a rule of thumb, in the Washington D.C. area, a rainwater harvesting system is most likely to be economically and environmentally viable when the overall water demand is at least 75% of the total volume of runoff from the catchment area. This equates to approximately 50 gallons per day of demand for every 1,000 ft2 of catchment area. A few of the systems assessed are examples of under-utilized systems due to the discretionary nature of irrigation as a designated water use. Also, none of these systems are currently in operation. Another system never had the irrigation component of the water harvesting system brough online.

3. ***The facility budget should include a dedicated budget line for upkeep, maintenance, and repairs of the rainwater harvesting system.***
   Having a dedicated budget for the system is part of treating the system as an essential component of the building. This budget is a recognition that all systems will require maintenance and provides the financial ability to keep the system maintained and functioning. Requiring all repair and maintenance costs to be pulled from another budget provides an incentive for not maintaining the system and not repairing the system when needed.

4. ***Rainwater harvesting systems should be designed as simply as possible to meet the system needs.***
   Many of the failures in rainwater harvesting systems occur because of overly complicated designs and over-reliance on non-standard parts. Simple systems designs are easier to install, maintain, and repair. The system serving the FDA White Oak building is a great example of a simple system that satisfies a nondiscretionary water use (cooling tower makeup) - rainwater is piped directly from the roof of the cooling tower facility via gravity to the cooling tower sump, passing through a vortex filter to provide necessary treatment prior to use.

5. ***Rainwater harvesting systems require careful installation by an experienced contractor and construction oversight.***
   All too often, rainwater harvesting systems are not installed correctly and are never fully brought online or have operational problems from the beginning. Careful oversight, use of an experienced contractor, clearly defined scopes of work, and defined responsibility for the functionality of the rainwater harvesting system at commissioning can reduce these issues. The building should not be considered complete and operational without an operational rainwater harvesting system.

6. ***Systems used as part of stormwater management are more likely to be economically viable and must remain functional.***
   Integrating the rainwater harvesting system into the site stormwater management plan can provide an additional recurring financial benefit from reduced stormwater fees (where applicable) and/or be viewed to offset the initial cost of the system. When on-site stormwater management is required, the financial investment in the rainwater harvesting system can be viewed as only the additional cost of the rainwater harvesting system beyond a comparable alternative stormwater management practice. In addition, if the rainwater harvesting system is a part of regulatory compliance, it increases the incentive to appropriately maintain and repair the system to keep it operational and in compliance. While one of the systems technically collects stormwater (rainwater runoff from a non-rooftop surface), none of the buildings included in this assessment were formally integrated into the overall stormwater mitigation plan/requirements for the site.

VII. Water Harvesting System Screening for Economic and Environmental Viability

Systems for which the following are established are more likely to consistently function as intended and provide maximum benefits with respect to potable water replacement, stormwater mitigation, and financial savings:

1. System design that follows established national standards and codes.
2. Appropriate contributing surface.
3. Year-round, dedicated water demand appropriate for available rainwater supply.
4. Responsibility for maintaining and troubleshooting the system is clearly assigned to

specific maintenance staff/supervisor/service contract.

5. Dedicated budget line/funding source for upkeep.
6. Integration into stormwater mitigation plan for the site whenever possible.

These six items were chosen because if they are not part of a water harvesting system, they will not be economically or environmentally viable. While there are other important pieces to creating a successful system, these should be included in every system.