Chapter 14 – Rainwater Capturing Systems

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14.1 Overview of Practice

Capture and Reuse BMP measures include a number of devices intended to intercept precipitation, store it for a period of time, and provide a means for reuse of the water. These capture devices include cisterns, rain barrels, and vertical storage or "fat downspouts." The capture and reuse approach to stormwater management can be applied in both site development and retrofit applications. Use as a BMP for highway runoff is limited. Generally, use of stored rainwater in potable applications is not advised in the absence of treatment; however, in addition to reducing stormwater runoff, the intercepted water is ideal for fire protection and irrigation.

14.1.1 Types of Capture and Storage Devices

Cisterns are containers designed to hold large volumes of water (by definition, cistern volumes are typically 500 gallons or more). Cisterns may be located underground or on the surface. Cisterns are available in a variety of sizes and materials, including fiberglass, concrete, plastic, and brick.

Figure 14.1. Various Size Cisterns (PADEP, January 2005)

Rain Barrels are containers designed exclusively to capture runoff from roof leaders and downspouts. Rain barrels vary in volume, and are sized based on the roof area from which they are receiving runoff or as a minimum volume computed by a water budget approach, as discussed later in this document.

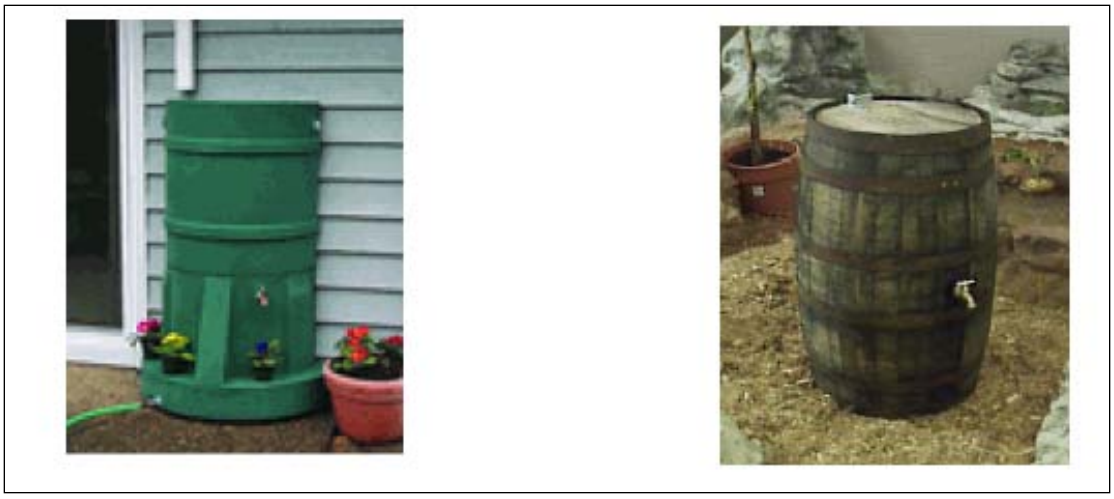

Figure 14.2. Rain Barrels (PADEP, January 2005)

Vertical Storage units or "fat downspouts" function in the same manner as cisterns and rain barrels, but are typically much larger and usually rest against the building from which they are intercepting runoff. Often, the water stored in these vertical storage units is used to provide fire protection. When employed as storage for fire protection, the storage volume is dictated by applicable codes. The design and sizing of vertical storage units and fat downspouts must be accomplished by working closely with both the architect and structural engineer.

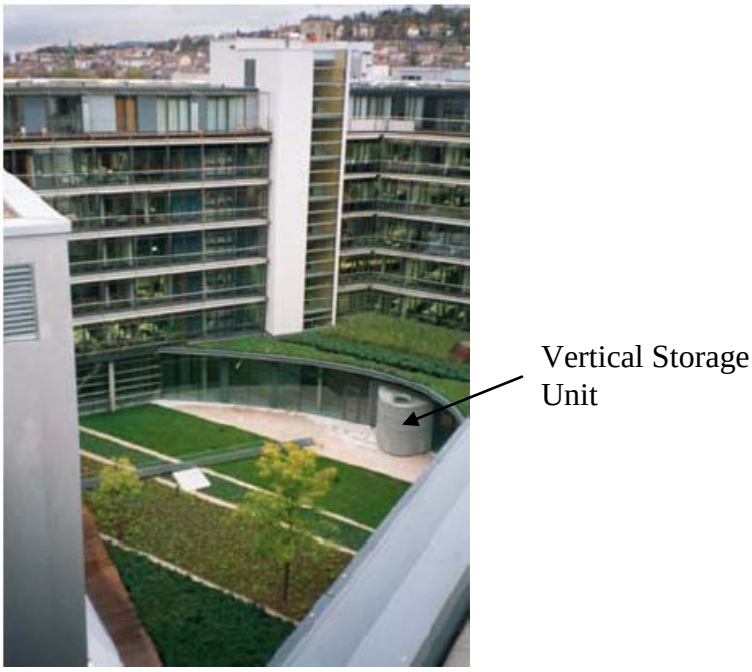

Figure 14.3. Vertical Storage (Fat Downspouts)
(PADEP, January 2005)

Proprietary storage units, such as RainStore, may be located beneath paths and walkways. These storage devices often provide a supplemental irrigation supply.

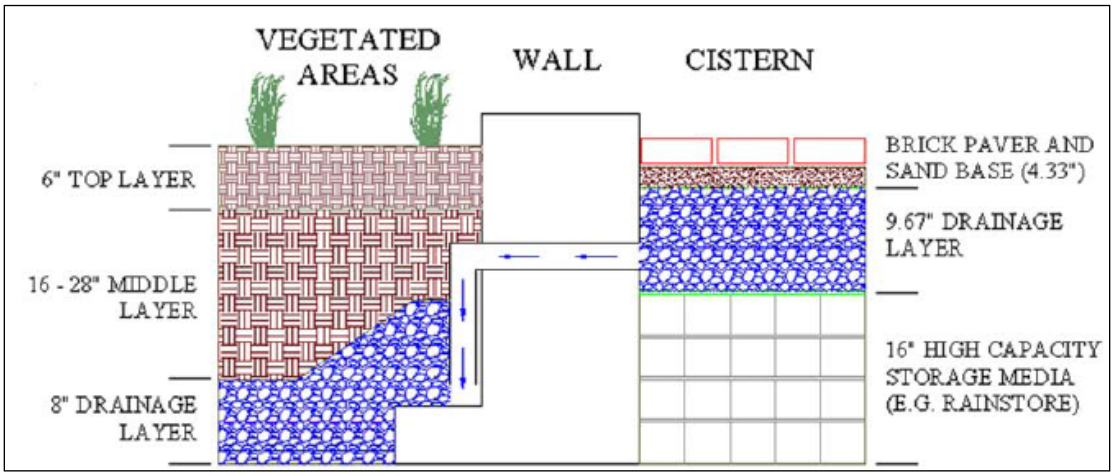

Figure 14.4. Storage of Runoff Beneath Brick Walkway
(specifications from PADEP, January 2005)

14.1.2 Application of Stored Rainwater

While the use of stored rainwater as a potable supply is not recommended, a number of non-potable needs may be addressed by a capture and reuse approach. These include:

- Irrigation of landscaped areas and gardens
- Storage for fire protection needs
- "Greywater" needs such as flushing toilets
- Athletic field irrigation

In addition to satisfying non-potable water needs, rainwater capture devices can serve to reduce runoff volume and the frequency of surcharge events in urban combined sewer systems.

14.2 Design Considerations

- The first step in the consideration of a capture and reuse system is to determine the water demand for the proposed reuse application. The demand is critical in determining the feasibility and size of the harvesting system. The volume of water harvested and stored, at a minimum, must equal the computed demand.

- The capture and storage system must provide drawdown between storm events such that the required stormwater storage volume is available.

- The conveyance system that delivers reused stormwater or greywater from the storage system must not cross connect with domestic or commercial potable water systems.

- Storage units and conveyance systems must be clearly marked as non-potable water.
- Screens may be used as a means to filter debris from capture and storage units.
- Rainfall storage units should be protected from direct sunlight by positioning and landscaping.
- When providing an overflow outlet for the storage unit, the proximity to building foundations must be considered.
- In cold climates, capture and reuse systems should be disconnected during the winter months to prevent freezing.
- Underground cisterns must be watertight.
- Rain barrels and surface cisterns should have a cover with a tight fit capable of keeping out unwanted surface water, animals, dust, and light.
- Cisterns, rain barrels, and vertical storage systems should be equipped with a means for overflow in the event of heavy runoff producing events.
- Buried cisterns should possess observation risers extending to at least 6 inches above grade.
- Re-use applications may require that the stored rainwater be pressurized. Stored water will exhibit a pressure of 0.43 psi per foot of elevation. Irrigation systems will usually require a minimum of 15 psi.

Source: PADEP, January 2005

14.3 Stormwater Performance

The employment of capture and reuse systems exhibits a positive impact on the volume, peak rate, and quality of stormwater runoff from a site.

The volume reduction is simply the volume of runoff from a single storm event that is captured and stored by the harvesting system. If the cistern or barrel is empty at the start of the precipitation event, the maximum potential volume reduction is the actual volume of the capture device.

Because capture and reuse devices take a volume of water out of the total site runoff, the reduced volume may result in a reduced rate of runoff from the site.

The removal of pollutants from stormwater entering a capture device takes place through filtration of the recycled primary storage, and natural filtration through soil and vegetation of any overflow discharge. A number of factors influence the pollutant removal

performance of a rainwater harvesting system. These include the volume below the outlet of the system allocated to sediment accumulation, the hydraulic residence time, and the frequency of maintenance.

14.4 Design Approach

The first design element to consider in the installation of a capture and reuse system is that of a first flush diverter. Rooftops can collect dust, leaves, twigs, insect bodies, animal feces, pesticides, and other airborne residue. A first flush diverter routes the first flush of stormwater from the catchment surface away from the storage tank. A number of factors influence the recommended volume of water that should be diverted. These include the frequency of dry days, amount of accumulated debris, and the catchment area. One rule of thumb for first flush diversion is to divert a minimum of 10 gallons for every 1,000 square feet of collection surface. (Texas Water Development Board, 2005)

The most basic first flush diverter is a 6 or 8 inch PVC standpipe. The diverter fills with the first-flush volume, backs up, and then allows water to enter the conveyance and storage system. A pinhole drilled at the bottom of the pipe or a hose bib fixture left slightly open permits the gradual leakage of the first-flush volume (TWDB, 2005). The following lengths of PVC piping are required for first flush storage.

Diameter (in)	Length (inches) per Gallon of Storage
3	33
4	18
6	8
8	5

Table 14.1. Length of Piping Per Gallon of Storage (TWDB, 2005)

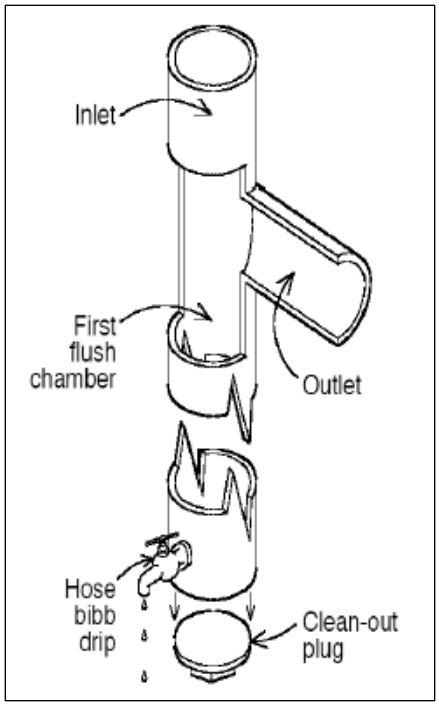

Figure 14.5. Simple Standpipe First Flush Diverter
(TWDB, 2005)

Another variation of first flow capture devices is the standpipe equipped with a ball valve. In this configuration, as the chamber fills, the ball floats up and seals on the seat, trapping the first flush water and routing additional inflow into the storage tank.

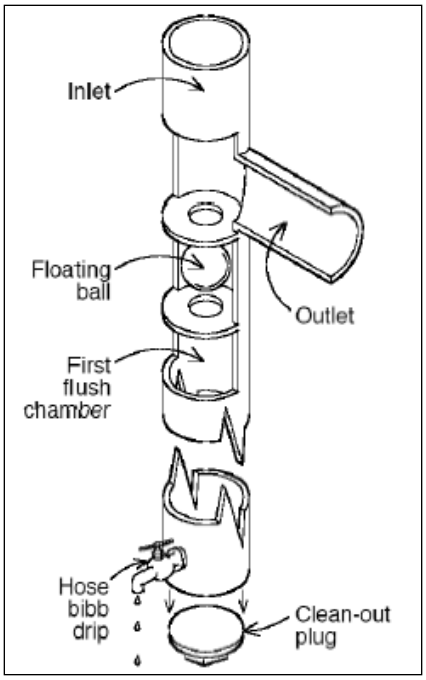

Figure 14.6. Standpipe With Ball Valve
(TWDB, 2005)

The next step in the design process is to size the capture system. Typically, the system must be designed such that the volume of water captured and stored equals or exceeds the volume of water for which anticipated use is planned (demand). The first consideration is that of how much water can be collected. Theoretically, about 0.62 gallons of water per square foot per inch of rainfall can be collected; however, in practice, some precipitation is lost to the first-flush bypass, evaporation, splash-out, and leakage. Rough catchment surfaces are less efficient at conveying water, as water trapped in pore spaces tends to be lost to evaporation. Additionally, intense rainfall events often result in the inability of the system to capture the entire volume of water landing on the catchment surface. Obviously, once storage cisterns or barrels are full, rainwater is lost as overflow. For design purposes, collection efficiencies of 75 to 90 percent should be considered. The catchment area is the "footprint" of the roof. Regardless of the roof pitch, the total area covered by the collection surface should be considered in estimating the supply of captured water. Only catchment areas whose runoff is collected by a conveyance system (roof gutter) should be considered. (TWDB, 2005)

One popular method for sizing a rainwater harvesting and storage system is to employ the monthly water balance method. This method begins by assuming a volume of rainwater already in storage, adding the volume of water captured each month, and subtracting the demand. Two different methods of estimating monthly rainfall are commonly used; the *average rainfall method*, and the *median rainfall method*. The Virginia State Climatology Office maintains an online database with monthly climate information from various stations across the state. This information can be obtained at:

http://climate.virginia.edu/online_data.htm#monthly

Average rainfall is computed by summing historical rainfall and dividing it by the period of record. Median rainfall is the amount of rainfall that occurs in the midpoint of all historic rainfall totals for any given month. When the data is available, employing the median rainfall provides for the most conservative approach to sizing rainfall harvesting systems. The following example shows a typical water budget approach to determining the feasibility and sizing of a rainfall harvesting system.

Given Data: Average monthly rainfall for Louisa County
2,500 square-foot catchment area
85% assumed catchment efficiency
Demand as shown in Table 13.2 on the following page

The supply of monthly rainfall is computed as the product of average rainfall, catchment area, catchment efficiency, and the 0.62 gallons per square foot per inch of rainfall constant. The calculation of monthly supply is shown below for January with an average precipitation of 3.14 inches:

Monthly Supply = (Catchment Area)(Average Rainfall)(Rainfall Constant)(Catchment Efficiency)

$$2{,}500\,ft^2 \times 3.14in \times 0.62\frac{gal/ft^2}{in} \times 0.85 = 4{,}137\,gal$$

This value is added to the initial storage volume at the beginning of the month (1,000 gallons for this example), and then the monthly demand is subtracted. The result becomes the initial volume for the month of February, and the calculation is repeated. The monthly budget calculation is presented in the following table with column (A) water demand is in gallons; (B) average rainfall is in inches; (C) rainfall collected is in gallons; and (D) end-of-month storage is in gallons.

Month	A Water Demand (gal)	B Average Rainfall (in)	C Rainfall Collected (gal)	D End of Month Storage (1,000 gal to start)
January	4,500	3.14	4,137	637
February	4,500	3.04	4,005	142
March	4,500	3.80	5,007	649
April	4,500	3.06	4,032	180
May	4,500	3.68	4,848	529
June	4,500	3.69	4,862	890
July	4,500	4.36	5,744	2,134
August	4,500	4.26	5,613	3,247
September	4,500	3.65	4,809	3,556
October	4,500	3.57	4,703	3,759
November	4,500	3.58	4,717	3,976
December	4,500	3.32	4,374	3,850

Table 14.2. Monthly Water Budget

Employing the average monthly rainfall and the monthly water budget approach, we see from Table 13.2 that the storage unit(s) in this scenario would be sized to hold a *maximum* of 3,976 gallons (observed at the end of November) in order to retain all excess rainwater and meet the demand for each month. Alternatively, the *minimum* size storage would only have to be 1,126 gallons [3,976 - (3,850 – 1000)] if the goal is to meet all monthly demands *and* have 1,000 gallons in storage at the end of December each year. In this scenario we must be willing to spill some water during heavy rainfall months.