VIRGINIA DEQ STORMWATER DESIGN SPECIFICATION No. 6

RAINWATER HARVESTING

VERSION 1.9.5
March 1, 2011

SECTION 1: DESCRIPTION

Rainwater harvesting systems intercept, divert, store and release rainfall for future use. The term rainwater harvesting is used in this specification, but it is also known as a cistern or rainwater harvesting system. Rainwater that falls on a rooftop is collected and conveyed into an above- or below-ground storage tank where it can be used for non-potable water uses and on-site stormwater disposal/infiltration. Non-potable uses may include flushing of toilets and urinals inside buildings, landscape irrigation, exterior washing (e.g. car washes, building facades, sidewalks, street sweepers, fire trucks, etc.), fire suppression (sprinkler) systems, supply for chilled water cooling towers, replenishing and operation of water features and water fountains, and laundry, if approved by the local authority. Replenishing of pools may be acceptable if special measures are taken, as approved by the appropriate regulatory authority.

In many instances, rainwater harvesting can be combined with a secondary (down-gradient) runoff reduction practice to enhance runoff volume reduction rates and/or provide treatment of overflow from the rainwater harvesting system. Some candidate secondary practices include:

- Rooftop Disconnection: Design Specification No. 1 (excluding rain tanks and cisterns). This may include release to a compost-amended filter path
- Sheet Flow to a Vegetated Filter Strip or Conserved Open Space: Design Specification No. 2
- Grass Channel: Design Specification No. 3
- Infiltration and Micro-Infiltration: Design Specification No. 8
- Micro-Bioretention (rain garden): Design Specification No. 9
- Storage and release in a foundation planter (Urban Bioretention – Stormwater Design Specification No. 9, Appendix 9-A)
- Dry Swale**:** Design Specification No. 10
- Underground infiltration soak-away pit (see explanation on **page 14**).

Section 5.3 (Physical Feasibility & Design Applications) provides more detail on system configurations, including the use of secondary practices.

In addition, the actual runoff reduction rates for rainwater harvesting systems are "user defined," based on tank size, configuration, demand drawdown, and use of secondary practices. A Cistern Design Spreadsheet (CDS) is provided as a companion to this specification, and is discussed in more detail in **Section 6** (Design Criteria).

SECTION 2: PERFORMANCE

The overall stormwater functions of the rainwater harvesting systems are described in **Table 6.1**.

Table 6.1: Summary of Stormwater Functions Provided by Rainwater Harvesting

Stormwater Function	Performance
Annual Runoff Volume Reduction (RR)	Variable up to 90% [2]
Total Phosphorus (TN) EMC Reduction[1] by BMP Treatment Process	0%
Total Phosphorus (TN) Mass Load Removal	Variable up to 90% [2]
Total Nitrogen (TN) EMC Reduction[1] by BMP Treatment Process	0%
Total Nitrogen (TN) Mass Load Removal	Variable up to 90% [2]
Channel Protection	Partial: reduced curve numbers and increased Time of Concentration
Flood Mitigation	Partial: reduced curve numbers and increased Time of Concentration
[1] Nutrient mass removal is equal to the runoff reduction rate. Zero additional removal rate is applied to the rainwater harvesting system only. Nutrient removal rates for secondary practices will be in accordance with the design criteria for those practice. [2] Credit is variable and determined using the Cistern Design Spreadsheet. Credit up to 90% is possible if all water from storms with rainfall of 1 inch or less is used through demand, and the tank is sized such that no overflow from this size event occurs. The total credit may not exceed 90%.	

SECTION 3: DESIGN TABLE

Rainwater harvesting system design does not have a Level 1 and Level 2 design table. Runoff reduction credits are based on the total amount of annual internal water reuse, outdoor water reuse, and tank dewatering discharge calculated to be achieved by the tank system using the Cistern Design Spreadsheet.

SECTION 4: TYPICAL DETAILS

Figures 6.1 through 6.6 of **Section 5.3** provide typical schematics of cistern and piping system configurations, based on the design objectives (year-round internal use, external seasonal irrigation, etc.).

Figures 6.7 through 6.9 of **Section 5.4** provide typical schematics of Cistern tank configurations, based on the desired Treatment Volume and stormwater management objectives (Treatment Volume only, channel protection, etc.).

SECTION 5: PHYSICAL FEASIBILITY & DESIGN APPLICATIONS

A number of site-specific features influence how rainwater harvesting systems are designed and/or utilized. These should not be considered comprehensive and conclusive considerations, but rather some recommendations that should be considered during the process of planning to incorporate rainwater harvesting systems into the site design. The following are key considerations.

5.1 Site Conditions

Available Space. Adequate space is needed to house the tank and any overflow. Space limitations are rarely a concern with rainwater harvesting systems if they are considered during the initial building design and site layout of a residential or commercial development. Storage tanks can be placed underground, indoors, on rooftops or within buildings that are structurally designed to support the added weight, and adjacent to buildings. Designers can work with Architects and Landscape Architects to creatively site the tanks. Underground utilities or other obstructions should always be identified prior to final determination of the tank location.

Site Topography. Site topography and tank location should be considered as they relate to all of the inlet and outlet invert elevations in the rainwater harvesting system. The total elevation drop will be realized beginning from the downspout leaders to the final mechanism receiving gravity-fed discharge and/or overflow from the cistern.

These elevation drops will occur along the sloping lengths of the underground roof drains from roof drain leader downspouts at the building all the way to the cistern. A vertical drop occurs within the filter before the cistern. The cistern itself must be located sufficiently below grade and below the frost line, resulting in an additional elevation drop. When the cistern is used for additional volume detention for channel and/or flood protection, an orifice may be included with a low invert specified by the designer. An overflow will always be present within the system, with an associated invert. Both the orifice (if specified) and the overflow will drain the tank during large storms, routing this water through an outlet pipe, the length and slope of which will vary from one site to another.

All these components of the rainwater harvesting system have an elevation drop associated with them. The final invert of the outlet pipe must match the invert of the receiving mechanism (natural channel, storm drain system, etc.) that receives this overflow. These elevation drops and associated inverts should be considered early in the design, in order to ensure that the rainwater harvesting system is feasible for the particular site.

Site topography and tank location will also affect the amount of pumping needed. Locating storage tanks in low areas will make it easier to route roof drains from buildings to cisterns. However, it will increase the amount of pumping needed to distribute the harvested rainwater back into the building or to irrigated areas situated on higher ground. Conversely, placing storage tanks at higher elevations may require larger diameter roof drains with smaller slopes. However, this will also reduce the amount of pumping needed for distribution. In general, it is often best to locate the cistern close to the building, ensuring that minimum roof drain slopes and enclosure of roof drain pipes are sufficient.

Available Hydraulic Head. The required hydraulic head depends on the intended use of the water. For residential landscaping uses, the cistern should be sited up-gradient of the landscaping areas or on a raised stand. Pumps are commonly used to convey stored rainwater to the end use in order to provide the required head. When the water is being routed from the cistern to the inside of a building for non-potable use, often a pump is used to feed a much smaller pressure tank inside the building which then serves the internal demands through gravity-fed head. Cisterns can also use gravity- to accomplish indoor residential uses (e.g., laundry) that do not require high water pressure. In cases where cisterns are located on building roofs in order to operate under gravity-fed conditions, the structure must be designed to provide for the added weight of the rainwater harvesting system and stored water.

Water Table. Underground storage tanks are most appropriate in areas where the tank can be buried *above* the water table. The tank should be located in a manner that will not subject it to flooding. In areas where the tank is to be buried partially below the water table, special design features must be employed, such as sufficiently securing the tank (to keep it from “floating”), conducting buoyancy calculations when the tank is empty, etc. The tank may need to be secured appropriately with fasteners or weighted to avoid uplift buoyancy. The tank must also be installed according to the tank manufacturer’s specifications.

Soils. Storage tanks should only be placed on native soils or on fill in accordance with the manufacturer's guidelines. The bearing capacity of the soil upon which the cistern will be placed should be considered, as full cisterns can be very heavy. This is particularly important for above-ground cisterns, as significant settling could cause the cistern to lean or in some cases to potentially topple. A sufficient aggregate, or concrete base, may be appropriate depending on the soils. The pH of the soil should also be considered in relation to its interaction with the cistern material.

Proximity of Underground Utilities. All underground utilities must be taken into consideration during the design of underground rainwater harvesting systems, treating all of the rainwater harvesting system components and storm drains as typical stormwater facilities and pipes. The underground utilities must be marked and avoided during the installation of underground tanks and piping associated with the system. Appropriate minimum setbacks from septic drainfields should be observed, as specified by Virginia law and regulations.

Contributing Drainage Area. The contributing drainage area (CDA) to the cistern is the impervious area draining to the tank. In general, only rooftop surfaces should be included in the CDA. Parking lots and other paved areas can be used in rare circumstances with appropriate treatment (oil/water separators) and approval of the locality. Areas of any size, including portions of roofs, can be used based on the sizing guidelines in this design specification. Runoff should be routed directly from rooftops to rainwater harvesting systems in closed roof drain systems or storm drain pipes, avoiding surface drainage, which could allow for increased contamination of the water.

Rooftop Material. The quality of the harvested rainwater will vary according to the roof material over which it flows. Water harvested from certain types of rooftops, such as asphalt sealcoats, tar and gravel, painted roofs, galvanized metal roofs, sheet metal or any material that may contain asbestos may leach trace metals and other toxic compounds. In general, harvesting rainwater from such roofs should be avoided, unless new information determines that these materials are sufficient for the intended use and are allowed by Virginia laws and regulations. If a sealant or paint roof surface is desired, it is recommended to use one that has been certified for such purposes by the National Sanitation Foundation (ANSI/NSF standard). The 2009 Virginia Rainwater Harvesting Manual and other references listed at the end of this specification describe the advantages and disadvantages of different roofing materials.

Water Quality of Rainwater. Designers should also note that the ***pH*** of rainfall in Virginia tends to be acidic (ranging from 4.5 to 5.0), which may result in leaching of metals from the roof surface, tank lining or water laterals to interior connections. Once rainfall leaves rooftop surfaces, pH levels tend to be slightly higher, ranging between 5.5 to 6.0. Limestone or other materials may be added in the tank to buffer acidity, if desired.

Hotspot Land Uses. Harvesting rainwater can be an effective method to prevent contamination of rooftop runoff that would result from mixing it with ground-level runoff from a stormwater hotspot operation. In some cases, however, industrial roof surfaces may also be designated as stormwater hotspots.

Setbacks from Buildings. Cistern overflow devices should be designed to avoid causing ponding or soil saturation within 10 feet of building foundations. Storage tanks should be designed to be watertight to prevent water damage when placed near building foundations. In general, it is recommended that underground tanks be set at least 10 feet from any building foundation.

Vehicle Loading. Whenever possible, underground rainwater harvesting systems should be placed in areas without vehicle traffic or be designed to support live loads from heavy trucks, a requirement that may significantly increase construction costs.

5.2 Stormwater Uses

The capture and reuse of rainwater can significantly reduce stormwater runoff volumes and pollutant loads. By providing a reliable and renewable source of water to end users, rainwater harvesting systems can also have environmental and economic benefits beyond stormwater management (e.g., increased water conservation, water supply during drought and mandatory municipal water supply restrictions, decreased demand on municipal or groundwater supply, decreased water costs for the end-user, potential for increased groundwater recharge, etc). To enhance their runoff reduction and nutrient removal capability, rainwater harvesting systems can be combined with other rooftop disconnection practices, such as micro-infiltration practices (Stormwater Design Specification No. 8) and rain gardens or foundation planters (Stormwater Design Specification No. 9). In this specification, these allied practices are referred to as "secondary runoff reduction practices."

While the most common uses of captured rainwater are for non-potable purposes, such as those noted above, in some limited cases rainwater can be treated to potable standards. This assumes that (1) the treatment methods and end use quality meet drinking water standards and regulations, and (2) the harvesting system is approved by the Health Department and the local governing authority. Treating harvested water to potable standards may drive up installation and maintenance costs significantly.

5.3 Design Objectives and System Configurations

Many rainwater harvesting system variations can be designed to meet user demand and stormwater objectives. This specification focuses on providing a design framework for addressing the water quality treatment volume (T_v) credit objectives and achieving compliance with the regulations. From a rainwater harvesting standpoint, there are numerous potential configurations that could be implemented. However, in terms of the goal of addressing the design treatment volume, this specification adheres to the following concepts in order to properly meet the stormwater volume reduction goals:

- Credit is only available for dedicated year-round drawdown/demand for the water. While seasonal practices (such as irrigation) may be incorporated into the site design, they are not considered to contribute to the treatment volume credit (for stormwater purposes) unless a drawdown at an equal or greater rate is also realized during non-seasonal periods (e.g. treatment in a secondary runoff reduction practice during non-irrigation months).
- System design is encouraged to use rainwater as a resource to meet on-site demand or in conjunction with other runoff reduction practices (especially those that promote groundwater recharge).
- Pollutant load reduction is realized through reduction of the volume of runoff leaving the site.
- Peak flow reduction is realized through reduced volume and temporary storage of runoff.

Therefore, the rainwater harvesting system design configurations presented in this specification are targeted for continuous (year-round) use of rainwater through (1) internal use, and (2) irrigation and/or treatment in a secondary practice. Three basic system configurations are described below.

Configuration 1: Year-round indoor use with optional seasonal outdoor use (Figure 6.1). The first configuration is for year round indoor use along with optional seasonal outdoor use, such as irrigation. Because there is no on-site secondary runoff reduction practice incorporated into the design for non-seasonal (or non-irrigation) months, the system must be designed and treatment credit awarded for the interior use only. (However, it should be noted that the seasonal irrigation will provide an economic benefit in terms of water usage). Stormwater credit can be enhanced by adding a secondary runoff reduction practice (see Configuration 3 below).

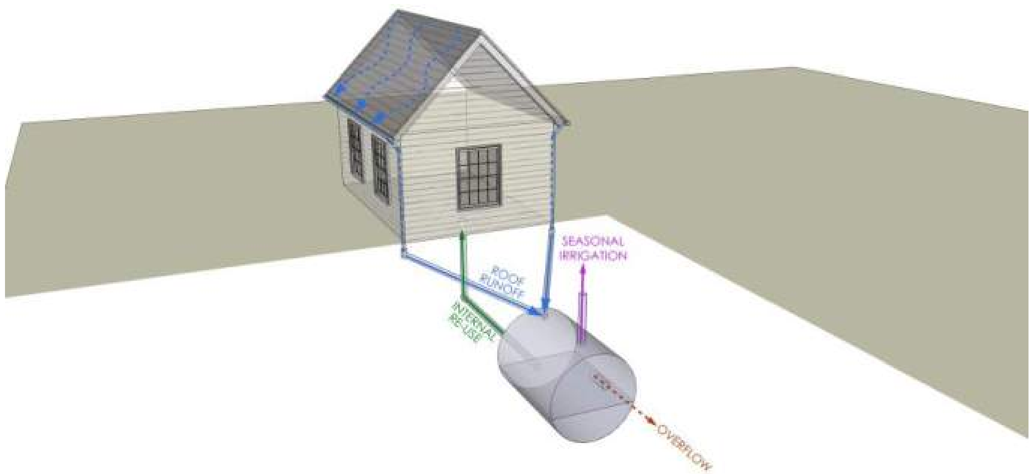

Figure 6.1. Configuration 1: Year-round indoor use with optional seasonal outdoor use

Configuration 2: Seasonal outdoor use and approved year-round secondary runoff reduction practice (Figure 6.2). The second configuration uses stored rainwater to meet a seasonal or intermittent water use, such as irrigation. However, because these uses are only intermittent or seasonal, this configuration also relies on an approved secondary practice for stormwater credit. Compared to a stand-alone BMP (without the upgradient tank), the size and/or storage volume of the secondary practice can be reduced based on the storage in the tank. The tank's drawdown and release rate should be designed based on the infiltration properties, surface area, and capacity of the receiving secondary runoff reduction practice. The release rate therefore is typically much less than the flow rate that would result from routing a detention facility. The secondary practice should serve as a "backup" facility, especially during non-irrigation months. In this regard, the tank should provide some meaningful level of storage and reuse, accompanied by a small flow to the secondary practice. This is especially important if the size and/or storage volume of the secondary practice is reduced compared to using that practice in a "stand-alone" design (i.e., without an upgradient cistern). See Section 5.4 -- Tank Design 3 -- for more information.

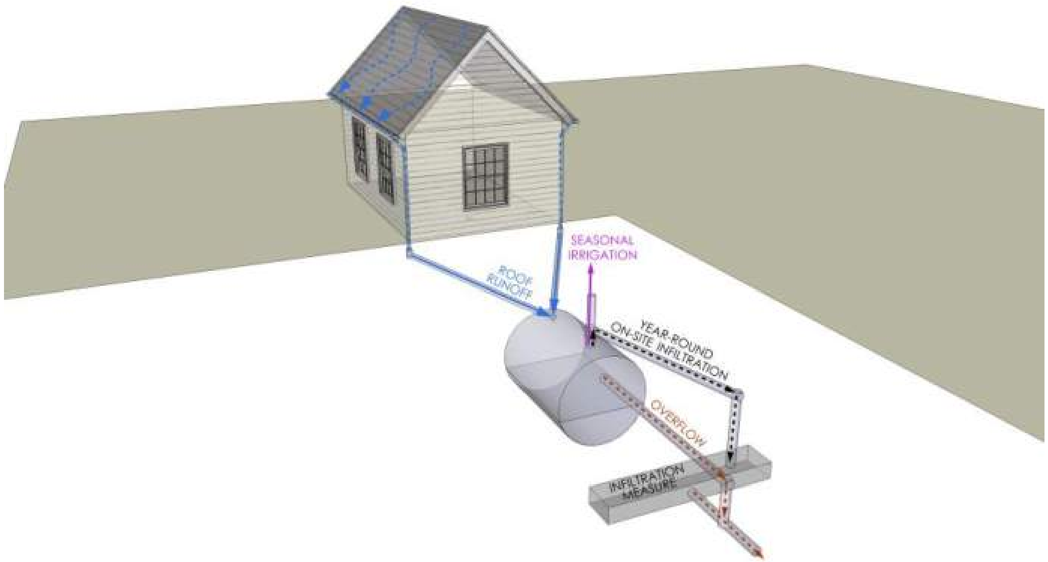

Figure 6.2. Configuration 2: Seasonal outdoor use and approved year-round secondary practice

Configuration 3: Year-round indoor use, seasonal outdoor irrigation, and non-seasonal treatment in a secondary runoff reduction practice (Figure 6.3). The third configuration provides for a year-round internal non-potable water demand, and a seasonal outdoor, automated irrigation system demand. In addition, this configuration incorporates a secondary practice during non-irrigation (or non-seasonal) months in order to yield a greater stormwater credit. In this case, the drawdown due to seasonal irrigation must be compared to the drawdown due to water released to the secondary practice. The minimum of these two values is used for system modeling and stormwater credit purposes.

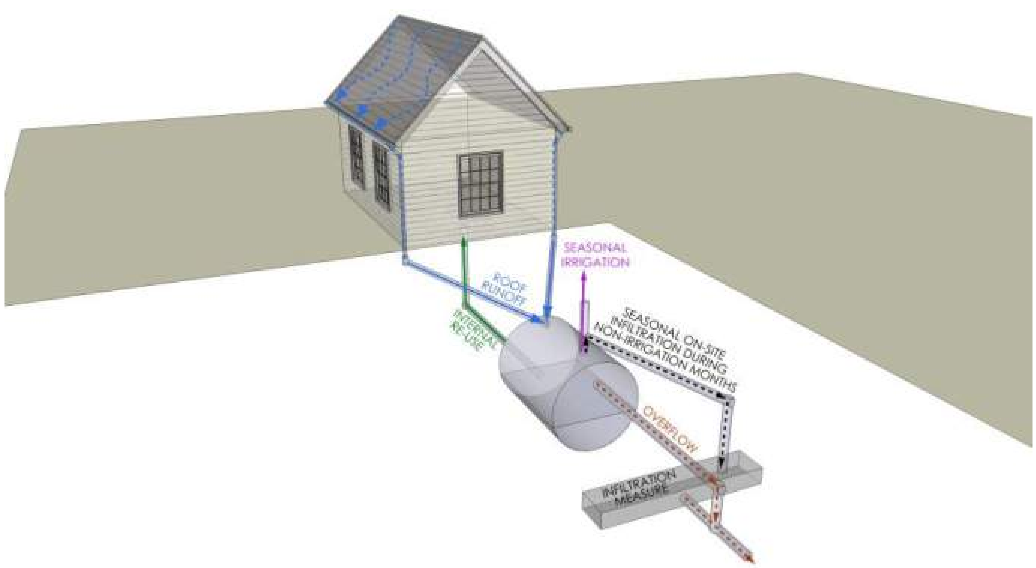

Figure 6.3. Configuration 3: Year-round indoor use, seasonal outdoor irrigation, and non-seasonal on-site treatment in secondary practice

5.4 Design Objectives and Tank Design Set-Ups

Pre-fabricated rainwater harvesting cisterns typically range in size from 250 to over 30,000 gallons. There are three basic tank design configurations used to meet the various rainwater harvesting system configurations that are described in **Section 5.3**.

Tank Design 1. The first tank set-up (**Figure 6.4**) maximizes the available storage volume associated with the Treatment Volume (T_v) to meet the desired level of Treatment Credit. This layout also maximizes the storage that can be used to meet a demand. An emergency overflow exists near the top of the tank as the only gravity release outlet device (not including the pump, manway or inlets). It should be noted that it is possible to address channel and flood protection volumes with this tank configuration, but the primary purpose is to address the water quality T_v.

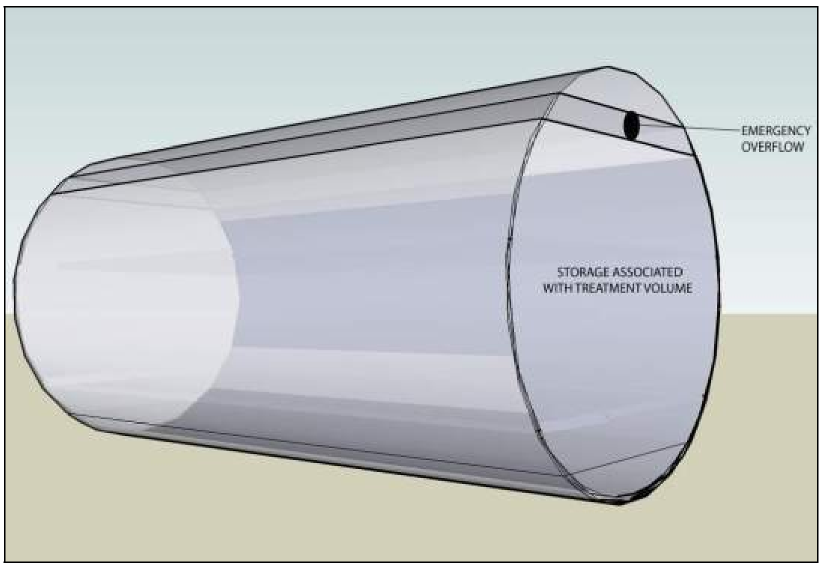

Figure 6.4. Tank Design 1: Storage Associated with Treatment Volume (Tv) only

Tank Design 2. The second tank set-up (**Figure 6.5**) uses tank storage to meet the Treatment Volume (T_v) objectives as well as using an additional detention volume above the treatment volume space to also meet some or all of the channel and/or flood protection volume requirements. An orifice outlet is provided at the top of the design storage for the T_v storage level, and an emergency overflow is located at the top of the detention volume level. This specification only addresses the storage for the T_v. However, in combination with other approved hydrologic routing programs, the Runoff Reduction spreadsheet may be used to model and size the Channel Protection and Flood Protection (detention) volumes.

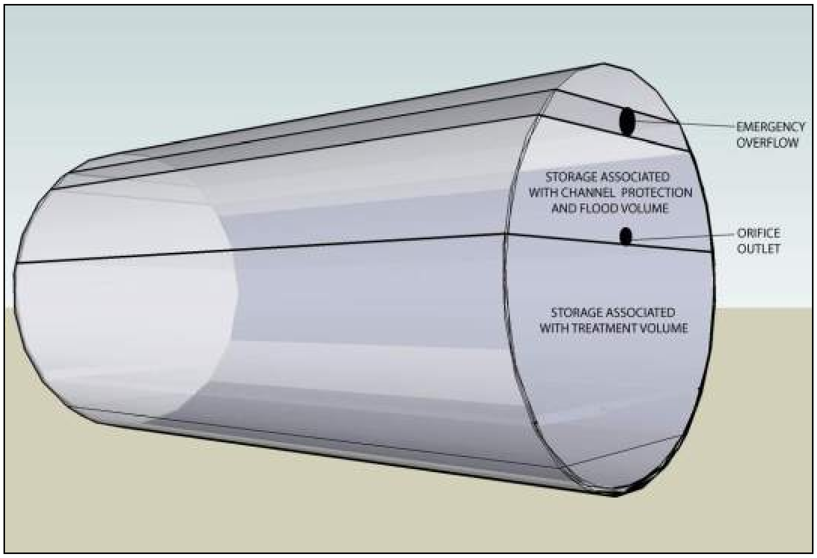

Figure 6.5. Tank Design 2: Storage Associated with Treatment, Channel Protection and Flood Volume

Tank Design 3. The third tank set-up (**Figure 6.6**) creates a constant drawdown within the system. The small orifice at the bottom of the tank needs to be routed to an appropriately designed secondary practice (e.g., rain garden, micro-scale infiltration, urban bioretention, etc.) that will allow the rainwater to be treated and allow for groundwater recharge over time. The release should not be discharged to a receiving channel or storm drain without treatment, and maximum specified drawdown rates from this constant drawdown should be adhered to, since the primary function of the system is not intended to be detention.

For the purposes of this tank design, the secondary practice must be considered a component of the rainwater harvesting system with regard to the runoff reduction percentage calculated in the Runoff Reduction Spreadsheet. In other words, the runoff reduction associated with the secondary practice must not be added (or double-counted) to the rainwater harvesting percentage. The reason for this is that the secondary practice is an integral part of a rainwater harvesting system with a constant drawdown. The exception to this would be if the secondary practice were also sized to capture and treat impervious and/or turf area beyond the area treated by rainwater harvesting (for instance, the adjacent yard or a driveway). In this case, only these additional areas should be added into the Runoff Reduction Spreadsheet to receive credit for the secondary practice.

While a small orifice is shown at the bottom of the tank in **Figure 6.6**, the orifice could be replaced with a pump that would serve the same purpose, conveying a limited amount of water to a secondary practice on a routine basis.

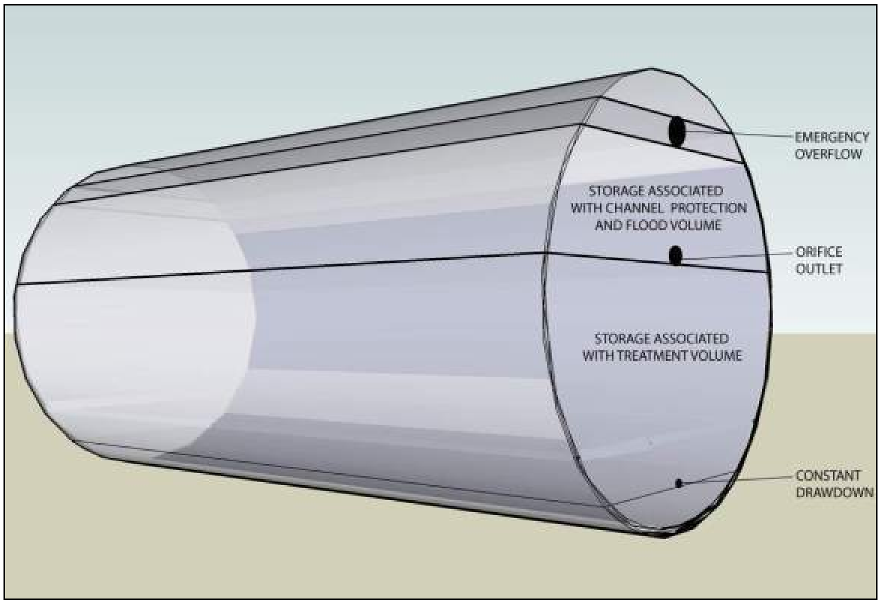

Figure 6.6. Tank Design 3: Constant drawdown, Storage Associated with Treatment, Channel Protection and Flood Volume

5.5. On-Site Treatment in a Secondary Practice

Recent rainwater harvesting system design materials do not include guidance for on-site stormwater infiltration or "disposal". The basic approach is to provide a dedicated secondary runoff reduction practice on-site that will ensure water within the tank will gradually drawdown at a specified design rate between storm events. Secondary runoff reduction practices may include the following:

- Rooftop Disconnection (Stormwater Design Specification No. 1), excluding rain tanks and cisterns. This may include release to a compost-amended filter path
- Vegetated filter strip (Stormwater Design Specification No. 2)
- Grass channel (Stormwater Design Specification No. 3)
- Infiltration and micro-infiltration (Stormwater Design Specification No. 8)
- Micro-bioretention (rain garden) (Stormwater Design Specification No. 9)
- Storage and release in foundation planter (Stormwater Design Spec No. 9, Appendix 9-A)
- Dry swale (Stormwater Design Specification No. 10)
- Underground infiltration soak-away pit (see the explanation below).

The secondary practice approach is useful to help achieve the desired treatment credit when demand is not enough to sufficiently draw water levels in the tank down between storm events. Of course, if demand for the harvested rainwater is relatively high, then a secondary practice may not be needed or desired.

While design specifications are available for most of the secondary practices proposed, an "*underground infiltration soak-away pit*" (or Infiltration facility, Stormwater Design Specification 8) may prove useful in some situations and may be used in conditions where the soil has moderate to high infiltration rates. The soak-away pit must be properly designed to adequately infiltrate the controlled design release rate. The design is subject to approval by the reviewing authority.

Use of a secondary practice may be particularly useful to employ in sites that use captured rainwater for irrigation during part of the year, but have no other use for the water during non-irrigation months. During non-irrigation months, credit cannot be realized unless on-site infiltration/treatment or another drawdown mechanism creates a year-round drawdown, since no stormwater benefit would be realized during non-seasonal periods.

The design of the secondary practice should account for soil types, ground surface areas, release rates, methods of conveyance (gravity fed or pumped), time periods of operation, and invert elevations to determine the disposal rate and sizing of the practice (both storage volume and surface area).

5.6 System Components

There are six primary components of a rainwater harvesting system (**Figure 6.7**):

- Roof surface
- Collection and conveyance system (e.g. gutter and downspouts)
- Pre-screening and first flush diverter
- Storage tank
- Distribution system
- Overflow, filter path or secondary runoff reduction practice

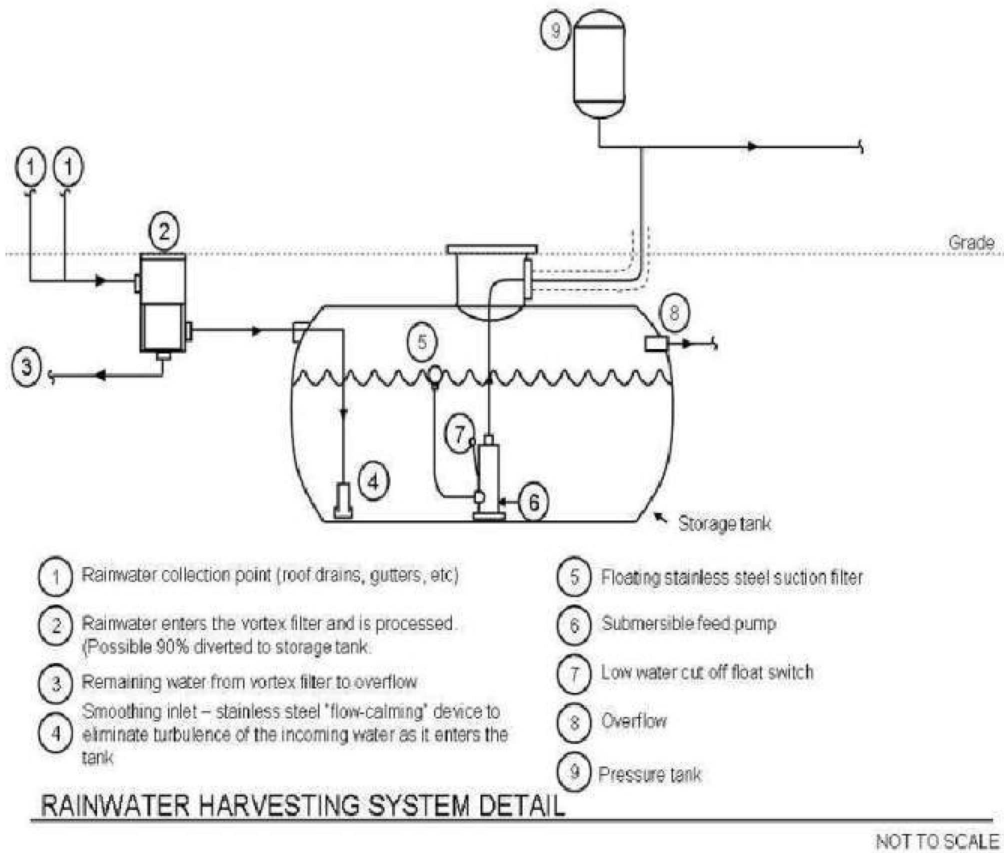

Figure 6.7. Sample Rainwater harvesting system System Detail

Each of these system components is discussed below.

Rooftop Surface. The rooftop should be made of smooth, non-porous material with efficient drainage either from a sloped roof or an efficient roof drain system. Slow drainage of the roof leads to poor rinsing and a prolonged first flush, which can decrease water quality. If the harvested rainwater will be used for potable uses, or uses with significant human exposure (e.g. pool filling, watering vegetable gardens), care should be taken in the choice of roof materials. Some materials may leach toxic chemicals making the water unsafe for humans. Rainwater can also be harvested from other impervious surfaces, such as parking lots and driveways; however, this practice is much less common and should be discouraged in general as it will require more extensive pretreatment or treatment, and will most likely increase maintenance since the quality of water is typically much lower.

Collection and Conveyance System. The collection and conveyance system consists of the gutters, downspouts and pipes that channel stormwater runoff into storage tanks. Gutters and downspouts should be designed as they would for a building without a rainwater harvesting system. Aluminum, round-bottom gutters and round downspouts are generally recommended for rainwater harvesting. Minimum slopes of gutters should be specified. At a minimum, gutters should be sized with slopes specified to contain the 1-inch storm at a rate of 1-inch/hour for treatment volume credit. If volume credit will also be sought for channel and flood protection, the gutters should be designed to convey the 2 and 10-year storm, using the appropriate 2 and 10 year storm intensities, specifying size and minimum slope. In all cases, gutters should be hung at a minimum of 0.5% for 2/3 of the length and at 1% for the remaining 1/3 of the length.

Pipes (connecting downspouts to the cistern tank) should be at a minimum slope of 1.5% and sized/designed to convey the intended design storm, as specified above. In some cases, a steeper slope and larger sizes may be recommended and/or necessary to convey the required runoff, depending on the design objective and design storm intensity. Gutters and downspouts should be kept clean and free of debris and rust.

Pre-Treatment: Screening, First Flush Diverters and Filter Efficiencies. Pre-filtration is required to keep sediment, leaves, contaminants and other debris from the system. Leaf screens and gutter guards meet the minimal requirement for pre-filtration of small systems, although direct water filtration is preferred. All pre-filtration devices should be low-maintenance or maintenance-free. The purpose of pre-filtration is to significantly cut down on maintenance by preventing organic buildup in the tank, thereby decreasing microbial food sources.

For larger tank systems, the initial first flush must be diverted from the system before rainwater enters the storage tank. Designers should note that the term “first flush” in rainwater harvesting design does not have the same meaning as has been applied historically in the design of stormwater treatment practices. In this specification, the term “first flush diversion” is used to distinguish it from the traditional stormwater management term “first flush”. The amount can range between the first 0.02 to 0.06 inches of rooftop runoff.

The diverted flows (first flush diversion and overflow from the filter) must be directed to an acceptable pervious flow path that will not cause erosion during a 2-year storm or to an appropriate BMP on the property, for infiltration. Preferably the diversion will be conveyed to the same secondary runoff reduction practice that is used to receive tank overflows.

Various first flush diverters are described below. In addition to the initial first flush diversion, filters have an associated efficiency curve that estimates the percentage of rooftop runoff that will be conveyed through the filter to the storage tank. If filters are not sized properly, a large portion of the rooftop runoff may be diverted and not conveyed to the tank at all. A design intensity of 1-inch/hour should be used for the purposes of sizing pre-tank conveyance and filter components. This design intensity captures a significant portion of the total rainfall during a large majority of rainfall events (NOAA 2004). If the system will be used for channel and flood protection, the 2 and 10 year storm intensities should be used for the design of the conveyance and pre-treatment portion of the system. For the 1-inch storm treatment volume, a minimum of 95% filter efficiency is required. This efficiency includes the first flush diversion. The Cistern Design Spreadsheet, discussed more in **Section 6**, assumes a filter efficiency rate of 95% for the 1-inch storm. For the 2 and 10 year storms, a minimum filter efficiency of 90% should be met.

- ***First Flush Diverters.*** First flush diverters direct the initial pulse of stormwater runoff away from the storage tank. While leaf screens effectively remove larger debris such as leaves, twigs and blooms from harvested rainwater, first flush diverters can be used to remove smaller contaminants such as dust, pollen and bird and rodent feces (**Figure 6.8**). Simple first flush diverters require active management, by draining the first flush water volume to a pervious area following each rainstorm. First flush diverters may be the preferred pre-treatment method if the water is to be used for indoor purposes. A vortex filter (see below) may serve as an effective pre-tank filtration device and first flush diverter.

- ***Leaf Screens.*** Leaf screens are mesh screens installed over either the gutter or downspout to separate leaves and other large debris from rooftop runoff. Leaf screens must be regularly cleaned to be effective; if not maintained, they can become clogged and prevent rainwater from flowing into the storage tanks. Built-up debris can also harbor bacterial growth within gutters or downspouts (TWDB, 2005).

- ***Roof Washers.*** Roof washers are placed just ahead of storage tanks and are used to filter small debris from harvested rainwater (**Figure 6.9**). Roof washers consist of a tank, usually between 25 and 50 gallons in size, with leaf strainers and a filter with openings as small as 30-microns (TWDB, 2005). The filter functions to remove very small particulate matter from harvested rainwater. All roof washers must be cleaned on a regular basis.

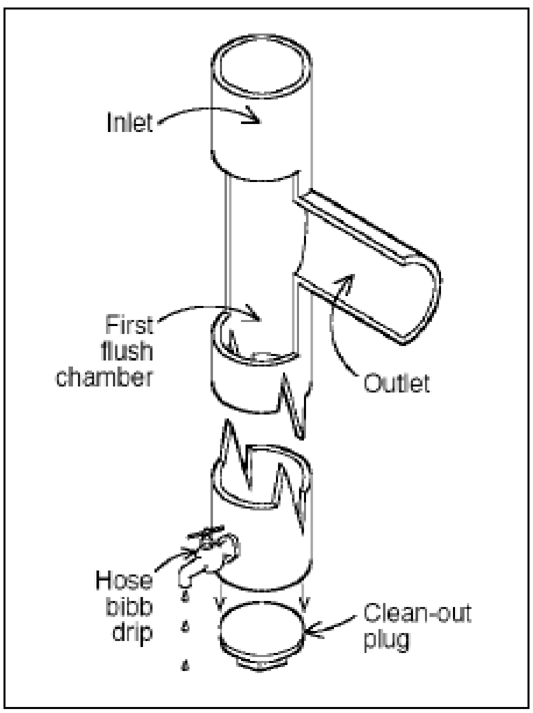

Figure 6.8. First Flush Diverter

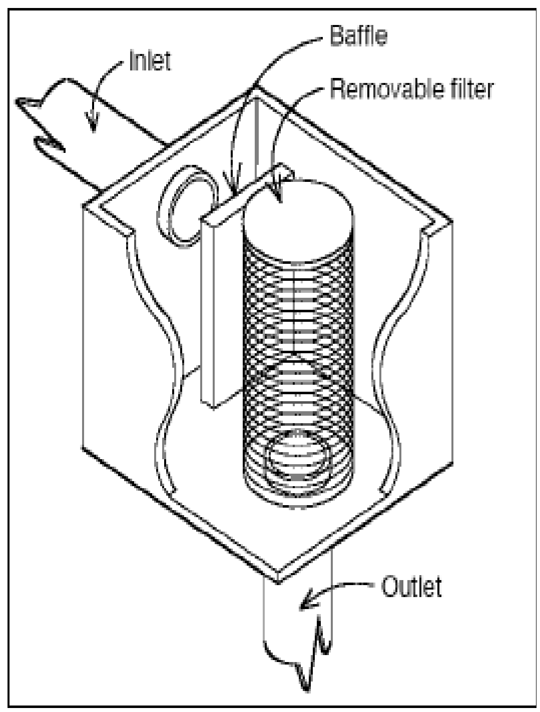

Figure 6.9. Roof Washer

- ***Vortex Filters.*** For large scale applications, vortex filters can provide filtering of rooftop rainwater from larger rooftop areas. Two images of the vortex filter are displayed below. The first image (**Figure 6.10**) provides a plan view photograph showing the interior of the filter with the top off. The second image (**Figure 6.11**) displays the filter just installed in the field prior to the backfill.

Figure 6.10. Interior of Vortex Filter

Figure 6.11. Installation of Vortex Filter prior to backfill

Storage Tanks. The storage tank is the most important and typically the most expensive component of a rainwater harvesting system. Cistern capacities range from 250 to over 30,000 gallons. Multiple tanks can be placed adjacent to each other and connected with pipes to balance water levels and increase overall storage on-site as needed. Typical rainwater harvesting system capacities for residential use range from 1,500 to 5,000 gallons. Storage tank volumes are calculated to meet the water demand and stormwater treatment volume credit objectives, as described in **Section 6** of this specification.

While many of the graphics and photos in this specification depict cisterns with a cylindrical shape, the tanks can be made of many materials and configured in various shapes, depending on the type used and the site conditions where the tanks will be installed. For example, configurations can be rectangular, L-shaped, or step vertically to match the topography of a site. The following factors that should be considered when designing a rainwater harvesting system and selecting a storage tank:

- Aboveground storage tanks should be UV and impact resistant.
- Underground storage tanks must be designed to support the overlying sediment and any other anticipated loads (e.g., vehicles, pedestrian traffic, etc.).
- Underground rainwater harvesting systems should have a standard size manhole or equivalent opening to allow access for cleaning, inspection, and maintenance purposes. This access point should be secured/locked to prevent unwanted access.
- All rainwater harvesting systems should be sealed using a water-safe, non-toxic substance.
- Rainwater harvesting systems may be ordered from a manufacturer or can be constructed on site from a variety of materials. **Table 6.2** below compares the advantages and disadvantages of different storage tank materials.
- Storage tanks should be opaque or otherwise protected from direct sunlight to inhibit algae growth and should be screened to discourage mosquito breeding and reproduction.
- Dead storage below the outlet to the distribution system and an air gap at the top of the tank should be added to the total volume. For gravity-fed systems, a minimum of 6 inches of dead storage should be provided. For systems using a pump, the dead storage depth will be based on the pump specifications.
- Any hookup to a municipal backup water supply should have a backflow prevention device to keep municipal water separate from stored rainwater; this may include incorporating an air gap to separate the two supplies. Local codes may have specifications for this.

Table 6.2. Advantages and Disadvantages of Various Cistern Materials

Tank Material	Advantages	Disadvantages
Fiberglass	Commercially available, alterable and moveable; durable with little maintenance; light weight; integral fittings (no leaks); broad application	Must be installed on smooth, solid, level footing; pressure proof for below-ground installation; expensive in smaller sizes
Polyethylene	Commercially available, alterable, moveable, affordable; available in wide range of sizes; can install above or below ground; little maintenance; broad application	Can be UV-degradable; must be painted or tinted for above-ground installations; pressure-proof for below-ground installation
Modular Storage	Can modify to topography; can alter footprint and create various shapes to fit site; relatively inexpensive	Longevity may be less than other materials; higher risk of puncturing of water tight membrane during construction
Plastic Barrels	Commercially available; inexpensive	Low storage capacity (20 to 50 gallons); limited application
Galvanized Steel	Commercially available, alterable and moveable; available in a range of sizes; film develops inside to prevent corrosion	Possible external corrosion and rust; must be lined for potable use; can only install above ground; soil pH may limit underground applications
Steel Drums	Commercially available, alterable and moveable	Small storage capacity; prone to corrosion, and rust can lead to leaching of metals; verify prior to reuse for toxics; water pH and soil pH may also limit applications
FerroConcrete	Durable and immoveable; suitable for above or below ground installations; neutralizes acid rain	Potential to crack and leak; expensive
Cast in Place Concrete	Durable, immoveable, versatile; suitable for above or below ground installations; neutralizes acid rain	Potential to crack and leak; permanent; will need to provide adequate platform and design for placement in clay soils
Stone or concrete Block	Durable and immoveable; keeps water cool in summer months	Difficult to maintain; expensive to build

Source: Cabell Brand, 2007, 2009

The images below in **Figures 6.12 to 6.14** display three examples of various materials and shapes of cisterns discussed in **Table 6.2** above.

Figure 6.12. Example of Multiple Fiberglass Cisterns in Series

Figure 6.13. Example of two Polyethylene Cisterns

Figure 6.14. Example of Modular Units

Distribution Systems. Most distribution systems require a pump to convey harvested rainwater from the storage tank to its final destination, whether inside the building, an automated irrigation system, or gradually discharged to a secondary runoff reduction practice. The rainwater harvesting system should be equipped with an appropriately-sized pump that produces sufficient pressure for all end-uses. The municipality may require the separate plumbing to be labeled as non-potable.

The typical pump and pressure tank arrangement consists of a multi-stage centrifugal pump, which draws water out of the storage tank and sends it into the pressure tank, where it is stored for distribution. When water is drawn out of the pressure tank, the pump activates to supply additional water to the distribution system. The backflow preventer is required to separate harvested rainwater from the main potable water distribution lines.

Distribution lines from the rainwater harvesting system should be buried beneath the frost line. Lines from the rainwater harvesting system to the building should have shut-off valves that are accessible when snow cover is present. A drain plug or cleanout sump, also draining to a pervious area, should be installed to allow the system to be completely emptied, if needed. Above-ground outdoor pipes should be insulated or heat-wrapped to prevent freezing and ensure uninterrupted operation during winter.

Overflow, Filter Path and Secondary Runoff Reduction Practice. An overflow mechanism should be included in the rainwater harvesting system design in order to handle an individual storm event or multiple storms in succession that exceed the capacity of the tank. Overflow pipes should have a capacity equal to or greater than the inflow pipe(s) and have a diameter and slope sufficient to drain the cistern while maintaining an adequate freeboard height. The overflow pipe should be screened to prevent access to the tank by rodents and birds.

The filter path is a pervious or grass corridor that extends from the overflow to the next runoff reduction practice, the street, an adequate existing or proposed channel, or the storm drain system. The filter path must be graded with a slope that results in sheet flow conditions. If compacted or impermeable soils are present along the filter path, compost amendments may be needed (see Stormwater Design Specification No. 4). It is also recommended that the filter path be used for first flush diversions.

In many cases, rainwater harvesting system overflows are directed to a secondary runoff reduction practice to boost overall runoff reduction rates. These options are addressed in **Section 5.5**.

SECTION 6: DESIGN CRITERIA

6.1. Sizing of Rainwater Harvesting Systems

The rainwater harvesting cistern sizing criteria presented in this section was developed using best estimates of indoor and outdoor water demand, long-term rainfall data, and rooftop capture area data, using a spreadsheet model (Forasté and Lawson, 2009). The Cistern Design Spreadsheet is primarily intended to provide guidance in sizing cisterns and to quantify the runoff reduction volume credit for input into the Runoff Reduction Spreadsheet for stormwater management compliance purposes. A secondary objective of the spreadsheet is to increase the beneficial uses of the stored stormwater, treating it as a valuable natural resource.

6.2. Incremental Design Volumes within Cistern

Rainwater tank sizing is determined by accounting for varying precipitation levels, captured rooftop runoff, first flush diversion (through filters) and filter efficiency, low water cut-off volume, dynamic water levels at the beginning of various storms, storage needed for treatment volume (permanent storage), storage needed for channel protection and flood volume (temporary detention storage), seasonal and year-round demand use and objectives, overflow volume, and freeboard volumes above high water levels during very large storms. See **Figure 6.15** for a graphical representation of these various incremental design volumes.

This specification does not provide design guidance for sizing the Channel and Flood Protection volume, but rather provides guidance on sizing for the 1-inch target storm Treatment Volume (T_V) Credit. See Chapter 10 ("Uniform Stormwater BMP Sizing Criteria") of the *Virginia Stormwater Management Handbook* (2010) for more information on design volumes and sizing criteria associated with various target storm events.

Note that the Treatment Volume is different from the "Storage Associated with the Treatment Volume". The Treatment Volume, as defined by DEQ in Table 10.2 of Chapter 10, is calculated by multiplying the "water quality" target rainfall depth (1 inch) with a composite of three site cover runoff coefficients (forest cover, disturbed soils/managed turf, and impervious cover). In the case of rainwater harvesting, because only rooftop surfaces are captured, only one runoff coefficient is applicable (impervious cover). Therefore, the only variable for Treatment Volume is surface area captured.

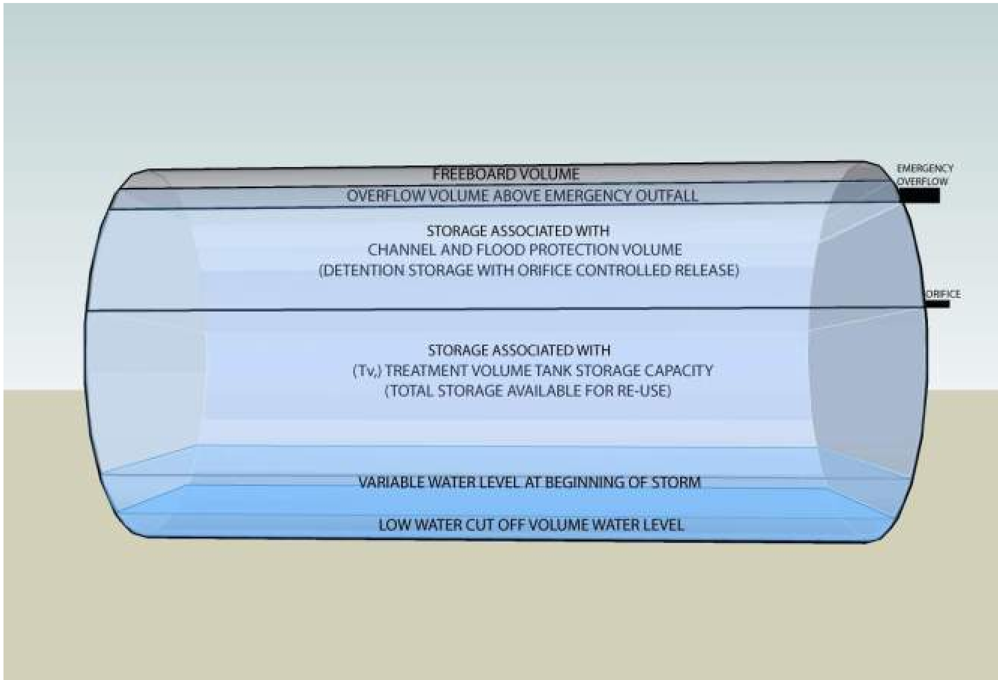

Figure 6.15. Incremental Design Volumes associated with tank sizing

The "Storage Associated with the Treatment Volume" is the storage within the tank that is modeled and available for reuse. While the Treatment Volume will remain the same for a specific rooftop capture area, the "Storage Associated with the Treatment Volume" may vary depending on demand and runoff reduction credit objectives. It includes the variable water level at the beginning of a storm and the low water cut-off volume that is necessary to satisfy pumping requirements.

6.3 Cistern Design Spreadsheet (CDS)

This specification is intimately linked with the Cistern Design Spreadsheet (CDS), which can be downloaded from the Virginia Stormwater BMP Clearinghouse web site at:

http://www.vwrrc.vt.edu/swc/NonProprietaryBMPs.html
(NOTE: The CDS is associated with this specification on that web page.)

The spreadsheet uses daily rainfall data from September 1, 1977 to September 30, 2007 to model performance parameters of the cistern under varying rooftop capture areas, demands on the system and tank size. The precipitation data is the same that was utilized by the Center for Watershed Protection (CWP) to determine the 90th percentile 1-inch water quality treatment volume target storm event, as presented and explained in Figure 10.1 in Chapter 10 of the Handbook. Precipitation data for four different regions throughout Virginia can be selected for use within the model.

- Richmond International Airport
- Reagan Airport (Alexandria)
- Lynchburg Regional Airport
- Millgap 2NNW (near Harrisonburg)

A runoff coefficient of 0.95 for rooftop surfaces and a filter efficiency rate of 95% for the 1-inch storm are assumed. It is assumed that filters are to be installed on all systems and that the first flush diversion is incorporated into the filter efficiency. The remaining precipitation is then added to the water level that existed in the cistern the previous day, with all of the total demands subtracted on a daily basis. If any overflow is realized, the volume is quantified and recorded. If the tank runs dry (reaches the cut-off volume level), then the volume in the tank is fixed at the low level and a dry-frequency day is recorded. The full or partial demand met in both cases is quantified and recorded. A summary of the water balance for the system is provided below.

Water Contribution:

- ***Precipitation to rooftop.*** The volume of water contributing to the rainwater harvesting system is a function of the rainfall and rooftop area captured, as defined by the designer.

- ***Municipal Backup (optional).*** In some cases, the designer may choose to install a municipal backup water supply to supplement tank levels. Note that municipal backups may also be connected post-tank (i.e. a connection is made to the non-potable water line that is used for pumping water from the tank for reuse), thereby not contributing any additional volume to the tank.

Water Losses:

- ***Rooftop Runoff Coefficient.*** The rooftop is estimated to convey 95% of the rainfall that lands on it's surface (i.e., $R_v = 0.95$).

- ***First Flush Diversion.*** The first 0.02 to 0.06 inch of rainfall that is directed to filters is diverted from the system in order to prevent clogging it with debris. This value is assumed to be contained within the filter efficiency rate.

- ***Filter Efficiency.*** Each filter has an efficiency curve associated with the rate of runoff and the size of the storm it will receive from a rooftop. It is assumed that, after the first flush diversion and loss of water due to filter inefficiencies, the remainder of the 1-inch storm will be successfully captured. This means that a minimum of 95% of the runoff from a 1-inch storm should be conveyed into the tank. The filter efficiency value is not adjustable at this time and cannot be modified as an input value in the CDS, but it should not be less than 95%. Some localities may require that a minimum filter efficiency for a larger storm event be met (e.g. minimum 90% filter efficiency for 2 or 10-year storm), depending on design objectives and local review agency policy. For the purposes of selecting an appropriately sized filter, a rainfall intensity of 1-inch/hour should be used for the 24 hour, 1-inch storm. The local rainfall intensity values for the 2 and 10 year storms should be used when designing for channel and flood protection volumes.

- ***Drawdown (Runoff Reduction Volume).*** This is the stored water within the cistern that is reused or directed to a secondary runoff reduction practice. It is the volume of runoff that is reduced from the rooftop drainage area. This is the water loss that translates into the Runoff Reduction Volume credit.

- ***Overflow.*** For the purposes of addressing treatment volume (not addressing channel or flood protections volumes), orifice outlets for both detention and emergency overflows are treated the same. This is the volume of water that may be lost during large storm events or successive precipitation events.

See **Appendix 6-A** for a detailed description of Spreadsheet Inputs.

6.4. Results for all Precipitation Events

The performance results of the rainwater harvesting system for all days during the entire period modeled, including the full spectrum of precipitation events, is included in the "Results" tab. This tab is not associated with determining the Runoff Reduction Volume Credit, but rather may be a useful tool in assisting the user to realize the performance of the various rainwater harvesting system sizes with the design parameters and demands specified.

- ***Demand Met.*** This is where the demand met for various size cisterns and rooftop area/demand scenarios is reported. A graph displaying the percentage of demand met for various cistern sizes is provided in this tab. Normally this graph assists the user in understanding the relationship between cistern sizes and optimal/diminishing returns. An example is provided below in **Figure 6.16**.

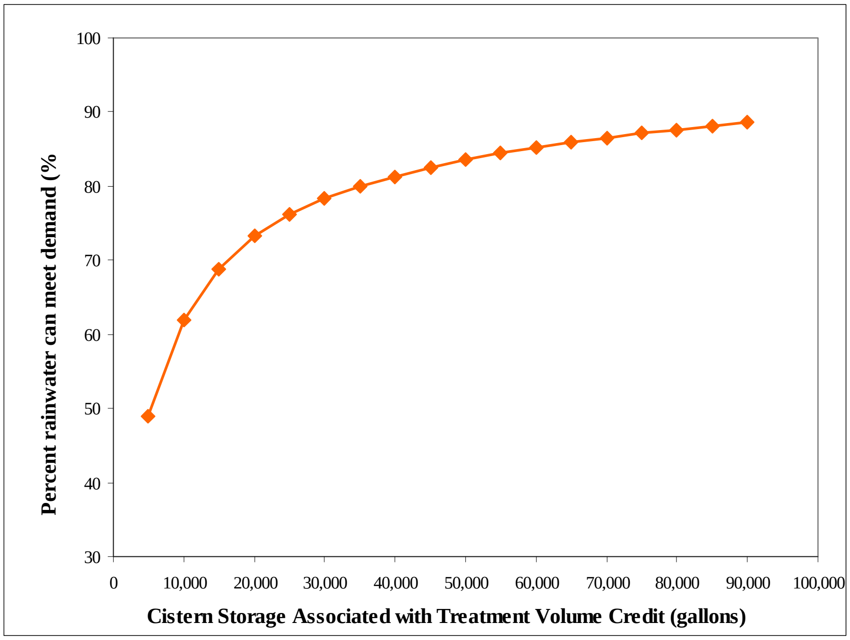

Figure 6.16. Percent Demand Met Vs. Storage for Re-use (Example)

At some point, larger cisterns no longer provide significant increases in percentages of demand met. Conversely, the curve informs the user when a small increase in cistern size can yield a significant increase in the percentage of time demand that is met.

- ***Dry Frequency.*** Another useful measure is the dry frequency. If the cistern is dry a substantial portion of the time, this measure can inform that user that he/she may want to decrease the size of the cistern, decrease the demand on the system or explore capturing more rooftop area to provide a larger supply, if feasible. It can also provide useful insight for the designer to determine whether he/she should incorporate a municipal backup supply to ensure sufficient water supply through the system at all times.

- ***Overflow Frequency.*** This is a metric of both overflow frequency and average volume per year for the full spectrum of rainfall events. This will inform the user regarding the design parameters and magnitude of demand and associated performance of the system. If the system overflows at a high frequency, then the designer may want to increase the size of the cistern, decrease the rooftop area captured, or consider other mechanisms that could increase drawdown (e.g. increase the area to be irrigated, incorporate or increase on-site infiltration, etc.).

- ***Inter-relationships and Curves of Diminishing Returns.*** Plotting various performance metrics against one another can be very informative and reveal relationships that are not evident otherwise. One such inter-relationship is the percentage of demand met versus tank size compared to the percentage of overflow frequency versus tank size, depicted on the same graph. A range of cistern sizes that tends to emerge, informing the designer where a small increase or decrease in tank size can have a significant impact on dry frequency and overflow frequency. Conversely, outside this range, changes in cistern sizes would yield small changes to dry frequency and overflow frequency, yet yield a large trade-off compared to the cost of the rainwater harvesting system.

6.5. Results for Precipitation Events of 1 Inch or Less

The amount of rooftop runoff volume that the tank can capture and use or draw down for all precipitation events of 1 inch or less is also quantified and recorded. These results are presented on the “Results Treatment Volume” tab. This information is used to calculate the Treatment Volume credit, which is used as an input to the Runoff Reduction spreadsheet.

- ***Treatment Volume Credit.*** A series of Treatment Volume credit values are calculated for multiple sizes of cisterns. A trade-off curve plots these results, which allows for a comparison of the credit earned versus cistern size. While smaller tanks may yield less credit than larger tanks, they are more cost-effective. Conversely, while larger tanks yield more credit, they are more costly. The curve assists the user to choose the appropriate tank size, based on the design objectives and site needs, as well as to understand the rate of diminishing returns.

- The Runoff Reduction and Treatment Volumes are also quantified; however, these results will automatically be calculated in a similar manner on the Runoff Reduction spreadsheet with the use of the Treatment Volume credit earned. Therefore, only the credit needs to be transferred, not the volumetric results.

- ***Overflow Volume from 1-inch storm.*** The frequency of cistern overflows and the average annual volume of the overflows resulting from precipitation events of 1-inch or less are also reported in this tab. A chart of the Treatment Volume Credit and Overflow Frequency for the 1-inch storm versus the storage volume is provided. An example is shown below in **Figure 6.17**.

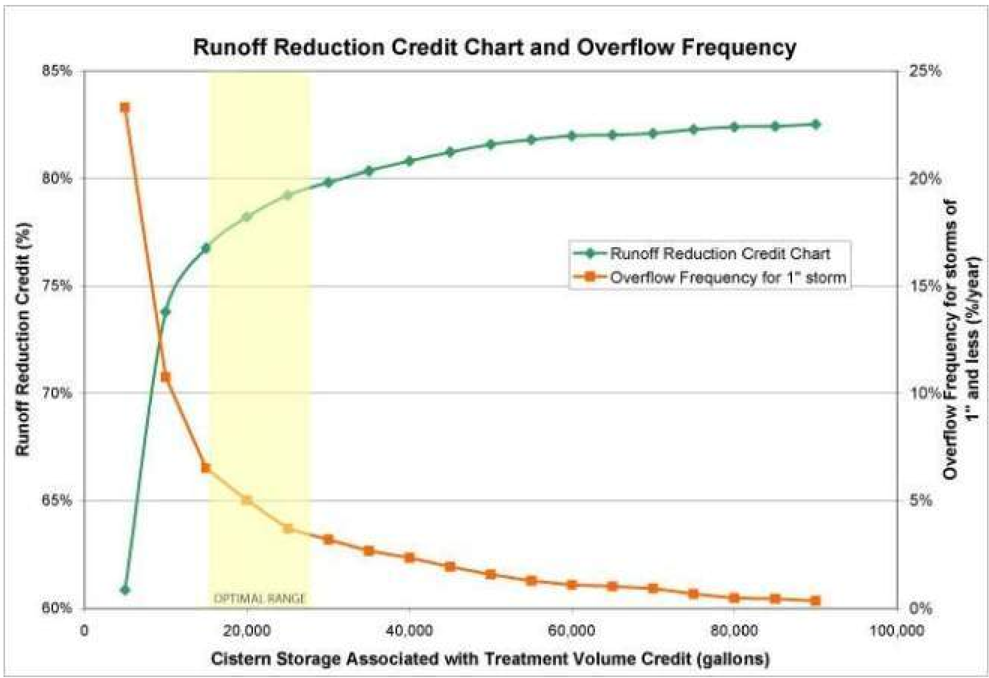

Figure 6.17. Percent Runoff Reduction Credit Vs. Storage for Re-use(Example)

These plotted results establish a trade-off relationship between these two performance metrics. In the above example, a 20,000 gallon cistern optimizes the runoff reduction credit and the overflow frequency (near the inflection point of both curves).

6.6. Results from Cistern Design Spreadsheet to be transferred to Runoff Reduction Spreadsheet

There are two results from this Cistern Design Spreadsheet that are to be transferred to the Runoff Reduction Spreadsheet, as follows:

1. First Value to Transfer: Once the cistern storage volume associated with the Runoff Reduction Volume credit has been selected, simply transfer that credit amount into the Runoff Reduction Spreadsheet column called “Credit” in the “2.f. To Rain Barrel, Rainwater harvesting system, Cistern” row in the blue cell (cell F30).

2. Second Value to Transfer: Then enter the rooftop area that was used in the Cistern Design Spreadsheet in the same row into the "Credit Area (acres)" column in the blue cell (cell G30).

See **Appendix 6-B** for STEP BY STEP INSTRUCTIONS for using the Cistern Design Spreadsheet.

6.7. Completing the Sizing Design of the Cistern

1. ***Low Water Cutoff Volume (Included).*** A dead storage area must be included so that the pump will not run the tank dry. This volume is included within the Cistern Design Spreadsheet volume modeled.

2. ***Cistern Storage Associated with Treatment Volume (Included).*** This is the volume that was designed for using the Cistern Design Spreadsheet.

3. ***Adding Channel Protection and Flood Volumes (Optional).*** Additional detention volume may be added above and beyond the Cistern Storage Associated with the Treatment Volume for Channel Protection and Flood Volumes. Typical routing software programs may be used to design for this additional volume. The local reviewing authority has the option of accepting an adjusted curve number, accounting for the volume that has already been reduced as a result of the storage provided within the storage for the Treatment Volume (methodology as presented in the runoff reduction spreadsheet), or requiring that the system be modeled assuming that the Storage associated with the Treatment Volume is full.

4. ***Adding Overflow and Freeboard Volumes (Required).*** An additional volume above the emergency overflow must be provided in order for the tank to allow very large storms to pass. Above this overflow water level will be an associated freeboard volume. This volume must account for a minimum of 5% of the overall tank size; however, sufficient freeboard should be verified for large storms. These volumes need to be added to the overall size of the cistern tank.

Adding all of the incremental volumes above yields the total size of the cistern tank:

Total Cistern Size = 1 + 2 + 3 + 4

See **Appendix 6-C** for more notes relating to the use and development of the spreadsheet and documentation on the methodology used.

6.8. Design for Potable Water Calculations

In situations with insufficient potable water supply, rainwater can be treated and used for potable water supply subject to state and local health requirements (The Virginia Department of Health maintains regulations pertaining to reuse of water for potable uses). This rainwater harvesting system use is *not* covered in this specification, although there is growing interest in using harvested rainwater for potable drinking water. If this use is permitted by the appropriate public health authority, and the rainwater harvesting system is equipped with proper filtering equipment, the increased water reuse rate would sharply reduce the demand on municipal water systems sharply, resulting in commensurate cost savings. It would also enable a more standard plumbing system, since potable and non-potable water would no longer need to be separated.

6.9. Rainwater Harvesting Material Specifications

The basic material specifications for rainwater harvesting systems are presented in **Table 6.3**. Designers should consult with experienced rainwater harvesting system and irrigation installers on the choice of recommended manufacturers of prefabricated tanks and other system components.

Table 6.3. Design Specifications for Rainwater harvesting systems

Item	Specification
Gutters and Downspout	Materials commonly used for gutters and downspouts include polyvinylchloride (PVC) pipe, vinyl, aluminum and galvanized steel. Lead should not be used as gutter and downspout solder, since rainwater can dissolve the lead and contaminate the water supply. ▪ The length of gutters and downspouts is determined by the size and layout of the catchment and the location of the storage tanks. ▪ Be sure to include needed bends and tees.
Pre-Treatment	At least one of the following (all rainwater to pass through pre-treatment): ▪ first flush diverter ▪ vortex filter ▪ roof washer ▪ leaf and mosquito screen (1 mm mesh size)
Storage Tanks	▪ Materials used to construct storage tanks should be structurally sound. ▪ Tanks should be constructed in areas of the site where native soils can support the load associated with stored water. ▪ Storage tanks should be water tight and sealed using a water-safe, non-toxic substance. ▪ Tanks should be opaque to prevent the growth of algae. ▪ Re-used tanks should be fit for potable water or food-grade products. ▪ Underground rainwater harvesting systems should have a minimum of 18 to 24 inches of soil cover and be located below the frost line. ▪ The size of the rainwater harvesting system(s) is determined during the design calculations.
Note: This table does not address indoor systems or pumps.	

SECTION 7: REGIONAL & SPECIAL CASE DESIGN ADAPTATIONS

7.1. Karst Terrain

Above-ground rainwater harvesting systems are a preferred practice in karst, as long as the rooftop surface is not designated as a stormwater hotspot.

7.2. Coastal Plain

Above-ground rainwater harvesting systems are a preferred practice in the coastal plain, since they avoid the flat terrain, low head and high water table conditions that constrain other stormwater practices.

7.3. Steep Terrain

Rainwater harvesting systems are ideal in areas of steep terrain.

7.4. Cold Climate & Winter Performance

Rainwater harvesting systems have a number of components that can be impacted by freezing winter temperatures. Designers should give careful consideration to these conditions to prevent system damage and costly repairs.

For above-ground systems, winter-time operation may be more challenging, depending on tank size and whether heat tape is used on piping. If not protected from freezing, these rainwater harvesting systems must be taken offline for the winter and stormwater treatment credit may not be granted for the practice during that off-line period. At the start of the winter season, vulnerable above-ground systems that have not been designed to incorporate special precautions should be disconnected and drained. It may be possible to reconnect the former roof leader systems for the winter.

For underground and indoor systems, downspouts and overflow components should be checked for ice blockages during snowmelt events.

7.5. Linear Highway Sites

Rainwater harvesting systems are generally not applicable for linear highway sites.

SECTION 8: CONSTRUCTION

8.1. Construction Sequence

It is advisable to have a single contractor to install the rainwater harvesting system, outdoor irrigation system and secondary runoff reduction practices. The contractor should be familiar with rainwater harvesting system sizing, installation, and placement. A licensed plumber is required to install the rainwater harvesting system components to the plumbing system.

A standard construction sequence for proper rainwater harvesting system installation is provided below. This can be modified to reflect different rainwater harvesting system applications or expected site conditions.

- Choose the tank location on the site
- Route all downspouts or roof drains to pre-screening devices and first flush diverters
- Properly Install the tank
- Install the pump (if needed) and piping to end-uses (indoor, outdoor irrigation, or tank dewatering release)
- Route all pipes to the tank
- Stormwater should not be diverted to the rainwater harvesting system until the overflow filter path has been stabilized with vegetation.

8.2. Construction Inspection

The following items should be inspected prior to final sign-off and acceptance of a rainwater harvesting system:

- Rooftop area matches plans
- Diversion system is properly sized and installed
- Pretreatment system is installed
- Mosquito screens are installed on all openings
- Overflow device is directed as shown on plans
- Rainwater harvesting system foundation is constructed as shown on plans
- Catchment area and overflow area are stabilized
- Secondary runoff reduction practice(s) is installed as shown on plans

SECTION 9: MAINTENANCE

9.1. Maintenance Agreements

Section 4 VAC 50-60-124 of the regulations specifies the circumstances under which a maintenance agreement must be executed between the owner and the local program. This section sets forth inspection requirements, compliance procedures if maintenance is neglected, notification of the local program upon transfer of ownership, and right-of-entry for local program personnel.

All rainwater harvesting systems must be covered by a drainage easement to allow inspection and maintenance. The easement should include the tank, the filter path and any secondary runoff reduction practice. If the tank is located in a residential private lot, its existence and purpose must be noted on the deed of record. Homeowners will need to be provided a simple document that explains the purpose of the rainwater harvesting system and routine maintenance needs. Where legally binding maintenance agreements apply, they should specify the property owner's primary maintenance responsibility, require homeowners to pay to have their system inspected by a qualified third party inspector, and authorize the qualifying local program staff to access the property for inspection or corrective action in the event this is not done.

9.2. Maintenance Inspections

All rainwater harvesting systems components should be inspected by the property owner in the Spring and the Fall each year. A comprehensive inspection by a qualified third party inspector should occur every third year. An example maintenance inspection checklist for Rainwater Harvesting can be accessed in Appendix C of Chapter 9 of the *Virginia Stormwater Management Handbook* (2010).

9.3. Rainwater harvesting system Maintenance Schedule

Maintenance requirements for rainwater harvesting systems vary according to use. Systems that are used to provide supplemental irrigation water have relatively low maintenance requirements, while systems designed for indoor uses have much higher maintenance requirements. **Table 6.4** describes routine maintenance tasks to keep rainwater harvesting systems in working condition.

Table 6.4. Suggested Maintenance Tasks for Rainwater harvesting systems

Activity	Frequency
Keep gutters and downspouts free of leaves and other debris	O: Twice a year
Inspect and clean pre-screening devices and first flush diverters	O: Four times a year
Inspect and clean storage tank lids, paying special attention to vents and screens on inflow and outflow spigots. Check mosquito screens and patch holes or gaps immediately	O: Once a year
Inspect condition of overflow pipes, overflow filter path and/or secondary runoff reduction practices	O: Once a year
Inspect tank for sediment buildup	I: Every third year
Clear overhanging vegetation and trees over roof surface	I: Every third year
Check integrity of backflow preventer	I: Every third year
Inspect structural integrity of tank, pump, pipe and electrical system	I: Every third year
Replace damaged or defective system components	I: Every third year
Key: O = Owner I = qualified third party inspector	

SECTION 10: COMMUNITY & ENVIRONMENTAL CONCERNS

Although rainwater harvesting is an ancient practice, it is enjoying a revival due to the inherent quality of rainwater and the many beneficial uses that it can provide (TWDB, 2005). Some common concerns associated with rainwater harvesting that must be addressed during design include:

Winter Operation. Rainwater harvesting systems can be used throughout the year if they are located underground or indoors to prevent problems associated with freezing, ice formation and subsequent system damage. Alternately, an outdoor system can be used seasonally, or year round if special measures and design considerations are incorporated. See **Section 7.4** for further guidance on winter operation of rainwater harvesting systems.

Local Plumbing Codes. Designer and plan reviewers should consult local building codes to determine if they explicitly allow the use of harvested rainwater for toilet and urinal flushing. In the cases where a municipal backup supply is used, rainwater harvesting systems should be required to have backflow preventers or air gaps to keep harvested water separate from the main water supply. Pipes and spigots using rainwater must be clearly labeled as non-potable.

Mosquitoes. In some situations, poorly designed rainwater harvesting systems can create habitat suitable for mosquito breeding and reproduction. Designers should provide screens on above- and below-ground tanks to prevent mosquitoes and other insects from entering the tanks. If screening is not sufficient in deterring mosquitoes, dunks or pellets containing larvicide can be added to cisterns when water is intended for landscaping use.

Child Safety. Above-grade residential rainwater harvesting systems cannot have unsecured openings large enough for children to enter the tank. For underground cisterns, manhole access should be secured to prevent unwanted access.

SECTION 11: REFERENCES

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APPENDIX 6-A

CISTERN DESIGN SPREADSHEET INPUTS

The spreadsheet model requires the following user inputs:

Regional location. Indicate the region that is closest to where the practice is being installed. Rainfall data associated with that region will automatically provide the relevant precipitation data for the design storm for that area.

Roof area. The user must estimate the total rooftop area that will be captured for contribution to the system; this combined with the target storm (1 inch of rainfall for the water quality Treatment Volume) yields the volume of rooftop runoff to be managed.

Irrigation use. The user must supply the total pervious area (in square feet) that will be irrigated; the spreadsheet will automatically calculate the demand based on a 1-inch per week watering during the appropriate season, unless the user specifies a different watering rate. The user can specify a start date and an end date in the year to specify the irrigation season (e.g., March 30 to September 1). If an on-site infiltration system is designed, the lesser drawdown rate (irrigation or on-site infiltration during the off-season) must be used to quantify the Treatment Volume credit.

Indoor use. The user then needs to define the parameters relating to indoor use of water; the spreadsheet will automatically calculate the demand according to the following criteria:

- Number of bedrooms – the user enters the number of bedrooms in the home. The spreadsheet uses the same approach that currently determines drainfield size by estimating the use required to accommodate 1.5 people per bedroom.
- Laundry use – the user selects either yes/no as to whether harvested rainwater will be used for laundry. The spreadsheet calculates laundry use as 1 load per person per week with an estimated water usage of 20 gallons per load (the upper end of use for Energy Star washers), with the number of people determined by the number of bedrooms selected.
- Toilet use – the user selects either yes/no about whether harvested rainwater will be used to flush toilets. The spreadsheet calculates use, based on a low flow toilet (1.2 gallons per flush) with three flushes per person per day, with the number of people determined by the number of bedrooms selected.
- Optional additional input – the user may enter an additional demand, such as bus or fire truck washing, street sweeper filling, etc.

Chilled Water Cooling Towers. The user may enter a quantity of water that will be needed for use in chilled water cooling towers.

Secondary Runoff Reduction Practice Drawdown. A cell is provided to enter an additional drawdown for secondary runoff reduction practices linked to the rainwater harvesting system. This rate will be specified by the designer and based on a practice that has been designed to properly accept and infiltrate, store, and/or treat this drawdown amount.

APPENDIX 6-B

STEP-BY-STEP INSTRUCTION FOR USING THE CISTERN DESIGN SPREADSHEET

TAB 1: INPUT

1. Select a Region in the drop down menu that is located closest to the proposed site.

2. Enter the rooftop area to be captured and routed to the cistern (square feet).

3. Enter the Irrigation data, as described in Appendix 6-A (Spreadsheet Inputs) of this design specification.

4. Enter the Indoor Demand – Flushing toilets/urinals, as described in Appendix 6-A.

5. Enter the Indoor Demand – Laundry, as described in Appendix 6-A.

6. Enter Additional Daily Uses (gallons per day).

7. Enter the amount that will be used for Chilled Water Cooling Towers (gallons per day).

8. Enter the On-Site infiltration design drawdown rate (gallons per day).

9. Enter the filter efficiency percentage for the 1-inch storm at a 1-inch/hour intensity. A minimum of 95% must be achieved and is assumed as the base value. However, if the filter achieves a higher efficiency rate, this higher value can be entered.

TAB 2: JULIAN DAY CALENDER

This tab is included for assistance in selecting a start date and end date for any demand practices. The day of the year should be selected according to the julian day dates specified in this tab.

TAB 3: RESULTS – TREATMENT VOLUME CREDIT

10. Select the Results – Treatment Volume Credit (TVC) tab to view modeling results for the 1-inch storm.

11. Observe the results for the Treatment Volume Credit highlighted in the green column, showing the dry frequency and the overflow frequency as they relate to the cistern storage associated with the TVC. If the TVC level is much higher or lower than design objectives for many of the cistern storage sizes, the input values should be assessed to determine if the demand can be increased or decreased.

TAB 4: RESULTS

12. Select the Results tab to view the modeling results for all storm events.

13. Observe the results for overflow frequency, dry frequency and percent of demand met by rainwater.

14. If the demand met for a particular storage size is adequate, observe the dry frequency, overflow frequency and TVC. If all of the design parameters meet design objectives and balance trade-offs reasonably well, move to the next step. If any of the resulting performance metrics are not acceptable design objectives, then re-visit the input spreadsheet to assess whether lower or higher demands can be achieved (e.g. decrease/increase in the area (sq. ft.) of irrigation increase/decrease in the rooftop area captured, if feasible; add to/subtract from an on-site infiltration facility; etc.).

RESULT TO BE TRANSFERRED TO RUNOFF REDUCTION SPREADSHEET

15. First Value to Transfer: Once the cistern storage volume associated with the TVC has been selected, simply transfer that credit amount into the Runoff Reduction Spreadsheet column called “Credit” in the “2.f. To Rain Barrel, Rainwater harvesting system, Cistern” row in the blue cell (cell F30).

16. Second Value to Transfer: Then enter the rooftop area that was used in the same row and in the Cistern Design Spreadsheet into the “Credit Area (acres)” column in the blue cell (cell G30).

APPENDIX 6-C

NOTES REGARDING THE CISTERN DESIGN SPREADSHEET USE AND METHODOLOGY

If a use is only seasonal (e.g. summer irrigation), the spreadsheet must set the input for irrigation to zero for the purpose of the Treatment Volume credit, unless an on-site infiltration facility is designed to infiltrate an equivalent volume of water during the non irrigation season.

With each documented daily use, the runoff volume is reduced. The Treatment Volume credit is a percentage equivalent to the sum of all the stored water that is used/disposed during the entire 30 year period divided by the entire volume that is generated during that same period for all storm events of 1-inch or less. That is:

$$Tv\% = \frac{\sum_{i=1}^{n} Vu}{\sum_{i=1}^{n} Tv}$$

Where:

$$\sum_{i=1}^{n} Tv = \sum_{i=1}^{n} \left[Pi \times SA \times Rv \times \left(\frac{1ft}{12in} \right) \times \left(\frac{7.48gallons}{1cf} \right) \right]$$

And

$$\sum_{i=1}^{n} Vu = \sum \left[Tv - ff - Ov \right]$$

Where: $Tv\%$ = Treatment Volume credit (%)

$\sum_{i=1}^{n} Vu$ = Runoff Reduction Volume.

(NOTE: This is the total volume of runoff that has been removed from the runoff for storms of 1 inch or less for the entire 30 year period. It is calculated adding the contribution all precipitation of 1 inch or less, times the runoff coefficient, minus the first flush diversion, minus the overflow.)

ff = First flush diversion and filter overflow due to filter inefficiency

Ov = Overflow from precipitation events of 1 inch or less

Rv = Runoff Coefficient of the Rooftop = 0.95

Pi = Precipitation of 1 inch or less (inches)

SA = Surface Area of the rooftop that is captured and conveyed to the cistern (sq. ft.)

i = Start day of modeling (First day modeled in 1977)

n = End day of modeling (Last day modeled in 2007)

The spreadsheet calculations should always be included with the stormwater management submittal package for local plan review. See Appendix 6-D for more information on recommended submittal package checklists and materials.

APPENDIX 6-D

PLAN SUBMITTAL REQUIREMENTS AND CHECKLIST RECOMMENDATIONS

It is highly recommended that designers of rainwater harvesting systems coordinate design efforts and communicate intent to both site designers and building architects, since a rainwater harvesting system links the building to the site. The effectiveness of such a system, in terms of use for demand and as a stormwater management tool, is also highly dependent on the efficiency of capturing and conveying rainwater from the building rooftop (or other impervious cover) to the storage tank.

The following lists are recommended items that plan reviewers may want to consider and/or require for submittals of rainwater harvesting systems being used as a stormwater management tool. To ensure effectiveness of design, the following items should be considered for inclusion with plan submittals:

A. Incorporation of Rainwater Harvesting System into Site Plan Grading and Storm Sewer Plan construction documents, as follows:

1. Include a roof plan of the building that will be used to capture rainwater, showing slope direction and roof material.

2. Display downspout leaders from the rooftops being used to capture rainwater.

3. Display the storm drain pipe layout (pipes between building downspouts and the tank) in plan view, specifying materials, diameters, slopes and lengths, to be included on typical grading and utilities or storm sewer plan sheets.

4. Include a detail or note specifying the minimum size, shape configuration and slope ~~to~~ of the gutter(s) that convey rainwater

B. Rainwater Harvesting System Construction Document sheet, to show the following:

1. The Cistern or Storage Unit material and dimensions in a scaleable detail (use a cut sheet detail from Manufacturer, if appropriate).

2. Include the specific Filter Performance specification and filter efficiency curves. Runoff estimates from the rooftop area captured for 1-inch storm should be estimated and compared to filter efficiencies for the 1-inch storm. It is assumed that the first flush diversion is included in filter efficiency curves. A minimum of 95% filter efficiency should be met for the Treatment Volume credit. If this value is altered (increased) in the Cistern Design Spreadsheet, the value should be reported. Filter curve cut sheets are normally available from the manufacturer.

3. Show the specified materials and diameters of inflow and outflow pipes.

4. Show the inverts of the orifice outlet, the emergency overflows, and, if applicable, the receiving secondary runoff reduction practice or on-site infiltration facility.

5. Show the incremental volumes specified for: (a) the low water cut-off volume level; (b) the storage volume associated with the Treatment Volume credit; (c) the storage volume associated with the Channel Protection Volume (if applicable); (d) the storage volume associated with the Flood Protection Volume (if applicable); and (e) the overflow freeboard volume.

6. Include a cross section of the storage unit displaying the inverts associated with the various incremental volumes (if requested by the reviewer).

C. Supporting Calculations and Documentation

1. Provide a drainage area map delineating the rooftop area (square feet) to be captured and indicating the 1-inch storm, 1 year storm and 10 year storm peak discharge values on the plan (11x17 is sufficient).

2. Provide calculations showing that the gutter, at its specified size and slope, will convey the design storm specified by regulatory authority.

3. Provide calculations showing that the roof drains, at their specified size, slope and material, will convey the design storm specified by regulatory authority.

4. Cistern Design Spreadsheet: a print-out of the “Input” tab, as modeled.

5. Cistern Design Spreadsheet: a print-out of the “Results - Treatment Volume Credit” tab, as modeled.

6. Cistern Design Spreadsheet: a printout of the “Results” tab, as modeled.

D. Stormwater Management Forms

1. The owner should treat a rainwater harvesting system as he/she would treat any other stormwater management facility. If a stormwater management maintenance agreement form is required by the jurisdiction, then the same form should be submitted for a rainwater harvesting system.

2. An Agreement Form or Note on the plans should be included to ensure that the minimum demand that was specified in the stormwater management plan submittal documents ~~are~~ is being met. Likewise, if the property (and rainwater harvesting system) is transferred to a different owner, the new owner must be held responsible to ensure the system will continue to archive ~~a~~ the specified year-round drawdown. If the year-round drawdown is not being met as specified, an alternative stormwater management plan may be required.