Green Roof

Description: A green roof is a layer of vegetation installed on top of a conventional flat or slightly sloped roof that consists of waterproofing material, root permeable filter fabric, growing media, and specially selected plants.

Advantages/Benefits:

- Runoff volume reduction
- Provides flow attenuation
- Extends the life of a conventional roof by up to 20 yrs.
- Provides increased insulation and energy savings
- Reduces air pollution
- Provides habitat for wildlife
- Increases aesthetic value
- Reduces urban heat island effect

Disadvantages/Limitations:

- Cost may be greater than a conventional roof
- Feasibility may be limited by load-bearing capacity of roof
- Requires more maintenance than a conventional roof
- Plant survival and waterproofing are potential issues
- May require irrigation

Selection Criteria:

40% – 90% Runoff Reduction Credit

Land Use Considerations:

X	**Residential**
X	**Commercial**
X	**Industrial**

Maintenance:

- May include watering, fertilizing, and weeding, typically greatest in the first two years when plants are becoming established.
- Maintenance largely depends on the type of green roof system installed and the type of vegetation planted.

M **Maintenance Burden**
L = Low M = Moderate H = High

SECTION 1: DESCRIPTION

Green roofs (also known as *vegetated roofs, living roofs,* or *ecoroofs*) are alternative roof surfaces that typically consist of waterproofing and drainage materials and an engineered growing media that is designed to support plant growth. Green roofs capture and temporarily store stormwater runoff in the growing media before it is conveyed into the storm drain system. A portion of the captured stormwater evaporates or is taken up by plants, which helps reduce runoff volumes, peak runoff rates, and pollutant loads on development sites.

There are two different types of green roof systems: intensive green roofs and extensive green roofs. Intensive systems have a deeper growing media layer, which is planted with a wider variety of plants, including shrubs and trees. By contrast, extensive systems typically have much shallower growing media (under 6 inches), which is planted with carefully selected drought tolerant vegetation such as sedums. Extensive green roofs are lighter and typically less expensive than intensive green roofs and are recommended for use on most development and redevelopment sites.

Green roofs typically contain a layered system of roofing, which is designed to support plant growth and retain water for plant uptake while preventing ponding on the roof surface. The roofs are designed so that water drains vertically through the media and then horizontally along a waterproofing layer towards the outlet. Green roofs are designed to have minimal maintenance requirements. Plant species are selected so that the roof does not need supplemental irrigation or fertilization after vegetation is initially established. Tray systems are also available with removable dividers allowing the media to meld together creating a seamless appearance but with less difficulty in construction.

SECTION 2: PERFORMANCE

The overall stormwater functions of green roofs are summarized in **Table 11.1**.

Table 11.1: Runoff Volume Reduction Provided by Green Roofs

Stormwater Function	Level 1 Design	Level 2 Design	Level 3 Design	Level 4 Design
Runoff Volume Reduction (RR)	40%	60%	80%	90%
Treatment Volume (Tv) Multiplier*	1.0	1.1	1.25	1.25

*Incorporated into LID spreadsheet calculations

SECTION 3: SCHEMATICS

See **Appendix 11-A** for schematics for use in green roof design.

SECTION 4: PHYSICAL FEASIBILITY & DESIGN APPLICATIONS

Several site-specific features influence how green roofs 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 green roofs into the site design. The following are key considerations:

Available Space. A prime advantage of green roofs is that it does not normally require additional space at a new development or redevelopment site, which can be important for tight sites or areas where land prices are high.

Accessibility. Green roof facilities must be accessible to various types of equipment for periodic maintenance. The design may include non-vegetated walkways (e.g., permeable paver blocks) to allow for easy access to the roof for weeding and making spot repairs.

Contributing Drainage Area. Green roofs are intended to capture and treat only the precipitation that falls on their own footprint. Nominal areas of run-on may be permitted with MWS staff approval.

Structural Capacity of the Roof. A structural engineer, architect, or other qualified professional should be involved with all green roof designs to ensure that the building has enough structural capacity to support a green roof.

Roof Pitch. Treatment is maximized on relatively flat roofs (a pitch of 1 to 2%). Some pitch is needed to promote positive drainage and prevent ponding and/or saturation of the growing media. Green roofs can be installed on rooftops with slopes up to 8%.

Building Codes. The green roof design should comply with the Metro Building Codes with respect to roof drains and emergency overflow devices. 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.

Irrigation or Baseflow. The green roof shall not receive non-stormwater flows, except for irrigation as necessary during the first growing season for the survival of plantings.

Applications. Green roofs are ideal for use on commercial, institutional, municipal and multi-family residential buildings. They are particularly well suited for use on ultra-urban development and redevelopment sites. Designers may wish to pursue other design objectives for vegetated roofs, such as energy efficiency, green building or LEED points, architectural considerations, visual amenities and landscaping features, which are often maximized with intensive vegetated roof systems. However, these design objectives are beyond the scope of this specification.

SECTION 5: DESIGN CRITERIA

5.1 Sizing of Green Roof

5.1.1 Stormwater Quality

Green roof areas should be sized to capture the Treatment Volume (Tv). The required size of a green roof will depend on several factors, including the porosity and hydraulic conductivity of the growing media and the underlying drainage materials. Designers may choose between either a Level 1, Level 2, Level 3, or Level 4 design that maximizes nutrient and runoff reduction.

Sizing of the surface area (SA) for green roofs is based on the computed Treatment Volume (T_v) of the contributing drainage area and the storage provided in the facility. The required surface area (in square feet) is computed as the Treatment Volume (in cubic feet) divided by the equivalent storage depth (in feet). The equivalent storage depth is computed as the depth of media (in feet) multiplied by the accepted porosity. Based on volume calculations, the minimum reservoir layer is sufficient to contain the required Treatment Volume for the typical green roof area. **Table 11.2** lists the design criteria for Level 1, 2, 3, and 4 designs.

Table 11.2 Green Roof Typical Section

	Level 1 (inches)	Level 2 (inches)	Level 3 (inches)	Level 4 (inches)	Porosity Value (n)
Vegetative Surface	Varies based on design or manufacturer's specification*				N/A
Media	4	6	8	9	0.3**
Drainage Layers	Varies based on design or manufacturer's specification*				N/A

*Must be in conformance to ASTM E2777-20 Standard Guide for Vegetative (Green) Roof Systems.

**Site designers and planners should consult with green roof manufacturers and material suppliers for specific porosity.

5.2 Functional Elements of a Green Roof System

A green roof is composed of up to eight different systems or layers, from bottom to top, that are combined to protect the roof and maintain a vigorous cover. Designers can employ a wide range of materials for each layer, which can differ in cost, performance, and structural load. The entire system as a whole must be assessed to meet design requirements. Some manufacturers offer proprietary vegetated roofing systems, whereas in other cases, the designer or architect must assemble their own system. Green roofs must be in conformance to ASTM E2777-20 Standard Guide for Vegetative (Green) Roof Systems.

5.3 Conveyance and Overflow

The drainage layer below the growth media should be designed to convey the 10-year storm without backing water up to into the growing media. The drainage layer should convey flow to an outlet or overflow system such as a traditional rooftop drainage system with inlets set slightly above the elevation of the green roof surface. Roof drains immediately adjacent to the growing media should be boxed and protected by flashing extending at least 3 inches above the growing media to prevent clogging.

5.4 Vegetation and Surface Cover

Plant selection for green rooftops is an integral design consideration, which is governed by local climate and design objectives. The primary ground cover for most vegetated roof installations is a hardy, low-growing succulent such as *Sedum, Delosperma, Talinum, Sempervivum, or Hieracium* that is matched to the local climate conditions and can tolerate the difficult growing conditions found on building rooftops. Nashville lies in the transition zone between USDA Plant Hardiness Zones 6 and 7 (AHS, 2003).

Vegetation Considerations:

- The species and layout of the planting plan should reflect the location of building, in terms of its height, exposure to wind, snow loading, heat stress, orientation to the sun, and shading by surrounding buildings.
- Designers should also match species to the expected rooting depth of the growing media, which can also provide enough lateral growth to stabilize the growing media surface.
- It is also important to note that many green roof plant species will *not* be native to the Southeast (which is in contrast to *native* plant recommendations for other stormwater practices, such as bioretention and constructed wetlands).
- When appropriate species are selected, most green roofs will not require supplemental irrigation, except during the first year that the green roof is being established and during periods of drought.
- Plant choices can be much more diverse for deeper intensive vegetated roof systems. Herbs, forbs, grasses, shrubs and even trees can be used, but designers should understand they have higher watering, weeding, and landscape maintenance requirements.

A planting plan must be prepared for a green roof by a Landscape Architect or by meeting the manufacturer's specifications. If a Landscape Architect is used, they shall certify the planting plan with certification statement, located on the planting plan. Standard certification statement can be found in **Appendix 11-B**.

5.5 Material Specifications

The American Society for Testing and Materials (ASTM) recently updated the Standard Guide for Vegetative (Green) Roof Systems (ASTM E2777-20). Specification for green roof components are described and referenced in **Table 11.3**.

Designers and reviewers should also fully understand manufacturer specifications for each system component, particularly if they choose to install proprietary "complete" vegetated roof systems or modules.

Table 11.3. Green Roof Material Specifications	
Material	**Specification**
Roof	Structural Capacity should conform to ASTM E2397, *Practice for Determination of Live Loads and Dead Loads Associated with Green (Vegetated) Roof Systems*. In addition, use standard test methods ASTM E2398 for *Water Capture and Media Retention of Geocomposite Drain Layers for Green (Vegetated) Roof Systems*, and ASTME 2399 for *Maximum Media Density for Dead Load Analysis*.
Waterproof Membrane	See Chapter 6 of Weiler and Scholz-Barth (2009) for waterproofing options that are designed to convey water horizontally across the roof surface to drains or gutter. This layer may sometimes act as a root barrier.
Root Barrier(Optional)	Impermeable liner that impedes root penetration of the membrane.
Drainage Layer	1 to 2-inch layer of clean, washed granular material, such as ASTM D448 size No. 8 stone. Roof drains and emergency overflow should be designed in accordance with Metro Codes.
Filter Fabric	Needled, non-woven, polypropylene geotextile. Density (ASTM D3776) > 16 oz./sq. yd., or approved equivalent. Puncture resistance (ASTM D4833) > 220 lbs., or approved equivalent.
Growth Media	Media should consist primarily of lightweight mineral aggregates and have an organic matter content < 15%. The silt content shall not exceed 15%. Media should provide sufficient nutrients and water holding capacity to support the proposed plant materials. Maximum medium water retention shall fall between 30% to 45% based upon ASTM E2399.
Plant Materials	Low plants such as sedum, herbaceous plants, and perennial grasses that are shallow-rooted, self-sustaining, and tolerant of direct sunlight, drought, wind, and frost are best for intensive green roofs. Plant species should be based upon the type and depth of growth media. See ASTM E2400, *Guide for Selection, Installation and Maintenance of Plants for Green (Vegetated) Roof Systems*.

SECTION 6: CONSTRUCTION

6.1 Construction Sequence

The typical construction sequence for green roof system installation is provided below. This can be modified to reflect different green roof system applications or expected site conditions.

Step 1. Construct the roof deck with the appropriate slope and material.

Step 2. Install the waterproofing method, according to manufacturer's specifications.

Step 3. Conduct a flood test to ensure the system is watertight by placing at least 2 inches of water over the membrane for 48 hours to confirm the integrity of the waterproofing system.

Step 4. Add additional system components (e.g., insulation, optional root barrier, drainage layer and interior drainage system, and filter fabric), taking care not to damage the waterproofing. Drain collars and protective flashing should be installed to ensure free flow of excess stormwater.

Step 5. The growing media should be mixed prior to delivery to the site. Media should be spread evenly over the filter fabric surface. The growing media should be covered until planting to prevent weeds from growing. Sheets of exterior grade plywood can also be laid over the growing media to accommodate foot or wheelbarrow traffic. Foot traffic and equipment traffic should be limited over the growing media to reduce compaction.

Step 6. The growing media should be moistened prior to planting, and then planted with the ground cover and other plant materials, per the planting plan, or in accordance with ASTM E2400. Plants should be watered immediately after installation and routinely during establishment.

Step 7. Conduct the final construction inspection (see **Section 9**). Then log the GPS coordinates for each green roof and submit them to MWS.

SECTION 7: AS-BUILT REQUIREMENTS

After the green roof has been constructed, the owner/developer must have an as-built certification of the green roof conducted by a registered Professional Engineer. The as-built certification verifies that the GIP was installed per the approved plan. The following items shall be provided in addition to the as-built requirements found in SWMM Volume 1.

1. Landscape Architect letter certifying that the SCM plantings have been installed in general conformance with the approved grading plans.
2. The Engineer shall include a copy of the GIP summary table found in **Appendix 11-C**.
3. Supporting documents such as invoices and photos shall be included in the submittal package.

SECTION 8: MAINTENANCE

8.1 Maintenance Inspections and Ongoing Operations

The requirements for the Maintenance Document are in Appendix C of Volume 1 of the Manual. They include the execution and recording of an Inspection and Maintenance Agreement or a Declaration of Restrictions and Covenants, and the development of a Long Term Maintenance Plan (LTMP) by the design engineer. The LTMP contains a description of the stormwater system components and information on the required inspection and maintenance activities. The property owner must submit annual inspection and maintenance reports to MWS.

A vegetated roof should be inspected twice a year during the growing season to assess vegetative cover, and to look for leaks, drainage problems and any rooftop structural concerns (see **Table 11.4**). In addition, the vegetated roof should be hand-weeded to remove invasive or volunteer plants, and plants/media should be added to repair bare areas (refer to ASTM E2400). Many practitioners also recommend an annual application of slow release fertilizer in the first few years after the vegetated roof is installed.

If a roof leak is suspected, it is advisable to perform an electric leak survey (i.e., Electrical Field Vector Mapping) to pinpoint the exact location, make localized repairs, and then reestablish system components and ground cover.

The use of herbicides, insecticides, and fungicides should be avoided, since their presence could hasten degradation of the waterproof membrane. Also, power-washing and other exterior maintenance operations should be avoided so that cleaning agents and other chemicals do not harm the vegetated roof plant communities.

Table 11.4. Typical Maintenance Activities Associated with Green Roofs	
Activity	**Schedule**
Water to promote plant growth and survival.	As needed
Inspect the vegetated roof and replace any dead or dying vegetation.	Following Construction
Inspect the waterproof membrane for leaking or cracks.	Semi-annually
Annual fertilization.	As needed
Weeding to remove invasive plants.	As needed
Inspect roof drains, scuppers and gutters to ensure they are not overgrown or have organic matter deposits. Remove any accumulated organic matter or debris.	Semi-annually
Inspect the green roof for dead, dying or invasive vegetation. Plant replacement vegetation as needed.	As needed

SECTION 9: REFERENCES

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APPENDIX 11-A
SCHEMATICS

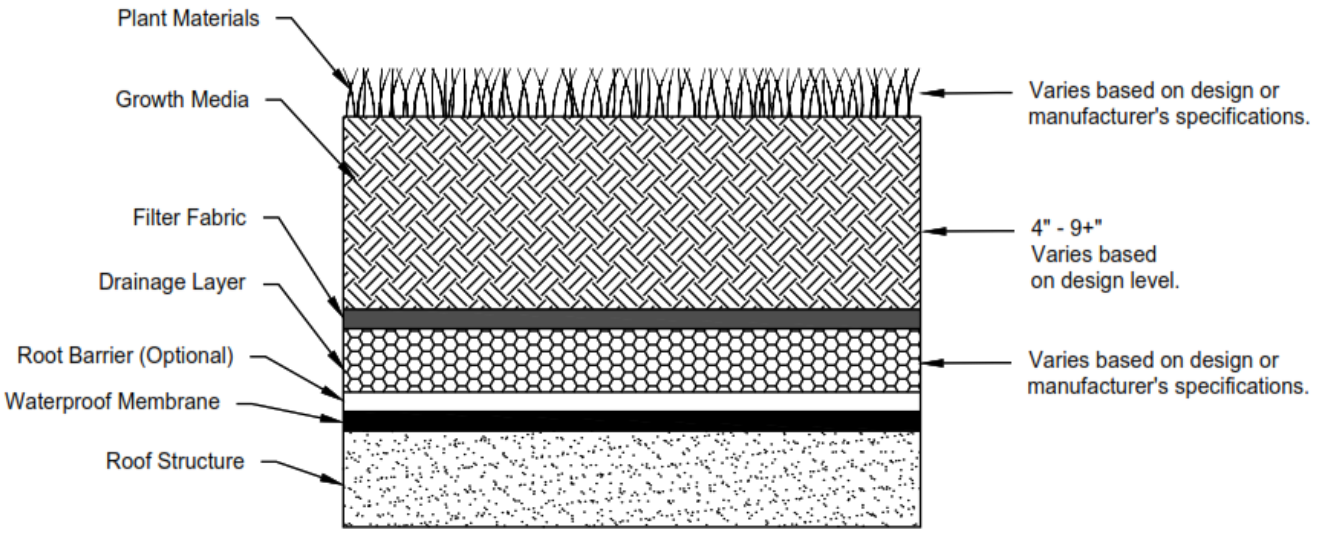

Figure 11.1. Typical Section – Intensive Vegetated Roof

APPENDIX 11-B
STANDARD NOTES

Required Green Roof Note:

- I hereby certify that this green roof planting is in keeping with the requirements listed in GIP-11. This green roof system is designed to establish a full and vigorous cover.

APPENDIX 11-C
AS-BUILT REQUIREMENTS

A printer friendly version of this table can be found on the MWS Development Services website or by request.

Green Roof Number:

	Design	As-Built
GIP Surface Area (SF)		
Media Depth (in)		

APPENDIX 11-D
MISCELLANEOUS PHOTOS

Figure 11.2. Photos of Vegetated Roof Cross-Sections (source: B. Hunt, NCSU)