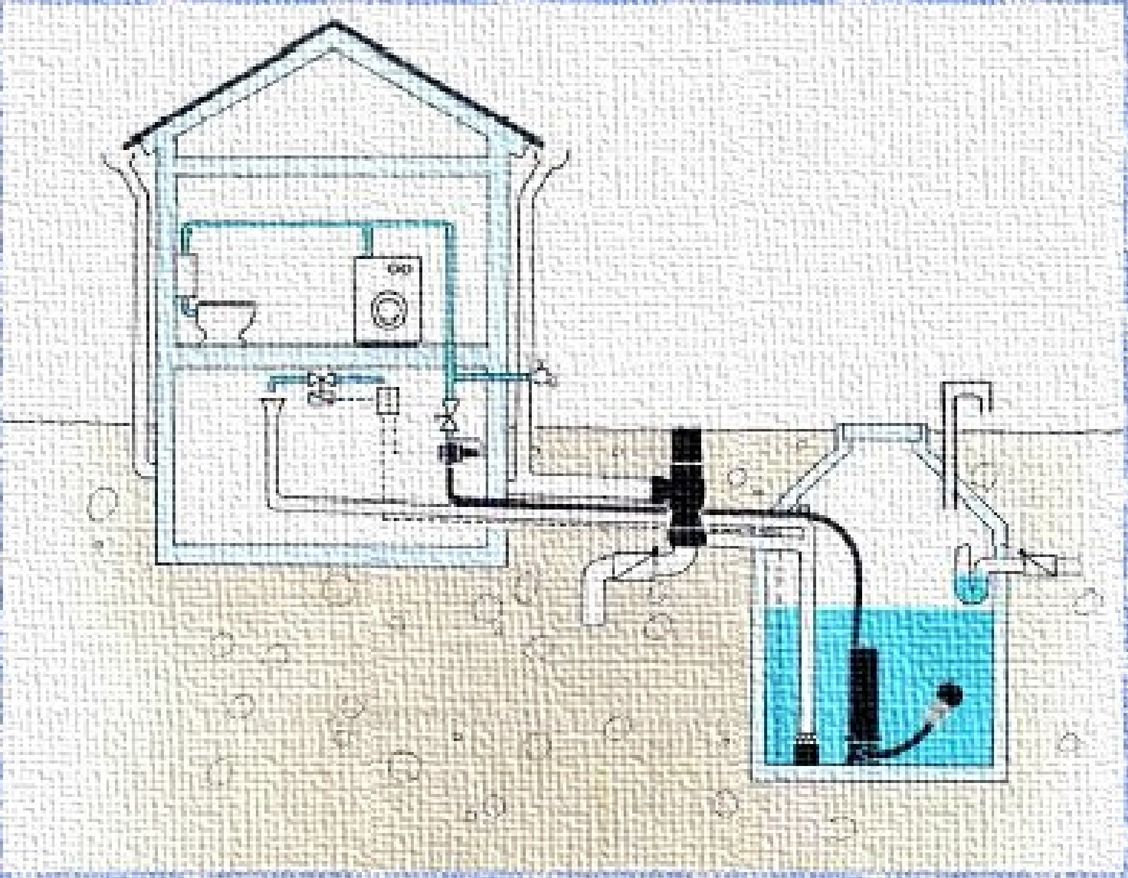
VIRGINIA RAINWATER HARVESTING MANUAL



A comprehensive guide to examining, designing and maintaining rainwater harvesting systems to abate stormwater runoff.

The Cabell Brand Center 2007

THE
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VIRGINIA RAINWATER HARVESTING MANUAL

Compiled by **The Cabell Brand Center**

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Contributing Authors: Adrienne LaBranche, Hans-Otto Wack, Ph.D., David Crawford,
Ed Crawford, and Cabell Brand

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Urgent Freshwater Problems

The water supply situation today is very different than it was 100, 50, or even 25 years ago. Populations continue to increase throughout the years, while water supplies remain constant. The amount of water available today is the same amount of water that was available 100 years ago. Since water is a finite resource, current and future plans must strive to maintain or improve available water quality while utilizing the available water resources as efficiently as possible.

Since only 2.5% of the world's water is freshwater, ensuring that this small amount of available water is utilized efficiently and quality is maintained is a daunting task. This is becoming even more important as populations increase worldwide. A recent report by Credit Suisse [1] stated that by 2025 18 countries will experience water demand beyond supply capabilities.

Worldwide water consumption is rising at double the rate of population growth[1]. Similarly, Virginia's water consumption is continually increasing. In 2005, 59% of the state's water was used for public water with 36% coming from groundwater sources [2]. These numbers are up from 2004 and 2003, where 57% and 54% of water was for public supply, with 33% and 12%, respectively, coming from groundwater [3, 4] .

Due to the increasing demand for public water supplies, groundwater levels are declining and municipal treatment plants are struggling to supply current demands while dealing with declining infrastructures. Decentralized rainwater harvesting offers an oftentimes overlooked alternative and sustainable water source.

Some countries like Australia, Bermuda, Germany, Belgium and India are requiring all new development in certain areas to be equipped with rainwater harvesting systems to preserve declining groundwater supplies. These regulations were made in response to the imbalance of population demand and available water supply. Some US housing developments are even incorporating rainwater harvesting in their low impact development designs as means to reduce municipal water demand and deter stormwater runoff. Furthermore, some state localities have restricted or prevented development in areas with insufficient drinking water supplies. In March of 2007, the Arizona Senate approved a bill that would allow counties and cities in rural Arizona to restrict housing developments without long-term water supplies [5].

Although Virginia is considered a "wet" state, as it received on average 45 inches of rainfall a year, the increasing populations place increasing demands on water supplies. As a result, planners, county and state officials, residents, and developers must look at alternative water sources to supply the demands.

Rainwater harvesting offers an affordable, simple, sustainable, and reliable alternative water source. Not only does rainwater harvesting supply water for indoor and outdoor use, it protects the environment from detrimental nonpoint source pollution by reducing rooftop runoff.

Rainwater harvesting is ideal for large retail and industrial buildings, especially ones with expansive parking lots. An industrial rainwater harvesting design starts with siphonic roof drainage, which is less expensive to install compared to traditional methods (see **Industrial** Systems). Rainwater is diverted from the flat roof to either an on-site storage tank(s) or pond. Stored water is then diverted both indoors and outdoors to be recycled for toilet flushing, linen washing, facility cleaning and irrigation. Not only does the company save water consumption costs, but it also reduces stormwater runoff on the site. The stormwater reduction aspect of rainwater harvesting holds this alternative water source above other alternative sources because rather than contributing to pollution through salt discharge (desalination) or energy consumption, it is reducing pollution and protecting local waterways. The ability of this system to reduce stormwater runoff can also be leverage for a company looking to attain building permits.

In the future, reducing stormwater runoff through low impact development may be included in building permits. Rainwater harvesting is a sustainable approach to accomplishing this, while providing an alternative water source. Acting proactively to protect the environment and conserve resources is beneficial today and tomorrow.

This manual details the benefits of rainwater harvesting, both economical and environmental, and addresses best management practices for rainwater harvesting design and utilization.

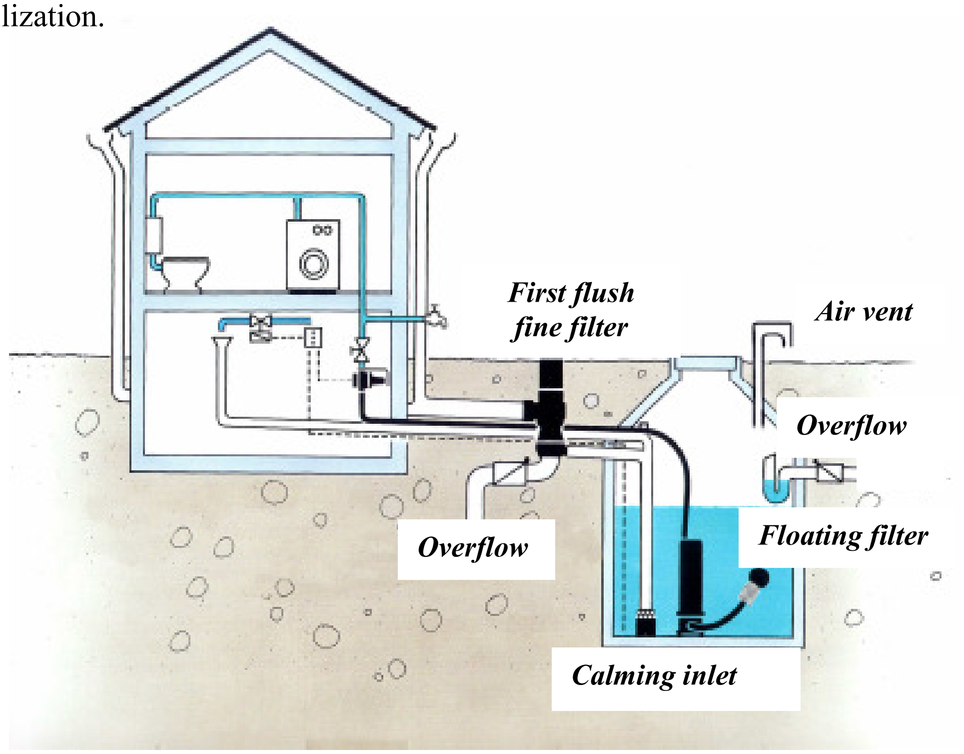


Fig. 1: Rainwater harvesting system
Graphic courtesy of WISY AG

The Trend

Today’s rainwater harvesting systems have evolved significantly and offer technologically advanced components. However, harvesting rooftop rainwater is more popular in European countries like Germany and England than the United States. Adoption is equally low in Virginia, with most adopters being rural dwellers with failing wells with no local municipal line and large corporations wishing to conserve water and reduce utility bills.

Harvesting rainwater has a long-term impact on the local water resources by reducing demands for surface and groundwater withdrawals. Also, harvesting rainwater protects the integrity of local waterways by reducing nonpoint source pollution. Including rainwater harvesting in local and regional water supply plans offers an alternative and sustainable water source while protecting the local environment.

Although rainwater harvesting has existed since the days of the early Romans, its popularity declined once central treatment facilities were able to supply treated drinking water. Today, rainwater harvesting is gaining popularity again for a variety of environmental and economic reasons. Obviously, technology and techniques have changed considerably from the days of the early Romans, but the theory remains the same.

What has spurred this shift back to the seemingly elementary process of collecting rainwater? Perhaps it is the rise in environmental awareness and the public’s desire to protect current resources; perhaps it is the increasing drought occurrences; perhaps it is the movement to conserve and promote sustainability; perhaps it is the desire to reduce stormwater runoff; perhaps it is to save money by utilizing this free source of water; or perhaps it is a combination of many of these factors. Whatever the reason, rainwater harvesting is indeed gaining popularity and can offer a sustainable alternative potable and non-potable water source.

On Earth Day, April 19, 2007, the EPA Administrator signed a statement of intent to “promote the use of green infrastructure approaches, such as rain-catching roofs and gardens, to lessen sewer overflows and runoff after storms” [6]. The news article directs readers to another site concerning green infrastructure, but this site fails to cover rainwater harvesting techniques beyond simple rain barrels. Rainwater harvesting systems are much more evolved than a rain barrel attached to a downspout. The Virginia Manual on Rainwater Harvesting will address the wide variety of rainwater harvesting system designs for residential, commercial and industrial buildings.

While the EPA recognizes the need to harvest rainwater to protect local waterways, modern rainwater harvesting literature is lacking. The Virginia Manual on Rainwater Harvesting further aims to educate Virginian residents about rainwater harvesting techniques. The addressed rainwater harvesting theories will apply to all US states, as will many of the included European techniques and standards.

Future of Rainwater Harvesting

Rainwater harvesting systems serve as an alternative decentralized water source, especially in the age when groundwater supplies are depleting and municipal water infrastructures are facing high replacement costs. Decentralized water sources, like rainwater, are needed to guarantee long-term ecologically sound water supplies. The use of decentralized rainwater harvesting systems is growing nationally and internationally, especially in industrial countries like Asia, Europe and the US.

Creating national and international rainwater harvesting system standards can assist in developing low maintenance, safe, and sustainable systems with minimum ecological disturbance. International businesses have made strides in recent years to produce high quality, sustainable rainwater harvesting components, which has influenced the market's expansion. However, the promise for economic gains fueled inferior companies to produce non-sustainable, mediocre products.

Rainwater harvesting design and installation requires a network of professionals. Component prefabrication companies, architects, engineers, craftsmen, water providers and local authority districts all are involved in designing, installing and regulating rainwater harvesting systems

The Virginia Manual of Rainwater Harvesting will detail rainwater harvesting application, design, installation, available technology, social and environmental impact, and water quality issues. In addition, installed rainwater harvesting systems, experiences with the technology, and examples of successfully designed and installed systems will be highlighted.

Systems

Rainwater harvesting is suitable for all building types ranging from residential to commercial and industrial and can be retro-fitted to existing buildings or integrated into new building designs. Collected rooftop water can be used for nonpotable (non-drinking water) and potable (drinking water) demands. Additional water treatment components must be installed to treat potable water to drinking water standards (see **Water Quality**).

Many households/businesses use potable water for nonpotable needs (see list below). A majority of the water a household/business uses is for nonpotable needs. Utilizing potable water for nonpotable needs wastes resources and places unneeded strain on local treatment plants.

Nonpotable demands include:

- Building washing/power washing
- Cooling towers
- Fire suppression
- Household cleaning

- Industrial processing
- Landscape irrigation
- Laundry washing
- Pool/pond filling
- Toilet flushing
- Vehicle washing

Potable demands include:

- Drinking water
- Cooking
- Bathing
- Dish washing

Residential

Residential systems can be designed for nonpotable and potable needs. We recommend that if potable water is available, rainwater harvesting should solely be used for nonpotable needs like toilet flushing, laundry washing and landscape irrigation. Plumbing for potable and nonpotable rainwater sources must be completely separate systems. Municipal or well water can also serve as a backup source of water if the rainwater runs dry. An air gap or backflow preventer is necessary between rainwater and municipal water supplies leading to the storage tank to prevent cross contamination (see **Plumbing**).

Rainwater harvesting can serve as an alternative water source for rural homes where municipal water is not available and well drilling has not proven profitable. Rainwater can also supplement well or municipal water supplies to reduce demand on these supplies to serve nonpotable demands in and around the home.

All systems require a guttering/conveyance system that drains rooftop runoff to a fine filter, which filters out a large percentage of contaminants before the water is stored onsite in an above or below ground tank. A system without a pressure pump relies on gravity feed; therefore, the tank must be located at a higher elevation than the garden and/or building, depending on desired water use. A pressure pump can pump water long distances for outside irrigation and indoor use and does not require the tank to be elevated. Figure 2 shows a small residential nonpotable system, ideal for irrigation purposes.

See **Tanks** section to determine whether an above or below ground tank is best and to determine tank size needed based on area rainfall and roof area. See **Water Quality** to determine the water treatment system that is most appropriate for the home's potable needs. See **Components** for the technical principles.

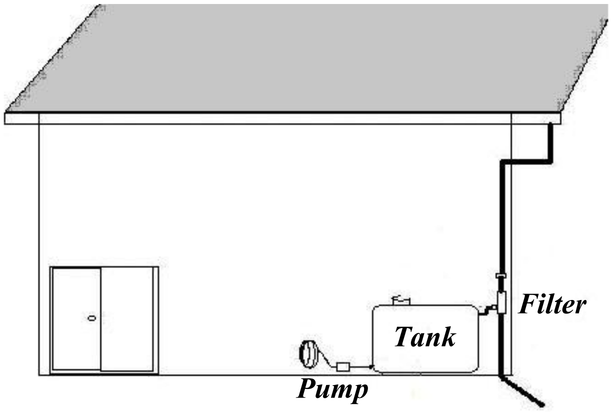


Fig. 2: Small residential nonpotable rainwater harvesting system
Graphic courtesy of Rainwater Management Solutions

Commercial

Commercial (or large residential) rainwater harvesting systems can also supply both potable and nonpotable needs. Needs may be different for a commercial building than a residential household. Many commercial or large residential buildings prefer to direct rainwater for toilet flushing, especially in buildings with high customer traffic. The soft rainwater is also beneficial for cleaning purposes as less detergent is needed. Water demand, roof size, and available onsite storage should be considered when sizing a collection tank.

Figure 3 shows a commercial or large residential above ground rainwater harvesting system and Fig. 4 shows a commercial or large residential below ground system. A larger filter is needed to filter water from a larger roof area. In nearly all cases, a submersible pump is necessary to pump water for indoor use. The addition of a calming inlet allows water to enter the tank without disturbing the important sediment layer on the bottom of the tank (See **Oxygenation**). A floating filter filters the water again before it is pumped for use while protecting the sediment layer and the pump.

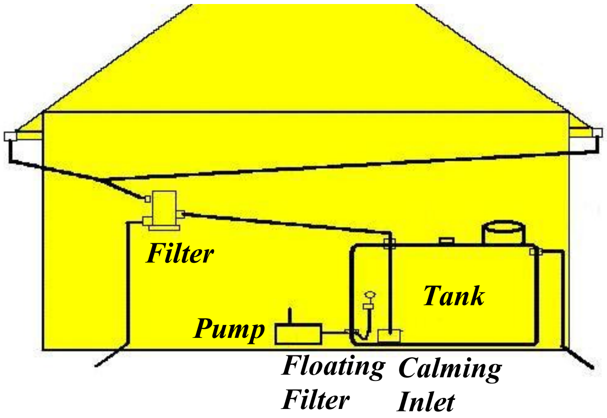


Fig. 3: Commercial or large residential above ground nonpotable rainwater harvesting system
Graphic courtesy of Rainwater Management Solutions

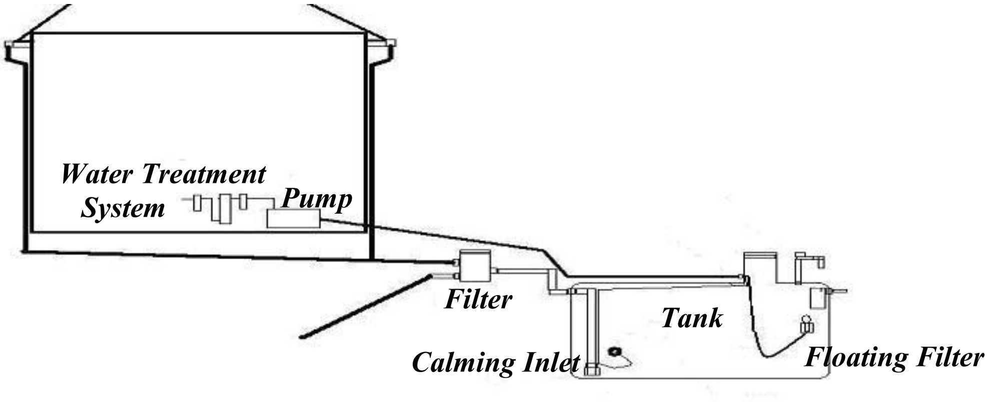


Fig. 4: Commercial or large residential below ground rainwater harvesting system
Graphic courtesy of Rainwater Management Solutions

See **Tanks** section to determine the tank size needed based on rainfall and roof area. See **Water Quality** to determine the water treatment system that is more appropriate for the home or business' potable needs. See **Components** for the technical principles.

Industrial

Industrial buildings with flat roofs are best suited with a siphonic roof drainage system, which follows the siphon principle to move water. A siphonic roof drainage system relies solely on gravity to move water and does not require a pitch to move water. Underslab piping can also be reduced or eliminated when utilizing siphonic roof drainage systems. Installation costs can be reduced by 30 to 40% due to the smaller pipe diameter and elimination or reduction in excavation, backfill, and trenching costs. Rooftop runoff is then diverted to an on-site storage tank or pond. Tanks range in size depending on the connected roof size.

Fig. 5: Siphonic roof drain
Photo compliments of Jay R. Smith

Harvested rooftop rainwater can be used indoors to flush toilets, clean floors, and wash linens or as irrigation. As in the commercial setting, the soft rainwater is beneficial for cleaning purposes as less detergent is needed, which not only saves money but also reduces the amount of detergent released into the environment.

Some companies opt to store water in a pond due to aesthetics, as opposed to large aboveground storage tanks. If rainwater is diverted to a pond, it should be equipped with an aerator in the form of a fountain to continually add oxygen. Water that is not used can also be directed for groundwater recharge.

Fig. 6: Collection pond with aeration fountain
Photo courtesy of Rainwater Management Solutions

See **Tanks** section to determine the tank size needed based on rainfall and roof area. Consultation with an engineer is needed to determine the pond area needed. See **Components** for the technical principles.

Agricultural

Rainwater harvesting is ideal for farm animal drinking water and agricultural and landscape irrigation, as it is salt free, easily attained, and reduces groundwater depletion and pumping from local streams. Rainwater can be collected from rooftop surfaces like barns, clubhouses, greenhouses and equipment storage buildings.

During summer months, Virginia often experiences quick, hard rainfalls. Such rain events produce too much water in too short a time period for the ground to absorb, which results in most of the rainwater being lost to runoff. Rainwater harvesting systems are capable of collecting rainwater from nearby roof surfaces during such rainfalls. Therefore, the heavy storm's rainwater can be reapplied to the field at a suitable rate to promote water infiltration.

Fire Suppression

Rainwater harvesting offers alternatives to municipally supplied water for fire suppression. Harvested rainwater can be directed to interior sprinkler systems and used in the advent of a building fire.

Fire suppression can go beyond indoor sprinkler systems and protect buildings from forest fires. Stored water flows backwards into the gutter system and overflows the gutters to form a shield of water. While forest fires are not as common in Virginia as they are in the arid west, rainwater could serve as protection for some homes located in heavily forested areas in the advent of a forest fire.

Another alternative is to collect rainwater for fire hydrants. Rooftop and street runoff can be directed to an underground tank connected to a fire hydrant. This prevents the reliance on potable water to fight fires and can reduce connection costs, especially in areas outside the main water distribution grid.

Virginia Rainwater Harvesting Application

Environment

When rain falls, it lands on a rooftop, drains to the gutters and drainpipes, and then is diverted either across land or to storm drain pipes. This rooftop runoff ultimately reaches local waterways. When the rainwater is carried across landscapes, it picks up detrimental pollutants like bacteria from animal excrements or decaying animals, chemicals, metals, nitrogen and phosphorus from fertilizers, oil, pesticides, sediment and trash [7]. All of these collected surface pollutants contaminate waterways and affect native aquatic plants and animals.

The Virginia Stormwater Management Act states that all localities covered under the Chesapeake Bay Preservation Act (Fig. 7) are required to adopt a local stormwater management program, while any localities located outside this area may voluntarily adopt a local stormwater management program [8].

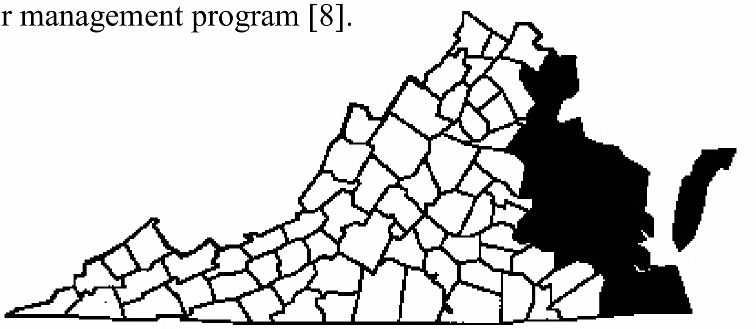


Fig. 7: Virginia counties regulated by Chesapeake Bay Preservation Act [9]

The Chesapeake Bay and its connecting rivers are plagued by nutrient and sediment pollution, which is a result of stormwater runoff. Effort is placed on protecting the Chesapeake Bay due to the diverse habitats and organisms that live in and around the watershed, which stretches through New York, Pennsylvania, Maryland, Delaware, Virginia, the District of Columbia, and West Virginia. Since Half of Virginia drains into the Chesapeake Bay watershed and two-thirds of Virginia's population lives within the Chesapeake Bay watershed, the health of this area impacts many.

Virginia population increases of nearly eight percent between 2000 and 2006 have resulted in an increase of 475,535 new homes [10]. Assuming each home has 1,500 square feet of roof area, 713 million square feet of impervious roof surfaces were installed during this time, resulting in 19 billion gallons of rooftop runoff per year. These impervious roof surfaces contribute to Virginia's ongoing problem of nonpoint source pollution.

Rainwater harvesting follows ecologically sound principles for water use as it reduces the impact on the land (see **Low Impact Development**), promotes sustainable practices, reduces stormwater runoff, reduces peak flow levels, reduces reliance on ground and surface water, allows for groundwater recharge, and promotes water conservation.

Through rainwater harvesting, individuals and businesses can divert rooftop runoff into an on-site storage tank or pond, thus preventing it from running across the landscape and further contributing to nonpoint source pollution. Modern rainwater harvesting systems are 95% efficient at collecting rooftop runoff. Five percent is lost in the first flush, which rids the system of large debris (see **Filters**).

Installing rainwater harvesting systems in areas where nonpoint source pollution from stormwater runoff is a severe threat to stream integrity can significantly reduce pollution loads. Since stormwater runoff can also lead to flooding in areas, harvesting rainwater combats flooding by reducing peak flow from high rain events.

Local cities may wish to investigate the economic and environmental impact of utilizing rainwater when investigating alternative water sources. For example, a student at Portland State University researched the feasibility of installing rainwater harvesting systems in an urban Portland neighbourhood. He determined that upon the installation of 4,500 gallon tanks, runoff could be reduced by 68%, while reducing demands on municipal water supplies for nonpotable water demands [11]. Also, an economic study in Sydney, Melbourne and southeast Queensland investigated the feasibility of utilizing rainwater harvesting over desalination to supply increasing water demands. The report stated that if five percent of households utilized rainwater harvesting, they would collect and supply as much additional water as planned by the desalination plant [12]. Desalination is a very expensive process, especially to provide potable water for nonpotable needs, and results in toxic concentrated salt by-products. Rainwater harvesting may prove profitable for localities wishing to conserve dollars, water and the environment. The economic benefits of rainwater extend beyond water supply costs, as discussed in the next section.

Economic

The economic feasibility of harvesting rainwater differs based on many factors, i.e. precipitation frequency, water consumption needs, prices of local water and wastewater treatment, cost of installation and maintenance. More importantly is the long-term economic feasibility, which is based on the building's operation lifespan and system design. The combination of a high building lifespan at least 40 years, high-quality and sustainable prefabricated components, and minimum system servicing needs equates to rainwater harvesting being economically feasible and ecologically sensitive.

Utilizing inferior quality, less expensive, prefabricated components translates to higher service costs as these components must be replaced during the life of the building. Installing high-quality prefabricated components that last the life of the building is a sustainable building practice that is both economic and environmentally responsible.

Taxes

Some states like Texas offer tax incentives for individuals and businesses interested in installing rainwater harvesting systems. In 2001, Virginia passed Senate Bill

1416, which gave income tax credit to individuals and corporations that installed rainwater harvesting systems. Unfortunately, this bill was never funded so it fell to the wayside. However, work is underway to lobby for future tax incentives as rainwater harvesting is an environmentally responsible and economically feasible approach to conserving water and reducing nonpoint source pollution.

Cost of water

The cost of municipally supplied water nationwide has increased by 9.8% from 1998 to 2001 [13], 4% between 2001 and 2002 [14], and 27% in the last five years [15]. Prices will continue to rise due to increasing costs to treat water to adapt to EPA's Safe Drinking Water Act guidelines, upgrade declining infrastructures, and instil conservation programs. Most US infrastructure was first installed after World War II and many are at or past the 50 year expected lifespan. Therefore, water costs are sure to rise to help offset the replacement/rehabilitation cost. Reducing potable water demand through rainwater harvesting could eliminate the need for infrastructure expansion.

Installing a rainwater harvesting system can help residents reduce their water supply costs. With rainwater harvesting systems, most of the cost is upfront cost, but systems ultimately pay for themselves within a few years, depending on the system and local water prices. This time could be reduced, depending on how quickly municipal water costs increase. Appropriately designed rainwater harvesting systems will have minimal maintenance costs associated with its upkeep (see **Maintenance and Cleaning**) and therefore will show the best long-term relationship between cost and financial benefit.

In some urban areas, rooftop runoff is directed to storm drains and then to water treatment facilities. These large pipes are expensive to install and travel many miles through urban areas. When a heavy rainfall occurs, the water treatment facilities are overwhelmed with stormwater, which causes systems to overflow and even contaminate local waterways with untreated sewage. Classifying rainwater as sewage is unnecessary, wastes resources, and causes unnecessary pollution.

Through a downspout disconnect program, many cities have reduced the number of downspouts connected to sewer systems. In doing so, rooftop runoff is instead land applied. While the disconnect program addresses wastewater treatment overloading, it does not necessarily address nonpoint source pollution from stormwater runoff. In fact, inappropriately directed downspouts (i.e. to impervious surfaces) can increase nonpoint source pollution.

Municipally supplied water is treated to drinking water standards. Potable water is not needed to flush toilets, wash clothes, wash vehicles, fill pools, fight fires, or irrigate lawns. Therefore, additional money and resources are being wasted when potable water is consumed for non-potable demands.

Rainwater harvesting's economic feasibility can also be calculated by its synergistic values. Rainwater is soft, which means less detergent is used and released into the environment. Also, rainwater harvesting systems with a connected vaporization system can raise site humidity and create a healthier microclimate. This is ideal for city areas dealing with air pollution. Likewise, utilizing rainwater as opposed to municipal and well water benefits local streams, lakes, ponds and groundwater sources since less water will be pulled from these sources. Such benefits may not have a direct price tag, but their value is long lasting and considerable.

Installing and utilizing rainwater harvesting systems can have a trickle-down effect and cause other companies/individuals/organizations to be more environmentally conscious for environmental, economic and political reasons. Rainwater harvesting systems typically increase residential property value and offer current and future residents the opportunity to live an environmentally responsible lifestyle.

LEED Certification

With continuing population increases, demand for housing and retail shops will also continue. Thus, development is not likely to stop anytime soon. However, green building design reduces the environmental impact of development. By following green building practices, LEED (Leadership in Energy and Environmental Design) certification can be attained.

In the late 1990's the United States Green Building Council (USGBC) developed a LEED certification process, which certifies buildings based on environmentally conscious design. Rainwater harvesting is one component that can lead to certification, as it is identified as a sustainable water source and reduces environmental impact through reduced stormwater runoff and reliance on municipally supplied water.

To attain basic LEED certification, 26 to 32 points are needed. The following rainwater harvesting applications will give points towards certification [16]:

- **1 point:** Reduce stormwater runoff
- **1 point:** Use captured rain to reduce potable water consumption
- **1 point:** Reduce generation of wastewater and potable water demand
- **1 point:** Conserve existing natural areas

According the USGBC website, twenty buildings in Virginia have some level of LEED rating [17]. A majority of these buildings are located in Northern Virginia where energy and water supplies are especially strained due to sheer population numbers. However, water conservation and stewardship is important throughout the state.

Low Impact Development

Low impact development (LID) aims to mimic a site's pre-development hydrology through the use of innovative techniques and design. Typical development designs include a variety of impervious surfaces like roofing and paving. Through LID, designs aim to curtail the stormwater runoff from these impervious surfaces or utilize alternative products that infiltrate, filter, store, or detain runoff water

Residents and business owners that wish to retrofit current buildings or build LID dwellings can look to rainwater harvesting as an approach to combating the serious issue of stormwater runoff. In fact, many Virginia localities are urging LID development. Including rainwater harvesting in retrofits or new designs not only reduces stormwater runoff, but also supplies the building with an alternative water source while reducing reliance on groundwater or municipal water.

Technical Standards and Rules

During the developmental phase of the modern rainwater harvesting system, some countries investigated water quality and technology improvements. Germany was the leader in these studies between 1987 and 1997. These studies and practical experiences assisted in drafting rainwater harvesting technical standards, which focused on improved prefabricated components. The studies also gathered data referring to potable and nonpotable rainwater quality, economic efficiency, and system design.

Creating national and international rainwater harvesting standards can assist in developing low maintenance, safe, and sustainable systems with minimum ecological disturbance. International businesses have made strides in recent years to produce high quality, sustainable rainwater harvesting components, which has influenced the market's expansion. However, the promise for economic gains fueled inferior companies to produce non-sustainable, mediocre products

Today's rainwater harvesting system designs should follow DIN 1989 Part 1: Planning, Installation, Operation and Maintenance [18], to ensure designs are high-quality and safe. DIN 1989 is a German compilation of standards comprised by skeptics and advocates from the private and public sectors [19]. German water providers, water quality specialists, local authority districts, professional organizations, and ministries of environment and health all follow these standards.

Adopting DIN 1989 would be another step to establishing international rainwater harvesting standards. All practical experiences confirm that the German standards are sufficient to reach a technically sustainable and safe rainwater harvesting design. Therefore, in countries where such standards and regulations do not exist, i.e. the US, the German standards can be adopted.

Rainwater harvesting design and installation requires a network of professionals. Component prefabrication companies, architects, engineers, craftsmen, water providers and local authority districts all are involved in designing, installing and regulating rainwater harvesting systems. Like every new technology, involving only the most qualified personnel ensures a successful and sustainable product.

Rainwater harvesting systems should be designed to ensure water maintains high-quality while in storage. This is accomplished through the implementation of high-quality products that divert, collect, and store water.

Systems should fulfill the following DIN 1989 guidelines:

- Fortify rooftop runoff with oxygen
- Eliminate fine and coarse particles prior to storage
- Ensure stored water is high in oxygen
- Protect stored water from contamination
- Provide high-quality, sustainable components

- Require minimum maintenance.

Components

By following the German standards for rainwater harvesting design, the aforementioned criteria can be achieved. This section details the various components necessary for rainwater harvesting and set guidelines for installation and maintenance. The following guidelines are not rules in Virginia, but are based on DIN 1989 standards and various US state standards. As a compilation, they serve as a guideline for creating best management practices in Virginia.

Plumbing

When utilizing both rainwater and potable municipal water supplies, there may be times when rainwater supplies are exhausted, therefore municipal potable water should also be a backup for non-potable needs. To ensure cross contamination does not occur, separate plumbing systems must be installed for both potable and non-potable rainwater. Therefore, two completely separate plumbing systems must exist to supply potable and non-potable water. Signs must be displayed at all faucets and spigots supplying non-potable water that state “not drinking water.” Also, rainwater spigots must be protected, especially in public buildings, against unauthorized usage. Removing knobs from outside spigots is one approach to prevent unauthorized use. Potable and nonpotable plumbing can be distinguished through different color pipes. All nonpotable water plumbing should be labeled as such.

In the event of a rainwater shortage, tanks can be partially filled with potable municipal supplies. Rainwater harvesting systems should be designed to incorporate either a backflow preventer or an air gap to ensure contamination does not occur between the rainwater and municipal water. The air gap should allow 2 cm. of airspace or space equivalent to 3 times the municipal water supply pipe diameter. The municipal water inlet must be installed above the highest possible rainwater level and overflow outlet to ensure cross contamination does not occur.

Tanks

Tanks are the most expensive component in the rainwater harvesting system. However, tanks, arguably, are the most important part of the rainwater harvesting system as supply is dependent on a fully functioning tank. There are many tank material options and vary based on local material availabilities and climate.

Fig. 8: Below ground tank

Image courtesy Rainwater Management Solutions

Tanks can be stored either above or below ground. Tank location is dependent on aesthetics, climate and soil conditions. Some prefer not to see the storage tank and opt to bury it. However, placing tanks underground add to the installation costs and may be limited in areas where soil is especially rocky. When tanks are installed below ground, water is maintained at a cool temperature and light is blocked, which reduces the chances of bacterial growth. Some tanks are not suitable for certain climatic areas like wooden tanks are not recommended for hot, dry locations. Since Virginia is a fairly humid state, wood tanks can be used throughout. However, installing tanks below ground may not be advisable in the mountainous regions and areas with a high groundwater level. The table below (Table 1) describes available tank materials and their corresponding advantages and disadvantages.

Table 1: Tank Comparison

Tank Material	Advantages	Disadvantages
Plastic		
Fiberglass	commercially available alterable and moveable little maintenance light weight	must be sited on smooth, solid, level footing pressure proof for below ground installation
Polyethylene	commercially available alterable, moveable, affordable, available in variety of sizes install above or below ground little maintenance	UV-degradable must be painted or tinted pressure proof for below ground installation
Trash cans (20-50 gallon)	commercially available inexpensive	must use only new cans small storage capabilities
Metal		
Galvanized steel tanks	commercially available alterable and moveable available in variety of sizes film develops inside to prevent corrosion	possibly corrosion and rust must be lined for potable use only above ground use
Steel drums (55-gallon)	commercially available alterable and moveable	verify prior to use for toxics prone to corrosion an rust small storage capabilities
Concrete		
Ferroconcrete	durable and immoveable install above or below ground	potential to crack and leak neutralizes acid rain
Monolithic/Poured-in-place	durable, immoveable, versatile install above or below ground decreases rainwater corrosiveness	potential to crack and leak permanent neutralizes acid rain in clay soil, do not place underground
Stone, concrete block	durable and immoveable keeps water cool in hot climates	difficult to maintain expensive to build

Wood		
Pine, redwood, cedar, cypress	attractive, durable contains natural preservative can be disassembled to move available in variety of sizes	expensive site built by skilled technician not for use in hot, dry locations only above ground use

[20-22]

Tanks should be located within close proximity to the building and overflow should be directed to another tank, infiltration device, pond, or pervious surface. Overflow piping must be the same or larger diameter to that of the inlet piping and water should be directed away from the building to protect the building from any water damage. If no alternatives exist, overflow can be connected to the public sewer system. This is typically only done in city settings where no pervious surfaces exist. If the tank will be gravity fed to irrigate gardens, it should be positioned high enough to allow for gravity feed. Otherwise, a pressure pump may be necessary to move water from the tank to the desired location (see **Pumps**).

Tanks should be placed on level ground. If situated on the ground, the foundation should be compact soil covered with sand. Creating a sturdy foundation ensures the tank does not tilt and ultimately collapse. In the event of overflow, water should be diverted away from the tank and foundation to maintain the foundation's integrity [22].

Conveyance systems

The conveyance system includes gutters, downspouts and return pipes and is responsible for transporting rainwater from the roof to the filter before it reaches the storage tank.

Gutters move rainwater from the roof surface to the downspouts. Therefore, they serve an integral part in transporting water efficiently and effectively. Specially designed guttering systems are not necessary for harvesting rainwater. Existing guttering systems can be retrofitted to divert water to storage tanks.

Guttering systems should be pitched to ensure all water runs out and the gutter is allowed to dry between rainfall events to prevent mosquito breeding and bacterial growth. The pitch should be 0.5% for 2/3 of its length and 1% for the remaining 1/3 length and ideally a semi-circular or trapezoidal shape [23].

Gutter systems should remain free from debris at all times. This ensures water moves freely from roof surfaces to the storage tank. Installing covered gutters or adding guards to existing gutters is ideal to prevent debris buildup and clogging.

Filters

The goal of a filter is to not only eliminate contaminants but also supply oxygen to water during the filtration process. An advanced filter does not restrict the diameter of the gutter and is positioned either vertically connected to the gutter system or horizontally connected to the downspouts (see Fig. 9).

Modern filters require extremely low maintenance and cleaning and can efficiently collect more than 90% of filtrated rainwater. To ensure the effectiveness of the filter, the appropriate filter should be paired with the appropriate roof area. Also, utilizing high quality filters ensures water is sufficiently filtered, oxygenated and directed to storage tanks.

We recommend first flush fine filters when filtering water from gutters and prior to storage. These filters require 5% of the water to flow through, which is when large contaminants from the roof surface are also flushed through. After the 5% first flush, the fine filter is wet and can start filtering fine contaminants as water is diverted to a storage tank. Filter meshes less than 0.5 mm work best.

Even with high rainfall events, filters should remain efficient in filtering water and diverting as much water as possible into the storage tank. Therefore, filters should be self-cleaning and self-drying between rainfall events. Filter fabric should dry between rainfall events to prevent algae and biofilm growth, which could block the fabric pores. Also, fabrics should be made of stable materials that do not change shape and can withstand temperature changes, ice formation, and frost.

Stainless steel is considered the best filter fabric because it can withstand all weather conditions, even ice formation and frost, is self cleaning and self drying, maintains shape, and does not rust, thus reducing contamination likelihood. The vortex filters in Fig. 10 include a removable stainless steel filter insert and the downspout filter in Fig. 10 is made constructed solely out of stainless steel.

Fig. 9: Downspout filter

Image courtesy of Hans Otto-Wack

Fig. 10: Vortex and downspout filters

Images courtesy of Wisy AG.

High quality filters need inspection only two to four times a year and last the lifespan of the building. Purchasing sustainable products for rainwater harvesting further emphasizes the environmental impact by conserving water, energy, and production resources. Research should be conducted to ensure high quality products are integrated into a building's rainwater harvesting design.

Calming inlets, located at the bottom of storage tanks, smooth the entering water to prevent it from disturbing fine particulate matter on the bottom of the tank (see Fig. 11). Water is directed upwards, which reduces the inflow speed and prevents water from whirling in the tank. Likewise, the calming inlet distributes the fresh, filtered water while oxygenating the water to further ensuring high-quality stored water. In round tanks, one calming inlet can evenly distribute the fresh rainwater. In larger square tanks, several calming inlets may be necessary to provide evenly distributed fresh rainwater.

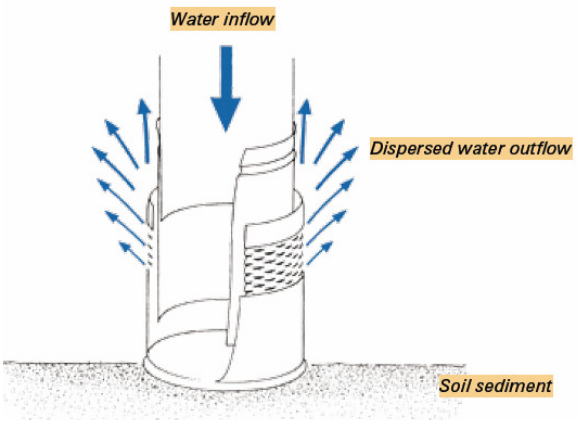


Fig. 11: Calming Inlet
Image courtesy of Wisy AG.

Soil sediment consists of fine particulate matter that settled to the tank bottom. This film is biologically active and converts organic materials to CO_2 and mineral substances. This natural process, similar to the aerobic cleaning processes in brooks, assists in cleaning the water and reduces the soil sediment layer. If the tank was cleaned, the biologically stable biofilm would be destroyed.

However, this balance only occurs when water is fine filtered prior to entering the tank. Therefore, only fine sediment collects in the tank. If larger organic matter is present in the tank, oxygen would be depleted and harmful anaerobic conditions would occur. Therefore, it is important to ensure water passes through a filter <0.5 mm prior to storage.

To aspirate the water from the tank, a floating filter is located at the end of the pump's suction hose (Fig. 12). It protects the soil sediment against destruction and protects the pump against particles. Floating filters are best when they are 0.2 mm particle size. Otherwise, a coarse meshed floating filter can be used. Filter fabric should also be high-quality stainless steel, like the first flush filter.

Fig. 12: Floating fine filter with pressure pump
Image courtesy of Wisy AG.

Cleaning and Maintenance

Appropriately designed rainwater harvesting systems require very little maintenance. However, like any household component, it should be checked periodically to ensure it is operating efficiently and appropriately.

Gutters: Gutters should be periodically flushed to clear them of organic matter and help eliminate any clogs. While some gutter guards are advertised as never clogging, they too should be monitored and checked periodically to ensure water is entering and flowing through the gutter.

Downspouts: Downspouts should be checked occasionally, especially where they connect to the gutter. Any debris should be removed to ensure the water flows through freely.

Filters: Modern filters do not require replacing and require little maintenance, unlike the old roofwasher design. Figure 13 shows the difference between the old design and the modern filter design. The roofwasher on the left requires periodic cleaning and filters need replacing yearly, while the filter on the right never needs replacing. However, the self-cleaning filter does require monitoring as buildup may occur, depending on the local environmental conditions. If the stainless steel filter insert needs cleaning, it can be washed in the dishwasher.

Fig. 13: Old and modern filter designs
Images courtesy of Rainwater Management Solutions and Wisy AG.

Tanks: If a first flush filter is not used, tanks will require yearly cleaning to remove organic debris buildup. If a first flush filter is used, tanks will not require cleaning as the biofilm on the bottom of the tank improves water quality by adding oxygen (see **Oxygenation**). In areas where acid rain is problem, water pH should be tested periodically. A neutralizing agent can be added to the tank to combat pH problems. Pieces of limestone rock can be placed in the tank to assist in neutralizing the water. Other common neutralizing agents and their dose are as follows:

- Limestone: 2 oz.
- Quicklime: 1 oz.
- Hydrated lime: 1 oz.
- Soda ash: 1 oz.
- Caustic soda: 1.5 oz.

Design & Installation

All rainwater harvesting system designs should be conducted by a licensed professional engineer experienced in rainwater harvesting design. Licensed plumbers are required by law to install any plumbing systems. Only licensed contractors should install any rainwater harvesting system, but special rainwater harvesting installers are not required.

The following list includes basic guidelines that should be followed when designing and installing rainwater harvesting systems:

- Only rooftop rainwater should be collected
- The roof materials should be selected carefully
- Potable storage systems (cistern) should be located at least 50 feet from possible contamination, i.e. septic tanks, termite treated buildings
- Storage tank must be located on a lower grade than the filter
- Storage tank must exclude light
- Systems must be equipped with overflow pipes that direct water to another tank, stormwater pipes, pervious surface, or pond
- Calming inlets are necessary to disperse water upwards and protect the oxygenating biofilm on the bottom of the tank
- Systems must be equipped with fine filters
- Floating filters should be incorporated at the pump aspiration hose
- Storage tanks should be accessible for maintenance and cleaning
- Storage tank openings must be covered and screened
- All system parts should be high-quality to last the lifetime of the building
- Systems designed for potable use must be equipped with appropriate water treatment components [24].

Water Quality

Due to the lack of readily available information concerning rainwater quality, the general public is often leery about consuming and utilizing rainwater for potable and/or nonpotable use. This manual aims to educate the Virginia and US population on the benefits and safety in utilizing rainwater.

Rainwater qualities:

- naturally soft
- slightly acidic (6.3 – 6.8)
- contains no sodium
- contains very few contaminants and bacteria
- perfectly safe for nonpotable use in and around a building.

Rainwater is considered uncontaminated until it falls on a roof and absorbs contaminates from both the roof and air, thus filtering is necessary before diverting rainwater to a storage tank or cistern.

Water quality standards

There are currently no US water quality standards specifically for rainwater harvesting. Rainwater harvesters should be aware of water borne pathogens and possible water contaminants in untreated rainwater.

Contaminates of concern include:

- algae
- chemical compounds (aerosols, disinfectants, etc.)
- microorganisms from organic solids (bird excrement, etc.)
- organic and inorganic solids (leaves, wood, moss, sand, dust, etc.)
- radionuclides [25].

Although contaminants may exist in untreated rainwater, many are diverted through the fine filter prior to entering the storage tank (see **Filters**) and are present in minimal amounts that do not affect water quality for nonpotable use. During dry spells, debris may accumulate on the roof surface. The debris is washed off the surface upon rainfall and diverted through the first flush filtering process.

All roofing material should be monitored for organic build up such as branches, leaves, dead animals, and animal excrement. It is recommended that overhanging branches should be trimmed back to reduce the organic matter build up and thwart animal access.

Standards do exist for drinking water quality and they should be abided if rainwater is to be used for drinking water. The EPA website [25] http://www.epa.gov/safewater/contaminants/index.html can be referenced for further information regarding drinking water regulations and contaminants.

Oxygenation

Oxygen in the stored water ensures collected rainwater maintains high in quality. Oxygen depletion can lead to anaerobic conditions. In anaerobic conditions, surface biofilms form reducing water quality and creating an offensive odor. Appropriately designed rainwater harvesting systems incorporate products that oxygenate the water to maintain high water quality.

Some filters are designed to oxygenate the water and provide continuous air flow to the storage tank (see **Filters**). Including air vents in the tank also allows air movement into and out of the tank, thus saturating the water with oxygen. Some tanks are even aerated through windmill aerators. These windmills are placed alongside rainwater tanks and either wind or electricity can move the windmill and cause air bubbles to enter the tank, much like a fish tank. The bubbles provide aeration and prevent anaerobic conditions.

Organic materials like leaves, moss, and bird excrement that reach water sources consume oxygen during decomposition, thus starve the water of healthy oxygen. Likewise, organic material is more likely to carry bacteria, thus fine filters are necessary to eliminate such contaminants, but home/business owners should also attempt to keep roofs clear of large debris.

Floating organic materials in the tank can form a layer on the surface, which can prevent oxygen diffusion, while a naturally forming biofilm layer produces oxygen to maintain water health. An angled overflow pipe can suction the fine particulate matter from the water surface (Fig. 14). Only four to six overflow events are necessary per year to remove the particulate matter. Tank size can be calculated to ensure overflow does occasionally occur, based on annual rainfall amount and roof area (see **Sizing a system**).

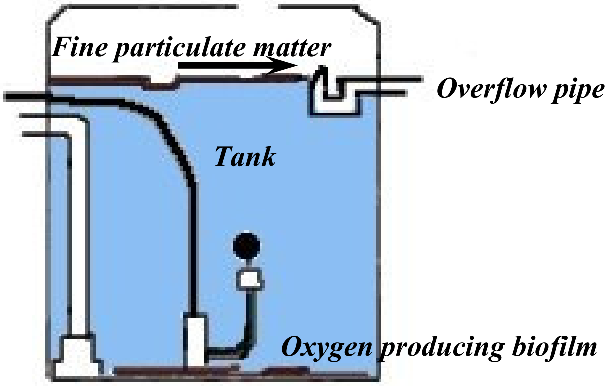


Fig. 14: Fine particulate matter and angled overflow pipe

Treating potable water

Treatment is needed to bring the water to drinking water standards, per federal guidelines (http://www.epa.gov/safewater/standards.html) [26], as Virginia follows federal drinking water standards. Rainwater can be treated onsite to supply water for potable needs. Treatment is available in several forms. The table below describes the various methods available and their advantages and disadvantages. When deciding on a water treatment system, discuss the options with your rainwater harvesting design engineer.

Table 2: Purification Options

Treatment	Advantages	Disadvantages
Chrlorine	inexpensive	odor, taste, carcinogen, does not kill all pathogens
Ozonation	no odor or taste, no chemicals needed	expensive, produces toxic by-products requires electricity
Reverse osmosis	removes most contaminants	likely to clog, wastes water, expensive
Ultraviolet (UV) light	kills most microbes, no chemicals needed	expensive requires electricity

[22, 27]

Fig. 15: Residential UV light potable water treatment
Photo courtesy of Rainwater Management Solutions.

Factors affecting water quality

In most areas, rain is pure water when falling from the sky. Contaminants are not collected until the rain falls on the roof surface. Contaminants on a roof surface depend on the roofing material, location to industrial plants, location to overhead trees and presence of animal excrements or remains. Metal roofs are ideal for rainwater harvesting for the following reasons:

- Impervious: rainwater runs off quickly
- Smooth: rainwater cleans the surface quickly
- Conducts heat: prevents bacteria from growing [28].

The table below highlights the types of roofing material and the contaminants associated with each surface.

Table 3: Roofing material and associated contaminants

Roofing Material	Contaminants
Asphalt Shingles	mold, algae, bacteria, dust, soot, moss, petroleum compounds, gravel grit
Aluminum	aluminum
Galvanized metal	lead, cadmium, zinc
Sheet metal	lead
Tar shingles	copper
Terra cotta	mold, algae, bacteria, moss
Wood	mold, algae, bacteria, moss, wood preservatives

[27, 29-31]

Aluminum is the best selection for rooftop rainwater harvesting. Although aluminum roofing may release aluminum into the water, it is only a trace amount that will not significantly affect the water quality [30]. Semi-porous roof surfaces like terra cotta and wood absorb some of the water, thus eliminating the system's water collection efficiency [31].

Some international companies have designed roofing material specifically designed for potable rainwater harvesting. The roofing material is typically pre-painted zinc and aluminum coasted steel. Some common brand roofs are Colorbond® and Zincalume®. Although these roofing materials are more common in Australia, the global market allows for availability even in the US.

Roofs with a pitch work best for rainwater harvesting, as water is easily moved through gravitational force. Since organic matter can build up between rain events, a steeper roof also allows water to move more efficiently and quickly across the surface, which helps clean the roof surface [32].

Vegetated roof surfaces with a soil base absorb most of the water that falls on the roof and only 10% to 20% of the runoff is collected. The collected runoff is typically a brown color, thus only suitable for landscape irrigation. However, up to 30% of rainfall runoff from vegetated roofs with a gravel base is collected. This water is also a clear color so it is suitable for both indoor and outdoor use.

Sizing a System

When sizing a system, several factors must be taken into consideration:

- Rainfall amount
- Roof area
- Available room on lot
- Water consumption (household size and needs)
- Intended use (potable, nonpotable, irrigation) [33].

The average person uses 50 gallons of water per person per day for potable and non-potable uses. We recommend that if potable water is available, rainwater should be used solely for nonpotable water uses, which can add up to 80% of the water used in and around a home/business.

Calculations

This section will detail how much water can actually be collected from a roof surface and how to determine what size of tank is needed, based on rainfall and roof area. Home/business owners can do these calculations on their own, but they should contact a rainwater harvesting design engineer to appropriately determine tank size.

One inch of rainfall collects 0.62 gallons per sq.ft of roof area; therefore, 620 gallons is collected when a one inch rainfall falls on a 1,000 sq.ft. roof area. The equation below calculates the yearly collectable amount of rainwater; depending on average rainfall, roof area and system efficiency.

average rainfall x **roof area (sq.ft.)** x **0.62 (conversion)** x **collection efficiency**

Example:
Assuming the average VA rainfall: 45 inches
Home: 2,500 sq.ft.
First flush filter: 95% efficient

45 inches rain x 2,500 sq.ft. x 0.62 x 0.95 = **66,262.5 gallons/yr**.

Now compare this number the household water usage.

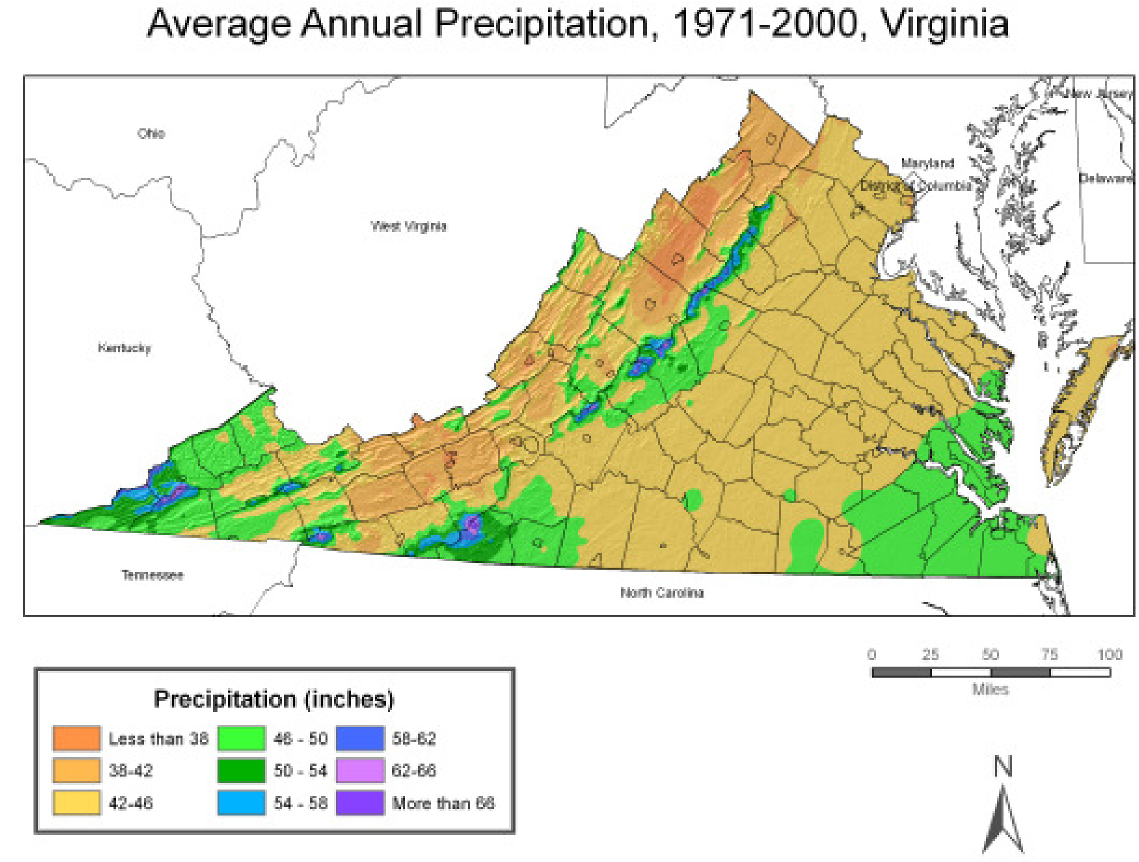
Assume:
50 gallons/day
4 people in household

50 gallons/day x 4 people x 365 days = **73,000 gallons/yr**.

Therefore, the collected rainwater could supply 90% of the household's annual water demand. This would cover likely cover all nonpotable water demands.

Virginia Rainfall Distribution

Virginia annual rainfall amounts can be as little as 35 inches in the Northwest and as high as 60 inches in the Southwest mountains (Fig. 16). Average rainfall throughout the state is 45 inches with the least rainfall falling in December through February (around 3 inches) and the most in July and August (around 4.2 inches) [34]. Unlike western US states, Virginia's rainfall is dispersed evenly throughout the year therefore; no additional calculations are needed to determine how much rainwater would be harvesting in the rainy season to supply water during the dry season.



Map copyright (c) 2006 by the PRISM Group and Oregon Climate Service, Oregon State University.

Fig. 16: Average Virginia annual precipitation [35]

The tables below details the amount of rainwater that can be harvested yearly on residential/commercial and industrial buildings, depending on rainfall amount and roof size, assuming 95% collection efficiency (5% lost in the first flush).

Table 4: Residential/Commercial rainfall catchment (gallons)

Roof size (sq. ft.)	Rainfall (inches) 35	40	45	50	55	60
1,000	21,615	23,560	26,505	39,450	32,395	35,340
2,000	41,230	47,120	53,010	58,900	64,790	70,680
3,000	61,845	70,680	79,515	88,350	97,185	106,020
4,000	82,460	94,240	106,020	117,800	129,580	141,360
5,000	103,075	117,800	132,525	147,250	161,975	176,700
6,000	123,690	141,260	159,030	176,700	194,370	220,590
7,000	144,305	164,920	185,535	235,600	226,765	247,380
8,000	164,920	188,480	212,040	235,600	259,160	282,720
9,000	185,535	212,040	238,545	265,050	291,555	318,060
10,000	206,150	235,600	265,050	294,500	323,950	353,400

Table 5: Industrial rainfall catchment (gallons)

Roof size (sq. ft.)	Rainfall (inches) 35	40	45	50	55	60
100,000	2,061,500	2,356,000	2,650,500	2,945,000	3,239,500	3,534,000
200,000	4,123,000	4,712,000	5,301,000	5,890,000	6,479,000	7,068,000
300,000	6,184,500	7,068,000	87,951,500	8,835,000	9,718,500	10,602,000

The table below categorizes the recommended tank size based on annual rainfall distribution and roof area. This table is only a recommendation and should not be the sole source to guide system design. Contact a rainwater harvesting design company to ensure your system is sized and designed appropriately and includes all necessary components, based on your needs.

Table 6: Recommended tank size (gallons)

Rainfall per yr in.	Roof area sq. ft. 1,000	2,000	3,000	4,000	5,000
35	1,500	3,000	5,000	10,000	10,000
40	2,500	5,000	5,000	10,000	10,000
45	2,500	5,000	10,000	10,000	10,000
50	2,500	5,000	10,000	10,000	10,000
55	3,000	5,000	10,000	10,000	10,000

Indoor Water Conservation

Today's appliances and irrigation components can save at least 30% of the daily water consumed. Only ultralow flush toilets are sold in the US now. These toilets can use as little as 1 gallon per flush and up to 1.6 gallons per flush. Utilizing water saving appliances will affect tank sizing as less water would be required for indoor use. Table 7 details water consumption differences for water saving appliances.

Table 7: Water Saving Appliance Comparison

Appliance	Standard	Water saving style	% Water Savings
Dishwasher	16 gallons/load	7.5 gallons/load	53%
Faucet	5 gallons/ minute	2.5 gallons/minute	50%
Toilet	5 – 7 gallons/flush	1 – 1.6 gallons/flush	68% – 85%
Shower head	12 gallons/minute	2.5 gallons/minute	80%
Washing machine	27 – 54 gallons	16 – 20 gallons	25% – 70%

[36]

Utilizing water saving devices not only saves money, but also further supports water conservation endeavours and saves water for future generations. The following irrigation section will address outdoor conservation tools and approaches.

Irrigation

As much as 60% of urban and suburban water consumption is used as landscape irrigation [37]. Fifty percent of that water can be lost to evaporation and runoff [38]. Therefore, when coupling rainwater harvesting systems with irrigation, home/business owners should take extra steps to ensure the harvested rainwater is applied as efficiently as possible across the landscape. Applying more water than needed can cause runoff and nonpoint source pollution, thus canceling out the conservation and reduction in nonpoint source pollution benefits of rainwater harvesting.

Scheduling

Ideally, irrigation should be scheduled on evapotranspiration (soil evaporation and plant transpiration) data, which is based on recent climatic conditions. Other US states have websites that show real-time data concerning evapotranspiration data that help guide irrigation timing. This allows irrigators to apply only the amount of water lost from soil evaporation and plant transpiration back to the land.

Some US states like Texas and Colorado provide real-time evapotranspiration data on a website. Irrigators only need to access the website, select the crop, and last time irrigated. The website then computes how many inches of water need to applied to replace the amount of water lost. Virginia does not currently have an interactive website like this, but Virginia Tech is working to utilize current weatherstation data to supply evapotranspiration numbers online.

Historical evapotranspiration data for select Virginia cities is available at the website: http://climate.virginia.edu/va_pet_prec_diff.htm. This website details potential evapotranspiration, which is calculated through historical climate data. This website can be used when determining how much water is needed for irrigation purposes.

Equation to determine water needed for irrigation in inches:

(Monthly ET rate – Average monthly rainfall) x **acres** x **27,154 gallons/acre**

Example: *Charlottesville, Virginia.*
5.55 inches/month average summer ET
4.31 inches/month average summer rainfall
2,000 sq.ft. turfgrass area

(5.55– 4.31 inches/acre) x 0.05 acres x 27,154 gallons/acre = **1,684 gallons/month**

This equation is only an estimation of plant water needs. A rainwater harvesting or irrigation consultant company can determine more accurately the irrigation needs, based on plant type and water needs.

Water Conservation Tips

All landscape irrigators should follow irrigation best management practices, whether for residential application or large-scale park application. The Virginia Rainwater Harvesting Manual stresses the importance of following these best management practices to ensure that the rainwater harvested is utilized efficiently and effectively when irrigating.

The Irrigation Association has a detailed Best Management Practice publication available online at www.irrigation.org/gov/pdf/IA_BMP_APRIL_2005.pdf [39]. The following will summarize these findings in coordination with utilizing harvesting rainwater for irrigation purposes.

Installation & Maintenance

- Hire a certified irrigation designer and contractor to design and install your irrigation system. Double your efforts by hiring a WaterSense partner (http://www.epa.gov/watersense/pp/irrprof.htm).
- Design system (type and output) to meet landscape (plant & soil) needs.
- Group plants will similar irrigation needs in the same irrigation zones.
- Large scale irrigation projects should be audited by a certified irrigation auditor to ensure system is applying water uniformly and efficiently.
- Ensure system is routinely maintained to ensure uniform and efficient water application.

Application

- Use drip/micro-irrigation or subsurface irrigation when applicable to reduce water loss through evaporation.
- Base irrigation timing on evapotranspiration rate and climatic conditions, plant needs, slope, soil infiltration, soil moisture, and rainfall.
- Select system components that reduce runoff and maintain sprinkler irrigation below infiltration rate to ensure excess water is not applied. Use soak cycles to ensure appropriate water is applied, while eliminating unnecessary runoff.
- Install water conserving irrigation heads.
- Utilize alternative nonpotable water source when available.
- Allow soil moisture to deplete /allow plants to wilt slightly before watering.
- Irrigate in the early morning when evaporation is low.

Native Plants

Including native plants in landscape design reduces irrigation demands, compared to non-native plantings. Native plants are adapted to the local climate and rainfall events. Therefore, supplemental irrigation is minimal. Non-native and invasive plantings may not be adapted to the local climate and often require extra water, fertilizer and pesticides to maintain health. Many commonly known horticultural plants are also Virginia native plants. Table 8 lists commonly known Virginia native plants. For complete listings, visit DCR's website at www.dcr.virginia.gov/natural_hertiage/nativeplants.shtml. To find local nurseries that sell Virginia native plants, visit the Virginia Native Plant society website at www.vnps.org.

Table 8: Virginia Native Plants

Herbaceous Plants	Trees & Shrubs
Aster	Redbud
Dephinium	Dogwood
Bleeding heart	Sugar maple
Iris	Sweetgum
Phlox	White oak
Black eyed Susan	Water oak
Coneflower	Virginia pine
Lobelia	Witch hazel
Goldenrod	Holly
	Azalea

[40-42]

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Virginia Application & Case Studies

Many individuals and companies within Virginia have adopted rainwater harvesting practices for a variety of reasons. The following will cover examples of actual rainwater harvesting systems located throughout Virginia, why rainwater harvesting was chosen, and the benefits of utilizing rainwater harvesting on the site.

Commercial

Hospital
New River Valley

At this site, a detention pond was converted to a retention pond.

Harvested rainwater was diverted to the pond. The pond water was then used to supply water to cooling towers and for irrigation.

Site benefits:

- Cost savings.
- Reduce water demands.
- Reduce environmental impact.

Nelson County Visitor's Center
Nelson County

Both above and belowground systems were installed on this site.

The aboveground system served as a demonstration tank for water conservation. With the demonstration tank, visitors could learn about rainwater harvesting, water conservation and environmental stewardship.

The belowground 3,400 gallon system was used for irrigating the grounds.

Site benefits:

- Education.
- Promote environmental stewardship.
- Reduce potable water demands for nonpotable needs.

Claude Moore Education Complex
Roanoke

This complex is equipped with siphonic roof drainage, which directs rainwater that falls on the 12,000 sq. ft. roof to two nonpotable 2,500 gallon storage tanks.

The collected rainwater supplies water for flushing toilets in the building.

Site benefits:
- Reduce potable water demands for nonpotable needs.
- Reduce stormwater runoff in impervious city settings.

Residential

Hillsville

The residential customer's well could not furnish water on a continual basis. The 5,000 gallon belowground rainwater storage system supplies the home with potable water.

In the advent that the rainwater runs out, the well serves as a backup by partially filling the tanks with well water. Upon rainfall, there is still room for rainwater to fill up the tanks and eliminate the need for well water.

Site benefits:
- Reduce demand on well water.
- Conserve groundwater resources.

Roanoke County

The home's original well went dry in 2001. A second well was drilled to a depth of 900 feet, but only produced a half-gallon per minute. This was inadequate to provide an ample water supply for peak demand.

Six 400 gallon storage tanks were placed in the crawl space, providing the customer with a 2,400 gallon capacity of stored rain water. The harvested rain water was filtered and sterilized for potable use. The project was coordinated with local officials, who issued a potable water permit for the rain water harvesting system.

Site benefits:

- An additional well was not required.
- Reduce environmental impact.

Charlottesville

This system consists of 3,400 gallons of belowground storage (as seen in the as heads on the hillside).

The system is nonpotable and supplied subsurface irrigation. Subsurface irrigation was chosen over aboveground irrigation for the turf area. Subsurface irrigation directs water to the roots and limits water loss to evaporation.

Site benefits:

- Increase water application uniformity.
- Conserve irrigation water.
- Reduce potable water demands for nonpotable needs.

Crozet

Belowground system includes 3,400 gallon tank. The residents at this site will use the collected rainwater for irrigation purposes.

Site benefits:
- Reduce potable water demands for nonpotable needs.
- Cost savings.

Salem

This residential system was installed with 20,000 gallon aboveground storage capacity.

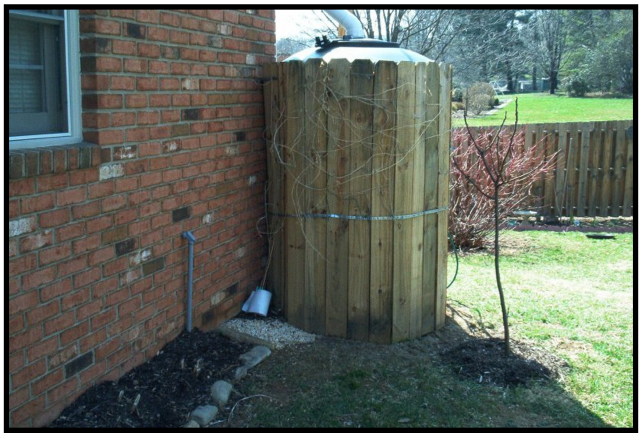
Collected rainwater is filtered and treated for future potable use. Currently, the system is used for pool filling and irrigation.

Upon installation and use, the customer's water bill was reduced by 70%.

Site benefits:

- Reduce demand for municipal water supplies.
- Cost savings.

Roanoke



This nonpotable residential system was installed during a drought period.

The 500 gallon tank was used for topping off a small pond and irrigating a small garden area.

The resident was then exempt from irrigation restrictions since irrigated water was not from municipal supplies.

Site benefits:

- Keep plants alive during drought, which is important for maintaining cooler temperatures around the house thus, increasing a home's energy efficiency.
- Reduce potable water demands for nonpotable needs.

Non-Profit Organization
White Hall

This site includes a 1,500 gallon aboveground system. Collected water is filtered and treated for potable water use. Downspout filters filter water prior to entering the storage tanks.

Collected and treated water is used in the greenhouse and adjoining staff spaces.

Site benefits:

- Reduce demand for municipal water supply.
- Cost savings.

Afton Mountain

This is the first pilot home under the USGB (US Green Building) residential building program.

Two 1,700 belowground tanks supply the home with 3,400 gallons of potable water storage capacity.

The home also has a well backup. When rainwater storage runs low, the system triggers for the well water to partially fill the tanks. Once rainfall starts again, the tanks fill with rainwater and the switch turns off the well water filling.

Site benefits:

- Reduce demand on well water.
- Conserve groundwater resources.
- Promote green buildings and environmental stewardship.

Franklin County

This lake home is equipped with underground storage tanks, totalling 3,400 gallon nonpotable storage capacity.

Collected rainwater is used onsite for landscape irrigation purposes.

Harvesting rainwater on this site is essential to protect the lake's integrity and reduce nonpoint source pollution resulting from rooftop stormwater runoff.

Site benefits:

- Reduce potable water demands for nonpotable needs.
- Reduce stormwater runoff and nonpoint source pollution.
- Promote environmental stewardship.

Agricultural

Culpeper

At this site, the area around the barn was extremely wet from run off and cattle waste. As a result, some of the cattle were developing hoof rot. Also, there existed no water outlets near the building for watering.

A 5,000-gallon storage system was installed to collect the barn runoff. Collected rainwater is diverted to a pasture watering cooler for farm animals.

Site benefits:

- Reduce rooftop runoff and eliminate potential nonpoint source pollution.
- Provide farm animals with safe drinking.

Charlottesville

A total of 5,100 gallons underground storage system was installed to supply potable water needs.

Harvested rainwater is filtered and treated prior to use by farmhands in the living quarters. Water is also directed for use in the stables, pasture watering coolers, and for bathing horses. The owners noted the horses' soft coat after bathing in rainwater.

A well serves as a backup water supply. When rainwater levels run out, water well is triggered to partially fill the storage tanks. Upon rainfall, rainwater further fills up the tanks.

Site benefits:

- Reduce demand on groundwater sources.
- Protect groundwater resources.
- Supply farm animals with safe drinking water.

Links

Water/Environment

Virginia Environmental Endowment	www.vee.org
Water Use it Wisely	www.wateruseitwisely.com/index.shtml
EPA Water Sense	www.epa.gov/watersense/pubs/outdoor.htm
Harvest H20	www.harvesth20.com
Department of Conservation and Recreation	www.dcr.virginia.gov
Virginia Native Plant Society	www.vnps.org
The Nature Conservancy	www.nature.org

Engineering/Products

Rainwater Management Solutions	www.rainwatermanagement.com
Jay R. Smith	www.jayrsmith.com
Wisy	www.wisy.de