

Summary Fact Sheet

Category: 1.0 Bioretention Systems

Practice: 1.5 Green Roofs

General Description: Green roofs, also known as vegetated roofs or eco-roofs, are structural components that help to mitigate the effects of urbanization on water quality by filtering, absorbing or detaining rainfall. They reduce runoff pollutant loadings through a variety of physical, biological and chemical treatment processes that filter pollutants and reduce the volume of roof runoff.

There are two basic types of green roofs: extensive and intensive. Extensive roofs form a thin vegetated sheath of self-sufficient mosses, sedums, and small shrubs. Their low profile allows them to be added to existing buildings, including those with sloping roofs. By contrast, intensive roofs are integral to the roof structure, permitting the use of trees and walkways. A greater depth of media and a greater roof structural capacity may be required to accommodate larger vegetation and surface features.

Water Quantity Controls

Green roofs store rainwater in the soil layer, reducing the volume and peak discharge rate of roof runoff. The storage capacity can be estimated using Equation 1. This equation is based on the fundamental principle of soil porosity and should be considered a general guideline. More complex calculations which route runoff through the green roof can be used for detailed analysis. Green roofs are generally sized to store the water quality volume (WQV), or the first 0.5" of rainfall. Adding additional soil depth will increase the storage capacity.

Equation 1:

$$\text{Storage volume} = (\text{green roof area}) * (\text{soil depth}) * (\text{soil porosity})$$

Part of the stored runoff will be retained on the roof and lost to evapotranspiration, and part of it will percolate down to the drainage layer and ultimately become surface runoff. The water retention capacity of the soil is dependent upon both the properties of the soil substrate and the vegetative cover, as well as climactic conditions.

Water Quality Controls

No conclusive water quality information can be presented at this time; research is ongoing.

Location: Green roofs can be placed on any residential, commercial, or industrial roof surface that is not reserved for patio or utility access.

Design Construction and Materials: Green roofs consist of several layers. From the bottom up, they are the waterproof membrane, root barrier, insulation layer, drainage layer, growing medium, and vegetation. A drainage layer is needed for flat roofs but may not be necessary for sloped roofs. A leak detection layer is optional.

The primary design variable is whether to construct an intensive or extensive roof, as described above. The decision may be influenced by the property owner's desired maintenance level and by the roof's structural capacity. Soil depth is another design variable and will determine the water storage capacity. Because all roofs in Fairfax County are designed to handle snow loads,

roof structures should easily be able to support the weight of a saturated extensive green roof. Intensive green roofs may require additional structural capacity.

Green roof plants are hardy, self-sustaining, drought-resistant plants mainly from the genres Sedum and Delosperma and are available from a variety of vendors.

Costs for extensive green roofs in the United States are \$15 to \$20 per square foot for all use types (e.g. high density residential, commercial, industrial). These costs include all green roof components, including the waterproofing membrane, soil substrate, and planting. By far, the highest costs associated with green roof construction are the soil substrate and the specialized plants. Planting costs are higher if plants are placed individually rather than pre-grown on vegetation mats.

Cost: Costs are given for an extensive green roof. The cost for a ½ acre (21780 ft²) extensive green roof is comprised of both the installation cost and annualized costs. A green roof is assumed to have a lifespan of 25 years, at which point it will be removed and replaced.

Item	Required Cost per Year (2005 Dollars)													
	0	1	2	3	4	5	6	7	8	9	10	...	25	
Installation ¹	250,000													
Weeding		500	500	500	500	500	500	500	500	500	500	500		
Infill with cuttings ²						6000						6000		
Soil replenishment						1000						1000		
Remove & Replace														250,000
Total Cost	250,000	500	500	500	500	500	7500	500	500	500	500	7500		250,000
Annualized Cost	\$11,600 / year (includes replacement in year 25). Excluding replacement: \$1,600 / year													

¹Developer Cost. Not included in annualized cost.

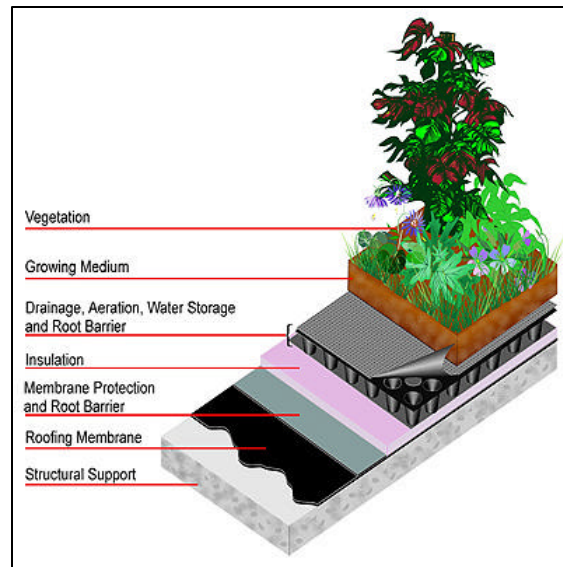
²Assume 5% of area needs replanting, and a density of 2 plugs per square foot.

Maintenance: Once a properly-installed green roof is established, its maintenance requirements are usually minimal. The main requirements for extensive roofs are weeding and periodic soil and plant replenishment. Intensive roofs require more structural as well as horticultural maintenance, similar to a conventional garden, because plantings tend to be both heavier and more elaborate than on extensive roofs.

Corrective actions for green roofs are generally limited to localized repairs. Repair leaks as necessary. An electric leak survey (i.e. Electrical Field Vector Mapping) can be performed to locate leaks in the membrane. More complex systems may have monitoring devices incorporated into the membrane. The soil media can be removed and the membrane repaired as needed. Long periods of drought or loss of soil to extreme high winds may require replacement of the media or replanting. If drought becomes an issue, corrective actions include installing an irrigation system or scheduling supplemental watering.

Performance and Inspection:

Soil stability and plant vitality are key to the function of green roofs. Green roofs should be inspected annually for erosion and plant health. However, wind or water erosion should not be a concern because of the plants' dense root structure. If erosion occurs, add soil, replant, and place temporary erosion control netting. Replace dead plants as necessary. Note: if slow-growing plants are selected, more than one season may be necessary to achieve full growth.



Extensive green roof cross-section

Source: American Wick Drain Corp.



Extensive green roof in Baltimore

Source: Katrin Scholz-Barth Consulting.

Potential LEED Credits:

- Primary: Sustainable Sites – Credit 7.2 “Landscape & Exterior Design to Reduce Heat Islands” (1 Point)
- Sustainable Sites – Credit 6 “Stormwater Management” (1-2 Points)
- Water Efficiency – Credit 1 “Water Efficient Landscaping” (1-2 Points)
- Other: Innovation & Design Process (1-4 Points)

Links to Additional Information:

Fairfax County Department of Public Works and Environmental Services. 2001. “Stormwater runoff quality control criteria.” *Public Facilities Manual*, 6-0400. Available at <http://www.co.fairfax.va.us/dpwes/publications/pfm/6-0400.htm>

Virginia Department of Conservation and Recreation. 2004. *Green Roof Project, Fairfax, Virginia*. Available at <http://www.dcr.virginia.gov/sw/docs/greenroofffx.pdf>