4.5 Green Roofs

Introduction

Green roofs (Figure 4.5-1) are practices that capture and store rainfall in an engineered growing media that is designed to support plant growth. A portion of the captured rainfall evaporates or is taken up by plants, which helps reduce runoff volumes, peak runoff rates, and pollutant loads on development 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. Extensive 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.

Green roofs are typically not designed to provide stormwater detention of larger storms (e.g., 2-year and 10-year) although some intensive green roof systems may be designed to meet these criteria. Green roof designs should generally be combined with a separate facility to provide large storm controls.

Design variants include Extensive Green Roofs, which have a shallow growing media layer that ranges from 3 to 6 inches thick, and Intensive Green Roofs, which have a growing media layer that ranges from 6 to 48 inches thick. This specification is intended for situations where the primary design objective of the green roof is stormwater management and, unless specified otherwise, addresses the design of extensive roof systems.

Figure 4.5-1. Green Roof (Photo: Center for Watershed Protection)

KEY CONSIDERATIONS: GREEN ROOFS

DESIGN CRITERIA:

- The use of extensive green roof systems (3 to 6 inches deep) should be considered prior to the use of more complex and expensive intensive green roof systems.
- Engineered growing media should be a light-weight mix and should contain less than 20% organic material.
- Waterproofing materials should be protected from root penetration by an impermeable root barrier.

BENEFITS:

- Helps reduce pollutant loads and post-construction runoff volumes without consuming valuable land.
- Particularly well suited for use on urban development and redevelopment sites.

LIMITATIONS:

- Can be difficult to establish vegetation in the harsh growing conditions found on rooftops in coastal South Carolina.
- Typically applied on flat roofs (1% to 2% pitch) but can be installed on roofs with up to 30% pitch if baffles are used.

SITE APPLICABILITY:

- Suburban Use
- Urban Use
- Construction Cost: High
- Maintenance: Low
- Area Required: Low

STORMWATER MANAGEMENT PRACTICE PERFORMANCE:

Runoff Reduction Credit Approach
(applies to Shellfish Bed, SMS4, and infiltration credit approaches)

- ▶ 100% credit for storage volume of practice

Coastal Zone Credit Approach

- ▶ 100% credit for storage volume of practice

Statewide Water Quality Requirement Credit Approach

- ▶ Runoff Reduction credit applies to infiltration requirement.

Pollutant Removal[1]
80% - Total Suspended Solids
45-60% - Total Phosphorus
45-60% - Total Nitrogen
N/A - Metals
45-60% - Pathogens

[1] = expected annual pollutant load removal

Green Roof Feasibility Criteria

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. Key constraints with green roofs include the following:

Structural Capacity of the Roof. When designing a green roof, designers must not only consider the stormwater storage capacity of the green roof but also the roof's structural capacity to support the weight of the additional water. A conventional rooftop typically must be designed to support an additional 15 to 30 pounds per square foot (psf) for an extensive green roof. As a result, 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. See Section 4.5 for more information on structural design considerations.

Hurricane-Prone Areas. As coastal South Carolina is subject to hurricanes, some may be concerned about the durability of green roofs in high winds. Having good vegetative cover and root growth in the growing media is the most effective way to reduce wind erosion of the media during high winds. New green roofs where the plants have not yet deeply rooted are the most susceptible to plant damage and media blow-off in a hurricane. Therefore, it is best to install a green roof three or more months prior to hurricane season, to allow enough time for the plants to get established.

Roof Pitch. Green roof storage volume 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 30% if baffles, grids, or strips are used to prevent slippage of the media. These baffles should be designed to ensure the roof provides adequate storage for the design storm.

Roof Access. Adequate access to the roof must be available to deliver construction materials and perform routine maintenance. Designers should also consider how they will get construction materials up to the roof (e.g., by elevator or crane) and how the roof structure can accommodate material stockpiles and equipment loads. If material and equipment storage is required, rooftop storage areas must be identified and clearly marked based on structural load capacity of the roof.

Roof Type. Green roofs can be applied to most roof surfaces. Certain roof materials, such as exposed treated wood and uncoated galvanized metal, may not be appropriate for green rooftops due to pollutants leaching through the media (Clark et al., 2008).

Setbacks. Green roofs should not be located near rooftop electrical and HVAC systems. A 2-foot wide vegetation-free zone is recommended along the perimeter of the roof with a 1-foot vegetation-free zone around all roof penetrations, to act as a firebreak. The 2-foot setback may be relaxed for small or low green roof applications where parapets have been properly designed.

Contributing Drainage Area. The entire contributing drainage area to a green roof (including the green roof itself) should be no more than 25% larger than the area of the green roof, unless design adaptations are made to ensure that the additional runoff is spread evenly on to the green roof surface.

Local Building Codes. The green roof design should comply with the local building codes with respect to roof drains and emergency overflow devices. Additionally, a structural engineer should certify that the design complies with structural building codes. For green roofs installed on historic

buildings or in historic districts, consult local building codes and architectural review criteria to determine if any special requirements exist for green roof design or maintenance.

Economic Considerations. Green roofs tend to be one of the most expensive BMPs on a per cubic foot captured basis. However, a green roof allows stormwater management to be achieved in otherwise unused space, a major benefit in space-constrained locations. Further, green roofs provide many other non-stormwater services with economic benefits, including increased insulation and roof life expectancy.

Green Roof Conveyance Criteria

The green roof drainage layer (refer to *Green Roof Design Criteria* section below) should convey flow from under the growing media directly to an outlet or overflow system such as a traditional rooftop downspout drainage system. The green roof drainage layer must be adequate to convey the volume of stormwater equal to the flow capacity of the overflow or downspout system without backing water up onto the rooftop or into the green roof media. 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. However, an adequate number of roof drains that are not immediately adjacent to the growing media must be provided so as to allow the roof to drain without 3 inches of ponding above the growing media.

Green Roof Pretreatment Criteria

Pretreatment is not necessary for green roofs.

Green Roof Design Criteria

Structural Capacity of the Roof. Green roofs can be limited by the additional weight of the fully saturated soil and plants, in terms of the physical capacity of the roof to bear structural loads. The designer should consult with a licensed structural engineer to ensure that the building will be able to support the additional live and dead structural load and to determine the maximum depth of the green roof system and any needed structural reinforcement.

In most cases, fully-saturated extensive green roofs have loads of about 15 to 30 pounds per square foot, which is fairly similar to traditional new rooftops (12 to 15 pounds per square foot) that have a waterproofing layer anchored with stone ballast. For a discussion of green roof structural design issues, consult Chapter 9 in Weiler and Scholz-Barth (2009) and ASTM E-2397, Standard Practice for Determination of Dead Loads and Live Loads Associated with Vegetative (Green) Roof Systems.

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 together to protect the roof and maintain a vigorous cover (see Figure 4.5-2). 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 green roofing systems; whereas, in other cases, the designer or architect must assemble the system. In this case, the designer or architect is advised to consult Luckett (2009), Weiler and Scholz-Barth (2009), Snodgrass and Snodgrass (2006) and Dunnett and Kingsbury (2004).

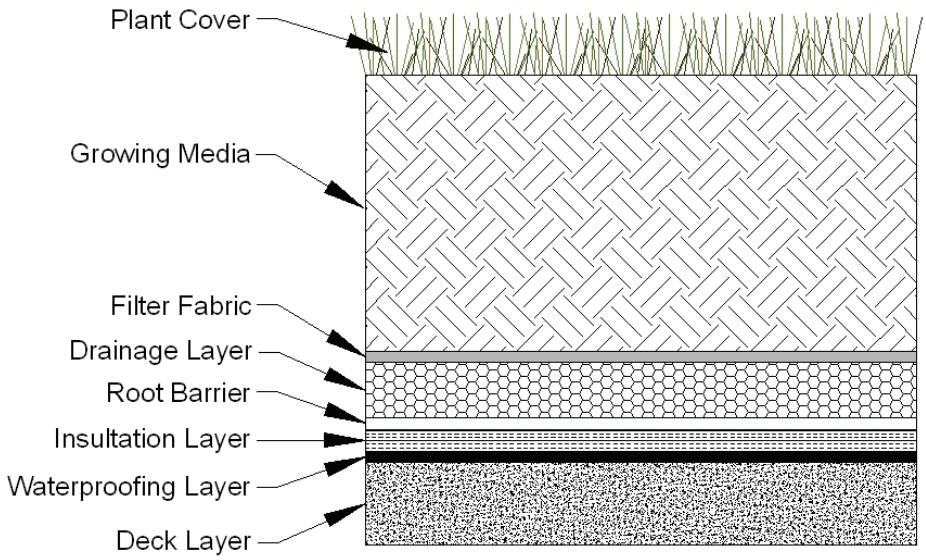

Figure 4.5-2 Green Roof Cross Section

The design layers include:

1. ***Deck Layer:*** The roof deck layer is the foundation of a green roof. It may be composed of concrete, wood, metal, plastic, gypsum, or a composite material. The type of deck material determines the strength, load bearing capacity, longevity, and potential need for insulation in the green roof system.
2. ***Leak Detection System (optional):*** Leak detection systems are often installed above the deck layer to identify leaks, minimize leak damage through timely detection, and determine leak locations.
3. ***Waterproofing Layer:*** All green roof systems must include an effective and reliable waterproofing layer to prevent water damage through the deck layer. A wide range of waterproofing materials can be used, including hot applied rubberized asphalt, built up bitumen, modified bitumen, thermoplastic membranes, polyvinyl chloride (PVC), thermoplastic olefin membrane (TPO), and elastomeric membranes (EPDM) (see Weiler and Scholz-Barth, 2009 and Snodgrass and Snodgrass, 2006). The waterproofing layer must be 100% waterproof and have an expected life span as long as any other element of the green roof system. The waterproofing material may be loose laid or bonded (recommended). If loose laid, overlapping and additional construction techniques should be used to avoid water migration.
4. ***Insulation Layer:*** Many green rooftops contain an insulation layer, usually located above, but sometimes below, the waterproofing layer. The insulation increases the energy efficiency of the building and/or protects the roof deck (particularly for metal roofs). According to Snodgrass and Snodgrass (2006), the trend is to install insulation on the outside of the building, in part to avoid mildew problems. The designer should consider the use of open or closed cell insulation depending on whether the insulation layer is above or below the waterproofing layer (and thus exposed to wetness), with closed cell insulation recommended for use above the waterproofing layer.

5. ***Root Barrier:*** Another layer of a green roof system, which can be either above or below the insulation layer depending on the system, is a root barrier that protects the waterproofing membrane from root penetration. A wide range of root barrier options are described in Weiler and Scholz-Barth (2009). Chemical root barriers or physical root barriers, which have been impregnated with pesticides, metals, or other chemicals that could leach into stormwater runoff, should be avoided in systems where the root barrier layer will come in contact with water or allow water to pass through the barrier.
6. ***Drainage Layer and Drainage System:*** A drainage layer is then placed between the root barrier and the growing media to quickly remove excess water from the vegetation root zone. The selection and thickness of the drainage layer type is an important design decision that is governed by the desired stormwater storage capacity, the required conveyance capacity, and the structural capacity of the rooftop. The depth of the drainage layer is generally 0.25 to 1.5 inches thick for extensive green roof system and increases for intensive designs. The drainage layer should consist of synthetic or inorganic materials (e.g., 1-2 inch layer of clean, washed granular material (ASTM D 448 size No. 8 stone or lightweight granular mix), high density polyethylene, etc.) that are capable of retaining water and providing efficient drainage. A wide range of prefabricated water cups or plastic modules can be used, as well as a traditional system of protected roof drains, conductors, and roof leaders. American Society for Testing and Materials (ASTM) E2396 and E2398 can be used to evaluate alternative material specifications.
7. ***Root-Permeable Filter Fabric:*** A semi-permeable needled polypropylene filter fabric is normally placed between the drainage layer and the growing media to prevent the media from migrating into the drainage layer and clogging it. The filter fabric must not impede the downward migration of water into the drainage layer.
8. ***Growing Media:*** The next layer in an extensive green roof is the growing media, which is typically 3 to 6 inches deep (minimum 3 inches). The recommended growing media for extensive green roofs is typically composed of approximately 80% to 90% lightweight inorganic materials, such as expanded slates, shales or clays, pumice, scoria, or other similar materials. The remaining media should contain no more than 20% organic matter, normally well-aged compost (see *Appendix C*). The percentage of organic matter should be limited, since it can leach nutrients into the runoff from the roof and clog the permeable filter fabric. The growing media typically has a maximum water retention of approximately 30%. It is advisable to mix the media in a batch facility prior to delivery to the roof. As there are many different types of proprietary growing medias and roof systems, the values provided here are recommendations only. Manufacturer's specifications should be followed for all proprietary roof systems. More information on growing media can be found in Weiler and Scholz-Barth (2009) and Snodgrass and Snodgrass (2006). The composition of growing media for intensive green roofs may be different, and it is often much greater in depth (e.g., 6 to 48 inches). If trees are included in the green roof planting plan, the growing media must be sufficient to provide enough soil volume for the root structure of mature trees.

9. ***Plant Cover:*** The top layer of an extensive green roof typically consists of plants that are non-native, slow-growing, shallow-rooted, perennial, and succulent. These plants are chosen for their ability to withstand harsh conditions at the roof surface. Guidance on selecting the appropriate green roof plants can often be provided by green roof manufacturers, and can also be found in Snodgrass and Snodgrass (2006). A mix of base ground covers (usually Sedum species) and accent plants can be used to enhance the visual amenity value of a green roof. See Greenroof Landscaping Criteria for additional plant information. The design should provide for temporary, manual, and/or permanent irrigation or watering systems, depending on the green roof system and types of plants. For most applications, some type of watering system should be accessible for initial establishment or drought periods.

Material Specifications: Standard specifications for North American green roofs continue to evolve, and no universal material specifications exist that cover the wide range of roof types and system components currently available. The ASTM has recently issued several overarching green roof standards, which are described and referenced in Table 4.5-1.

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

Table 4.5-1. Extensive green roof material specifications.

Material	Specification
Roof	Structural capacity should conform to ASTM E-2397-05, Practice for Determination of Live Loads and Dead Loads Associated with Green (Green) Roof Systems. In addition, use standard test methods ASTM E2398-05 for Water Capture and Media Retention of Geocomposite Drain Layers for Green (Vegetated) Roof Systems, and ASTME 2399-05 for Maximum Media Density for Dead Load Analysis.
Leak Detection System	Optional system to detect and locate leaks in the waterproof membrane.
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	Impermeable liner that impedes root penetration of the membrane.
Drainage Layer	Depth of the drainage layer is generally 0.25 to 1.5 inches thick for extensive designs. The drainage layer should consist of synthetic or inorganic materials (e.g., gravel, high density polyethylene, etc.) that are capable of retaining water and providing efficient drainage. A wide range of prefabricated water cups or plastic modules can be used, as well as a traditional system of protected roof drains, conductors, and roof leaders. Designers should consult the material specifications as outlined in ASTM E2396 and E2398. Roof drains and emergency overflow should be designed in accordance with District Construction Code (DCMR, Title 12).
Filter Fabric	Generally, needle-punched, non-woven, polypropylene geotextile, with the following qualities: ♦ Strong enough and adequate puncture resistance to withstand stresses of installing other layers of the green roof. Density as per ASTM D3776 ≥ 8 oz./sq yd. Puncture Resistance as per ASTM D4833 ≥ 130 lb. These values can be reduced with submission of a Product Data Sheet and other documentation that demonstrates applicability for the intended use. ♦ Adequate tensile strength and tear resistance for long term performance. ♦ Allows a good flow of water to the drainage layer. Apparent Opening Size as per ASTM D4751 ≥ 0.06 ≤ 0.2, with other values based on Product Data Sheet and other documentation as noted above. ♦ Allows at least fine roots to penetrate. ♦ Adequate resistance to soil borne chemicals or microbial growth both during construction and after completion since the fabric will be in contact with moisture and possibly fertilizer compounds.
Growth Media	80% lightweight inorganic materials and 20% organic matter (e.g. well-aged compost). Media typically has a maximum water retention of approximately 30%. Media should provide sufficient nutrients and water holding capacity to support the proposed plant materials. Determine acceptable saturated water permeability using ASTM E2396-05. Proprietary systems may vary from these specifications.
Plant Materials	Sedum, herbaceous plants, and perennial grasses that are shallow-rooted, low maintenance, and tolerant of direct sunlight, drought, and wind. See ASTM E2400-06, Guide for Selection, Installation and Maintenance of Plants for Green (Vegetated) Roof Systems.

Green Roof Sizing: Green roof areas can be designed to capture the entire Water Quality Volume. In some cases, they could be designed to capture larger design storm volumes as well. The required size of a green roof will depend on several factors, including the maximum water retention of the growing media and the underlying drainage and storage layer materials (i.e. prefabricated water cups or plastic modules). As maximum water retention can vary significantly between green roof products, verification of this value should be provided. ASTM tests E2396, E2397, E2398, or E2399, as appropriate, and performed by an ASTM-certified lab are considered acceptable verification. Site designers and planners should consult with green roof manufacturers and material suppliers as they can often provide specific sizing information and hydrology design tools for their products. Equation 4.5-1 below can be used to determine the storage volume retained by a green roof:

Equation 4.5-1. Storage Volume for Green Roofs

$$Sv = \frac{SA \times [(d_m \times \eta_1) + (d_{dl} \times \eta_2)]}{12}$$

where:

Sv	=	storage volume (ft^3)
SA	=	green roof area (ft^2)
d_m	=	media depth (in) (minimum 3″)
η_1	=	verified media porosity maximum water retention
d_{dl}	=	drainage layer depth (in)
η_2	=	verified drainage layer porosity maximum water retention

Note: If verified maximum water retention values are not available, a value of 0.25 may be used.

In the LID Compliance Calculator spreadsheet, the *Sv* for green roofs is given a 100% runoff reduction credit, and, for projects in the Coastal Zone, a 100% credit toward the storage requirement.

Green roofs can have dramatic rate attenuation effects on larger storm events and may be used, in part, to manage a portion of the 2-year and 10-year events. Designers can model various approaches by factoring in storage within the drainage layer. Routing calculations can also be used to provide a more accurate solution of the peak discharge and required storage volume.

Green Roof Landscaping Criteria

Since plant selection, landscaping, and maintenance are critical to the performance and function of green roofs, a planting plan should be provided for green roofs. The planting plan should be prepared for a green roof by a landscape architect, horticulturalist, or other professional experienced with green roofs.

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 green roof installations is a hardy, low-growing succulent, such as *Sedum, Delosperma, Talinum, Semperivum*, or *Hieracium* that is matched to the local climate conditions and can tolerate the difficult growing conditions found on building rooftops (Snodgrass and Snodgrass, 2006).

A list of some common green roof plant species that work well in Coastal South Carolina can be found in Table 4.5-2. In addition, consult local nurseries to expand the list of appropriate plant material.

Table 4.5-2. Ground covers appropriate for green roofs in Coastal South Carolina

Plant	Light	Moisture Requirement	Notes
Delosperma cooperii	Full Sun	Dry	Pink flowers; grows rapidly
Delosperma 'Kelaidis'	Full Sun	Dry	Salmon flowers; grows rapidly
Delosperma nubigenum 'Basutoland'	Full Sun	Moist-Dry	Yellow flowers; very hardy
Sedum album	Full Sun	Dry	White flowers; hardy
Sedum lanceolatum	Full Sun	Dry	Yellow flowers; native to U.S.
Sedum oreganum	Part Shade	Moist	Yellow flowers; native to U.S.
Sedum stoloniferum	Sun	Moist	Pink flowers; drought tolerant
Sedum telephiodes	Sun	Dry	Blue green foliage; native to region
Sedum ternatum	Part Shade	Dry-Moist	White flowers; grows in shade
Talinum calycinum	Sun	Dry	Pink flowers; self sows

Note: Designers should choose species based on shade tolerance, ability to sow or not, foliage height, and spreading rate. See Snodgrass and Snodgrass (2006) for a definitive list of green roof plants, including accent plants.

- ✧ Plant choices can be much more diverse for deeper intensive green 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.
- ✧ The species and layout of the planting plan should reflect the location of the building, in terms of its height, exposure to wind, heat stress, orientation to the sun, and impacts from surrounding buildings. (Wind scour and solar burning have been observed on green roof installations that failed to adequately account for neighboring building heights and surrounding window reflectivity.) In addition, plants should be selected that are fire resistant and able to withstand heat, cold, and high winds.
- ✧ 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. The planting plan should usually include several accent plants to provide diversity and seasonal color. For a comprehensive resource on green roof plant selection, consult Snodgrass and Snodgrass (2006).

- ✧ It is also important to note that, although invasive species should be avoided, most green roof plant species will not be native to Coastal South Carolina (which contrasts with 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 for temporary irrigation during drought or initial establishment. The planting window extends from the spring to early fall, although it is important to allow plants to root thoroughly before the first killing frost. Green roof manufacturers and plant suppliers may provide guidance on planting windows as well as winter care. Proper planting and care may also be required for plant warranty eligibility.
- ✧ Plants can be established using cuttings, plugs, mats, and, more rarely, seeding or containers. Several vendors also sell mats, rolls, or proprietary green roof planting modules. For the pros and cons of each method, see Snodgrass and Snodgrass (2006).
- ✧ The goal for green roof systems designed for stormwater management is to establish a full and vigorous cover of low-maintenance vegetation that is self-sustaining and requires minimal mowing, trimming, and weeding.

The green roof design should include non-vegetated walkways (e.g., paver blocks,) to allow for easy access to the roof for weeding and making spot repairs.

Green Roof Construction Sequence

Green Roof Installation. Given the diversity of extensive vegetated roof designs, there is no typical step-by-step construction sequence for proper installation. The following general construction considerations are noted:

- ✧ Construct the roof deck with the appropriate slope and material.
- ✧ Install the waterproofing method, according to manufacturer's specifications.
- ✧ Conduct a flood test to ensure the system is water tight by placing at least 2 inches of water over the membrane for 48 hours to confirm the integrity of the waterproofing system. Alternately, electric field vector mapping (EFVM) can be done to test for the presence of leaks; however, not all impermeable membranes are testable with this method. Problems have been noted with the use of EFVM on black EPDM membranes and with aluminized protective coatings commonly used in conjunction with modified bituminous membranes.
- ✧ Add additional system components (e.g., insulation, 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.
- ✧ The growing media should be mixed prior to delivery to the site. Media should be spread evenly over the filter fabric surface. If a delay between the installation of the growing media and the plants is required, adequate efforts must be taken to secure the growing media from erosion and the seeding of weeds. The growing media must be covered and anchored in place until planting. 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.

- ✧ 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.
- ✧ It generally takes two to three growing seasons to fully establish the vegetated roof. The growing medium should contain enough organic matter to support plants for the first growing season, so initial fertilization is not required. Extensive green roofs may require supplemental irrigation during the first few months of establishment. Hand weeding is also critical in the first two years (see Table 10.1 of Weiler and Scholz-Barth, 2009, for a photo guide of common rooftop weeds).
- ✧ Most construction contracts should contain a Care and Replacement Warranty that at least 50% coverage after one year and 80% coverage after two years for plugs and cuttings, and 90% coverage after one year for sedum carpet/tile.

Construction Supervision. Supervision during construction is recommended to ensure that the vegetated roof is built in accordance with these and the manufacturer's specifications. Inspection checklists should be used that include sign-offs by qualified individuals at critical stages of construction and confirm that the contractor's interpretation of the plan is consistent with the intent of the designer and/or manufacturer.

An experienced installer should be retained to construct the vegetated roof system. The vegetated roof should be constructed in sections for easier inspection and maintenance access to the membrane and roof drains. Careful construction supervision is needed during several steps of vegetated roof installation, as follows:

- ✧ During placement of the waterproofing layer, to ensure that it is properly installed and watertight.
- ✧ During placement of the drainage layer and drainage system.
- ✧ During placement of the growing media, to confirm that it meets the specifications and is applied to the correct depth (certification for vendor or source should be provided).
- ✧ Upon installation of plants, to ensure they conform to the planting plan (certification from vendor or source should be provided).
- ✧ Before issuing use and occupancy approvals.
- ✧ At the end of the first or second growing season to ensure desired surface cover specified in the Care and Replacement Warranty has been achieved.

Green Roof Maintenance Criteria

A green 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 4.5-3). In addition, the green roof should be hand-weeded to remove invasive or volunteer plants, and plants and/or media should be added to repair bare areas (refer to ASTM E2400).

If a roof leak is suspected, it is advisable to perform an electric leak survey (i.e., Electric Field Vector Mapping), if applicable, 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. Check with the membrane manufacturer for approval and warranty information. Also, power-washing and other exterior maintenance operations should be avoided so that cleaning agents and other chemicals do not harm the green roof plant communities.

Fertilization is generally not recommended due to the potential for leaching of nutrients from the green roof. Supplemental fertilization may be required following the first growing season, but only if plants show signs of nutrient deficiencies and a media test indicates a specific deficiency. If fertilizer is to be applied, it must be a slow-release type, rather than liquid or gaseous form.

Table 4.5-3. Typical maintenance activities associated with green roofs.

Activity	Schedule
♦ Water to promote plant growth and survival. ♦ Inspect the green roof and replace any dead or dying vegetation.	As needed (following construction)
♦ Inspect the waterproof membrane for leaking or cracks. ♦ Weeding to remove invasive plants (no digging or using pointed tools where there is potential to harm the root barrier or waterproof membrane). ♦ Inspect roof drains, scuppers, and gutters to ensure they are not overgrown or have organic matter deposits. Remove any accumulated organic matter or debris. ♦ Inspect the green roof for dead, dying, or invasive vegetation. Plant replacement vegetation as needed.	Semi-annually

An example maintenance checklist for green roofs is included in *Appendix F*.

Green Roof References and Additional Resources

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