Green Roofs

Description: A vegetated roof cover composed of hardy plants growing in an engineered plant medium, filter cloth, drainage layer, and waterproofing membrane. Green roofs provide benefits such as reducing runoff volume and peak discharge rate, reducing building cooling costs, and prolonging roof life.

Variations: Lightweight extensive roof covers and heavier-weight intensive roof covers, or "roof gardens." Can be accessible or inaccessible.

Components:

- Vegetation selected for its ability to thrive in rooftop climate.
- Engineered planting medium, not soil, typically composed of expanded clay or a mixture of clay and other materials.
- Filter layer.
- Containment (in modular systems refers to plant containers; in non-modular systems refers to barriers at roof perimeter and drainage structures).
- Drain layer, sometimes with built-in water reservoirs.
- Water proofing layer or roof membrane with root repellant.

Advantages/Benefits:

- Reduces site imperviousness for water quality treatment calculation
- Reduces Rational C number for overall site
- Energy savings: green roofs keep buildings cool
- Stormwater retention and water quality treatment
- Possible amenity space for public or users
- Prolongs roof life
- Sound absorption
- Life cycle costs comparable to traditional roof

Disadvantages/Limitations:

- For retrofits, strengthening structure may be required
- If leaks occur, may be harder to trace
- Design and installation require specialized knowledge
- Installation costs higher than for traditional roof

Design considerations:

- Good waterproofing material and installation are essential.
- Materials used must be lightweight.
- Building structure must be able to support saturated weight.
- Roofs with moderate to flat slopes are most appropriate. Maximum roof slope of 15%.

Selection Criteria:

✓	**Water Quality 80 % TSS Removal**
NA	**Accepts Hotspot Runoff**
✓	**Residential Subdivision**
✓	**High Density / Ultra Urban Use**

Maintenance:

- Watering and fertilization until well-established
- Occasional weeding
- Inspection for proper drainage
- Ordinary life cycle roof replacement

L	**Maintenance Burden**

L = Low M = Moderate H = High

General Description

A green roof is a vegetated roof cover that allows the roof to provide several environmental benefits. Although modern green roofs have only recently been embraced in urban American design, they have been used for centuries both as functional elements (to provide insulation to homes) and as amenities (to provide enjoyable "roof garden" space for city residents).

There are two classes of roof top vegetation systems: extensive and intensive. Each of these types can be further classified as accessible or inaccessible green roofs. Extensive systems, also known as low-profile, performance, or eco-roofs, are composed of a waterproof membrane covered with a shallow layer (4-6 inches) of growing medium and low growing vegetation. Intensive systems, also known as high profile or roof gardens are heavier weight systems that consist of a waterproof membrane covered with a deeper layer (6 to 24 inches) of growing medium and a variety of vegetation including some deeper-rooted vegetation (even trees). Either of these types of green roofs can be made accessible to the residents or users of a building or the general public and provide a green space and amenity to the users. However, it is more common for intensive green roofs to be designed as accessible space, while extensive green roofs are often only accessed for inspections and maintenance.

Green roofs provide numerous economic and environmental benefits. Green roofs prolong roof life by reducing temperature fluctuations on rooftops, thus reducing the stress caused by expansion and contraction of roofing materials and supports in variable temperatures. In addition, green roofs provide insulation to buildings, which reduces heating and cooling costs. The vegetation itself cools the rooftop as well. An accessible green roof can increase the unit value of apartments, condominiums, or office space.

While green roofs provide environmental benefits such as cleaning fine, airborne particles from the air (improving air quality), cooling buildings (reducing the urban heat island effect), and providing habitat for various types of plants and animals, the main focus of their use in Metro is the benefit to stormwater. The vegetated roof covers provide various stormwater benefits. Because green roofs are permeable surfaces, they slow runoff, attenuating the peak runoff rate. In addition, green roofs retain water, reducing runoff volumes from the roof. Finally, water quality off of green roofs is improved through the filtering of stormwater.

Key design considerations include structural capacity and the waterproofing layer.

The components of a green roof are as follows:

1. Structural roof support sufficient to hold green roof weight. For retrofit projects, an architect, structural engineer, or roof consultant must determine if added support to the building structure is needed.

General Description (Continued)

2. Waterproof membrane appropriate for green roof. These impermeable materials come in a number of forms, such as large sheets, rolls, or liquid form; and materials, such as bituminous membranes and liquid polymer-modified asphalt products, synthetic thermoset, hypalon, and reinforced thermoplastic resin. During construction, protective material for the waterproof membrane is necessary so that it is not punctured or damaged during the green roof installation stage. The protective layer also prevents breakdown from UV rays.
3. Root barrier, if not integral to membrane. Some waterproof membranes are equipped with an integral root barrier, which prevents the membrane from being compromised. However, other membrane products need an added root barrier.
4. Drainage layer. The drainage layer prevents damage to the waterproof membrane by draining excess rainfall off the roof through roof drains. In addition, it keeps the vegetation from drowning or rotting. The drainage can consist of a manufactured mat or a layer of gravel.
5. Filter fabric between the drainage layer and the growing medium prevents clogging.
6. Growing medium. A lightweight, well-drained engineered medium in which the vegetation grows. Typical components include: pumice perlite, expanded clay, sand, shale, compost, and coir.
7. Vegetation. Extensive green roofs must have hardy drought-tolerant plants such as succulents. These perennial plants should require little maintenance except while they are being established. Intensive green roofs that are used as amenity spaces can support a wider variety of plants, even shrubs and trees, since they are maintained areas, but hardy species are advisable.

Design and Implementation Considerations

The following design and implementation considerations must be incorporated into green roofs:

Structure
The structural capacity of the building must be sufficient to support the saturated weight of the green roof system. On new construction, it is relatively inexpensive to incorporate the structural requirements of the green roof at the outset. An existing building should be able to hold an additional 10 to 30 psf (for an extensive green roof). Structural retrofits to existing buildings can be costly.

Slope
The maximum slope for a roof with a vegetated system should be 15 percent. Studies have shown that gently sloping or flat roofs retain more runoff and thus fulfill the intended stormwater functions better. Note that steeper roofs require that the planting medium and vegetation layers do not slump or slip under their own weight, especially when wet, through the use of strapping or other methods.

Use
The intended function of the green roof affects design. Green roofs in Metro should be designed to perform stormwater functions of retention, peak flow attenuation, and filtration. It may also be desired that green roofs serve as green space, in which case accessibility and aesthetics will also be important design considerations.

Roof Climate
The microclimate on the roof, which is affected by the height of the roof, wind exposure, orientation to the sun, shading by other buildings, rainfall, temperatures, and humidity are important factors in green roof design, particularly in vegetation selection.

Waterproof Membrane
The waterproof membrane is a crucial component of the green roof system. Membranes come in various materials: bitumens, synthetic thermoset, hypalon and reinforced thermoplastic resin. If the membrane contains any organic material (bitumen is most common), a root barrier is necessary to prevent root penetration and destructive micro-organic activity. Many roof membranes are manufactured with root repellant as an integral component. Membranes with pesticides as an integral component are not permitted.

Drainage
Although green roofs retain a great deal of stormwater, drainage from the entire system is still a necessary design component so that the roofing membrane is not compromised and so that the vegetation does not drown or rot. Proper drainage can be provided in a number of ways. Commonly, drainage mat systems with pockets for water storage are used. The drainage layer must be protected by filter

Design and Implementation Considerations (Continued)

fabric. The drainage layer directs excess rainfall off of the roof through roof drains and downspouts. When impervious areas drain to the roof, flow directed to the green roof from these areas must be distributed evenly to prevent scour.

Protection
Parapets, edges, flashing, skylights, vents, chimneys, and mechanical systems must be well protected with a gravel skirt, and sometimes with a weep hole.

Growing Medium
Growing medium should be a lightweight mineral-based mix. Common components include pumice perlite, expanded clay, sand, shale, compost, and coir.

Vegetation
Vegetation must be suitable for harsh rooftop climates unless shading, irrigation, and fertilization will be provided. Plants must thoroughly cover the soil, at least 90% coverage. On extensive roofs, it is most practical to install hardy and indigenous plants such as succulents, sedums, mosses, semperviviums, and festucas that can survive with little maintenance aside from watering and fertilization in the short term, while the plants establish themselves. On intensive green roofs, a wide variety of plants, bushes, and even trees can make up the vegetation. Intensive green roofs require more maintenance than extensive green roofs.

Vegetation Installation
There are common methods of establishing vegetation on green roofs:

Method	Description/Advantages	Disadvantages
Vegetation Mats	Sod-like mats with pregerminated seeds. Provide full coverage, erosion control, with little maintenance or weeding requirements.	Little flexibility in design.
Plugs or potted plants	Well-rooted seedlings raised in a nursery and then planted on the green roof.	Take longer to achieve coverage, erosion control, need more watering and weeding.
Sprigs	Cuttings that are hand broadcast.	More maintenance than mats.
Seeds	Can be handbroadcast or hydroseeded.	More maintenance than mats.

Access
Access to the green roof is important, not only for maintenance but for the initial installation of the green roof. Materials including the membrane, drainage materials, growing medium, and plants will need to be brought up to the roof. This will be easiest if there is an elevator that goes to the roof. Otherwise,

Design and Implementation Considerations (Continued)

material must be hauled up via stairs, utility ladders, or even a crane. New buildings should be designed with easy access to the roof.

If the green roof is designed to be accessible, the access must not only be convenient for installation and maintenance purposes but also must adhere to Metro Building Codes and other regulations for access and safety.

Construction and Installation

It is best to choose a roof installer who has experience in working with green roof systems. Because an industry has built up around green roofs, it is possible to find companies that specialize in green roofing. Some companies specialize in handling the whole green roofing process from re-roofing to installation and initial maintenance, some have experience with design of green roofs, while others have created special components for use on green roofs.

As-Built Certification Considerations

After the green roof has been constructed, the developer must have an as-built certification of the green roof conducted by a registered professional engineer. The as-built certification verifies that the BMP was installed as designed and approved.

The following components are vital components of a properly working green roof and must be addressed in the as-built certification:

1. Protection of vulnerable areas (abutting vertical walls, roof vent pipes, outlets, air conditioning units, and perimeter areas) from leakage;
2. Profile view of facility including typical cross-sections with dimensions;
3. Growing medium specification including dry and saturated weight;
4. Filter fabric specification;
5. Drainage layer specification;
6. Waterproof membrane specification, including root barriers;
7. Stormwater piping associated with the site, including pipe materials, sizes, slopes, invert elevations at bends and connections; and
8. Planting and irrigation plan.

Operation and Maintenance

Each BMP on a site must be addressed in the overall Operations and Maintenance (O&M) Agreement (refer to Volume 1, Appendix C) for the development and submitted to Metro for approval with the plans submittal. The components of the O&M Agreement can be found in Section 6.7.1 of Volume 1. This section generally outlines the inspection and maintenance needs specific to green roofs. More detailed inspection and maintenance information can be found in Appendix C of Volume 1 in the form of an inspection and maintenance checklist. This information should be included in the O&M Agreement for the development.

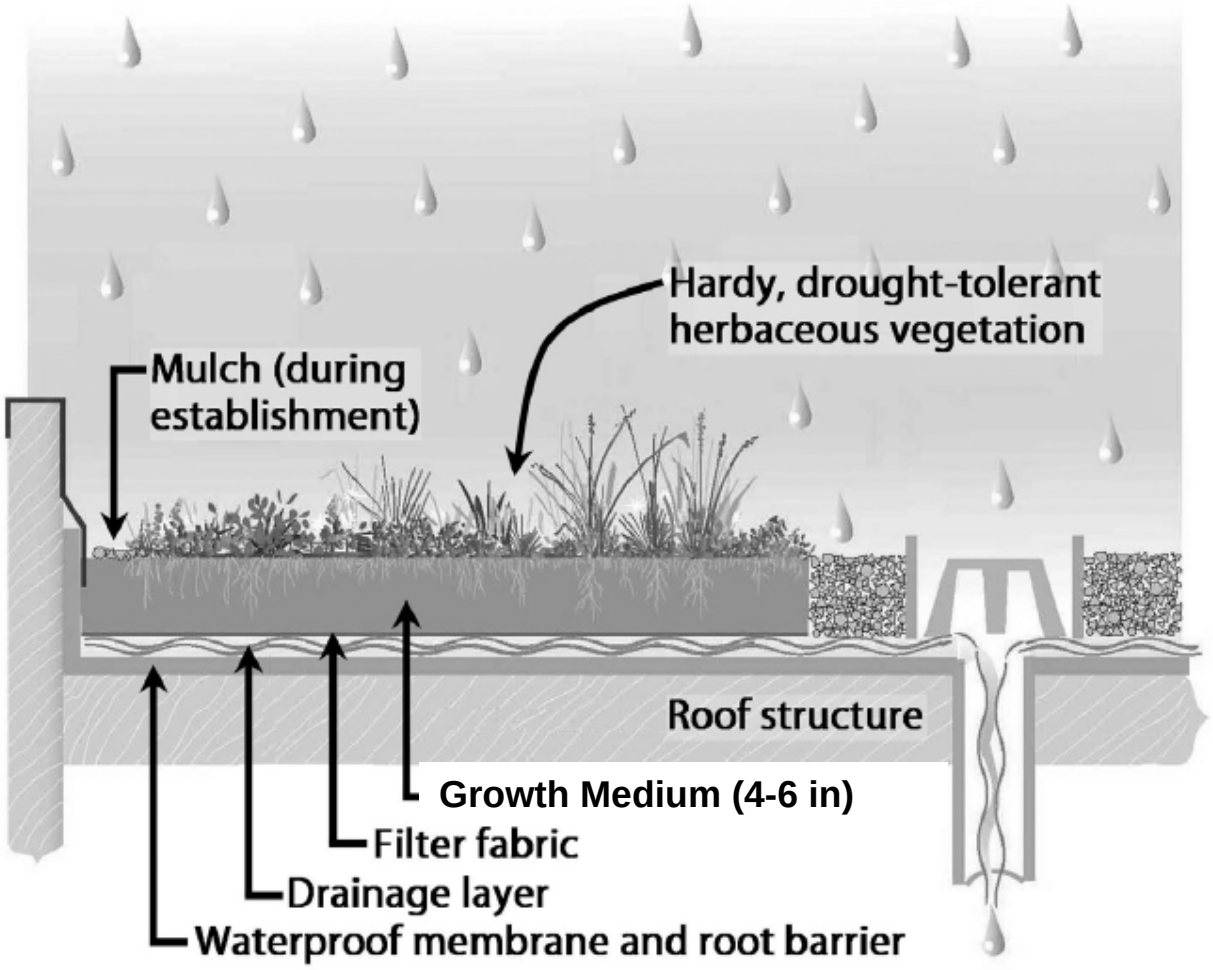
The O&M Agreement is to be used by the BMP owner or owners in performing routine inspections. The owner is responsible for the cost of maintenance and annual inspections, and the BMP owner must maintain and update the BMP operations and maintenance plan at least annually. At a minimum, the operations and maintenance plan must address:

1. Inspect and repair/replace green roof system components.
2. Ensure survival of vegetation.
3. Remove debris or dead vegetation.

Design Procedures

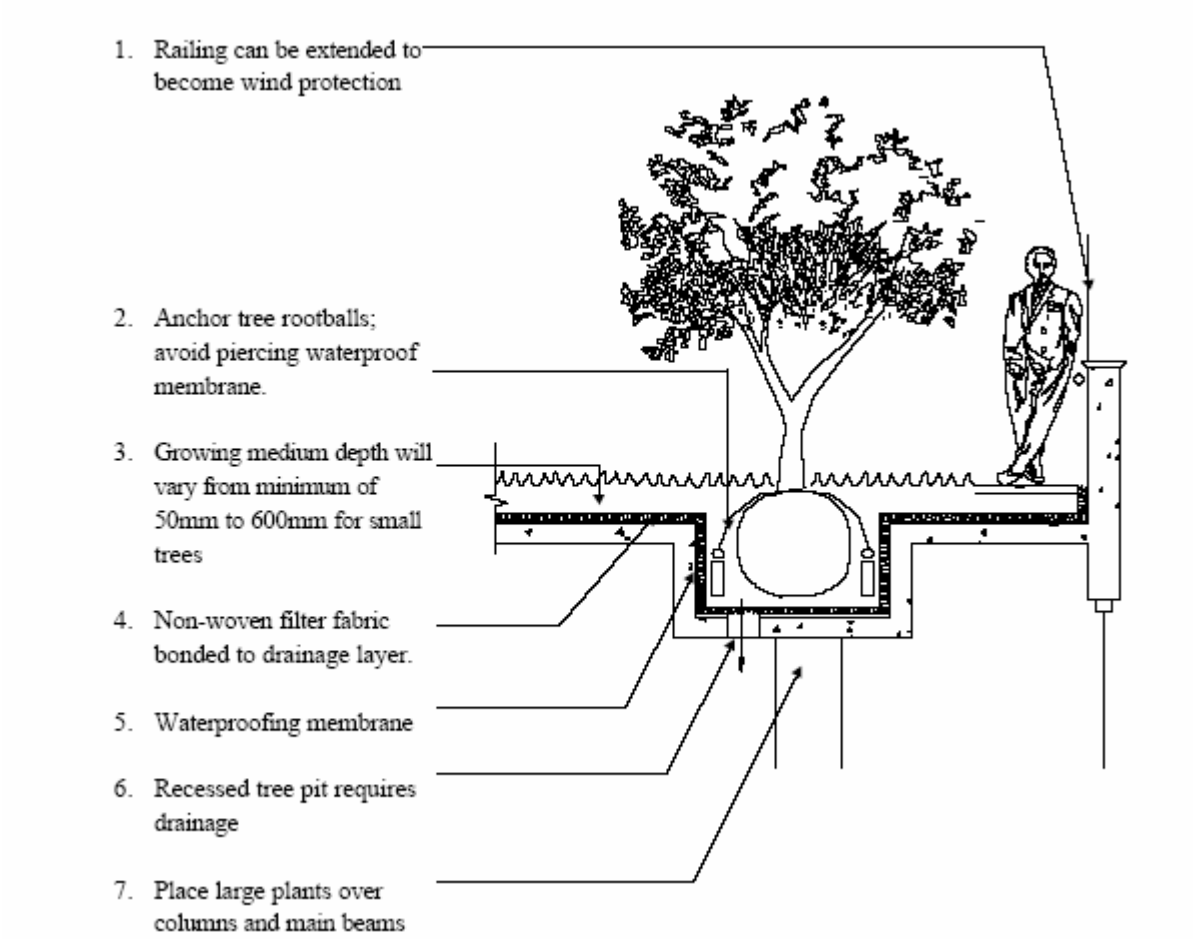
Specialized design and installation companies should be consulted for the design of the green roof.

For the purposes of water quality volume calculations, the area of the building(s)'s roof that is covered with the green roof structure is subtracted from the site's impervious area. Thus, the advantage of a green roof, from a water quality treatment volume standpoint is that the green roof reduces the WQ_v through the reduction in site's imperviousness percentage.



(*Source: Massachusetts Low Impact Development Toolkit)*

Figure 9.1 Extensive Green Roof (4 to 6 inches of growth medium)



Source: Public Works and Government Services Canada, 2002

Figure 9.2 Intensive Green Roof (6 to 24 inches of growth medium)

References

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Maryland Department of the Environment, 2000. Maryland Stormwater Design Manual, Volumes I and II. Prepared by Center for Watershed Protection (CWP).

Stormwater Manager's Resource Center. Accessed July 2004. Manual Builder. *www.stormwatercenter.net*.

Suggested Reading

Greenroof Research Program, Michigan State University. http://www.hrt.msu.edu/greenroof/

Greenroofs for Healthy Cities. http://www.greenroofs.net/index.php