C-8. Green Roof

Design Objective

Green roofs consist of low-growing plants with shallow root systems grown in a four-inch layer of light-weight growing media. Initially during a storm event, rain strikes the foliage and is intercepted. As rain continues, water percolates into and wets the growing media. Significant quantities of water do not begin to drain from the roof until the field capacity of the medium is filled. During small rainfall events, negligible runoff usually occurs and most of the precipitation eventually returns to the atmosphere by evapotranspiration (ET). Green roofs also have several additional benefits, including improving air quality, saving energy, and prolonging the life of the roof. Green roofs can be retrofitted to conventional roofs if structural support is adequate.

Design Volume

The design volume of a green roof is equivalent to the depth of water that can be stored within the growing media times the area of the green roof.

Important Links

Rule 15A NCAC 2H .1059. MDC for Green Roofs

SCM Credit Document, C-9. Credit for Green Roofs

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Figure 1: Comparison between a Green Roof and a Conventional Roof

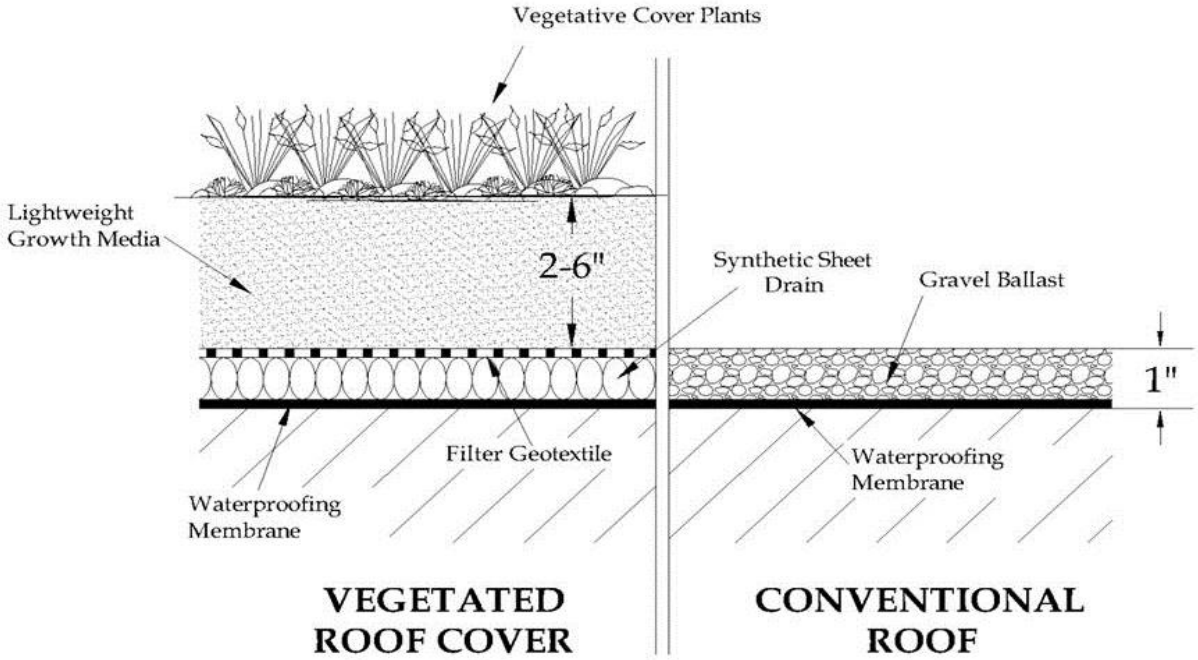
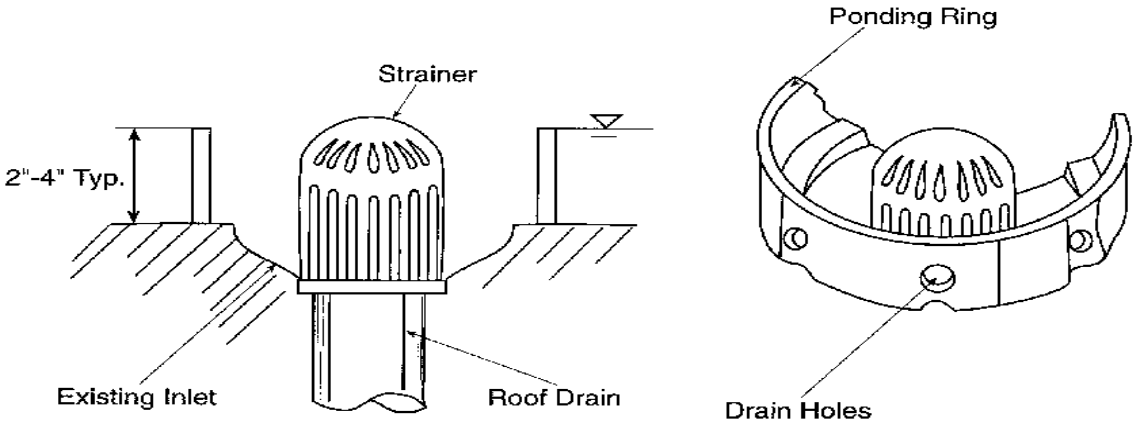


Figure 2: Downspout Inlet (Adapted from Tourbier, 1974)



Guidance on the MDC

GREEN ROOF MDC 1: MEDIA SPECIFICATION
The maximum organic fraction of the media shall be ten percent by volume.

Figure 3: Expanded Slate Growing Media (Dr. Elizabeth Fassman)

The purposes of green roof media are to:

- hold water for runoff storage,
- support plant life,
- minimize TSS and nutrient export,
- maintain high permeability,
- resist degradation,
- minimize weight, and
- support occasional foot traffic.

The media mix that has been found to effectively meet these goals is comprised of 80-95% light-weight aggregate (LWA) and 5-10% organic matter by volume. The low fraction of organic matter minimizes nutrient leaching from the media.

LWA provides pore space for air, water, and gas exchange, and ensures rapid drainage. The most commonly used LWAs are expanded slate or expanded shale. The organic fraction of the green roof media may be peat moss, composted bark, shredded wood waste (tree pruning), coconut coir fibre, and macadamia husks. The organics must be free of weeds seeds and pathogens, low in salts and heavy metals, and relatively stable so as not to decompose within five years (American Hydrotech Inc 2006). After plants are established, they will provide their

own organic material through decomposing roots and foliage. Compost other than composted bark is not recommended to avoid nutrient loading perspective. Garden soil should not be used because it is very likely to leach nutrients.

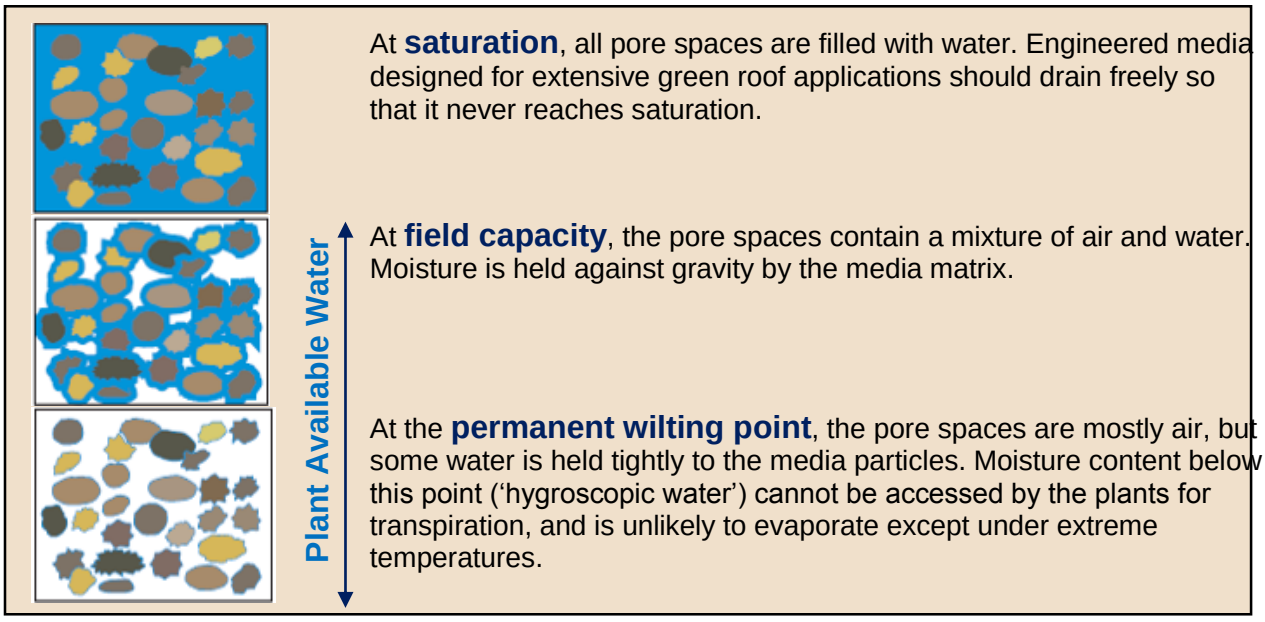
The media should not contain fine particles. Fines increase moisture storage, which may benefit plant growth, but unfortunately, they cause a decrease in permeability and an increase in weight. Maintaining high permeability of the growing media is important to prevent ponding and excess weight. High permeability media protects plants from freezing during winter, and prevents physical movement from freeze-thaw cycles.

Media transport cost can be substantial; therefore, often the most cost-effective supply will be the closest. Any proprietary green roof media products that are used should demonstrate that they have minimal moisture retention and permeability properties as described herein.

GREEN ROOF MDC 2: DESIGN VOLUME
The design volume for a green roof shall equal the media depth times the plant available water (PAW). The maximum rainfall depth that may be treated by a green roof is 1.5 inches.

Plant available water (PAW) means the difference between the field capacity of the media and the permanent wilting point as shown in Figure 4. (Fassman and Simcock 2012).

Figure 4. States of Soil Moisture



The supplier usually provides the hydrologic properties of the green roof media. If not, then the media should be laboratory-tested to determine the moisture contents at field capacity and at the permanent wilting point. In addition, the media should be tested for its saturated hydraulic conductivity.

The PAW of green roof media typically ranges between 20 and 65 percent (FLL 2008). The depth of rainfall that is considered to be treated by a green roof is determined simply by multiplying the depth of the green roof media (either 3 or 4 inches per Green Roof MDC 2) by the PAW. For example, a 3-inch deep layer of green roof media with 40 percent PAW treats the 1.2-inch storm.

Equation 1. Design Volume of a Green Roof

$$DV = PAW * D_{media} * A_{roof} * 1/12$$

Where:	DV	=	Design volume of roof (cu ft)
	D_{media}	=	Depth of green roof media (in)
	A_{roof}	=	Area of roof (sq ft)
	1/12	=	Conversion factor

The saturated hydraulic conductivity should not be less than 1.5 inches per minute. This conductivity will prevent ponding and freezing on the green roof, which can endanger the plants as well as the roof structure. Media permeability should be tested using ASTM E2399-11, Standard Test Method for Maximum Media Density for Dead Load Analysis of Green Roof Systems. Double or single-ring infiltration methods are <u>not</u> appropriate to test green roof systems.

GREEN ROOF MDC 3: MINIMUM MEDIA DEPTH
The minimum media depth shall be four inches if the roof will not be irrigated or three inches if the roof will be irrigated. For roofs with three-inch media depths, an irrigation plan shall be included in the Operation and Maintenance Plan.

Four inches of media is required to maintain a healthy cover of green roof plants. Providing less than 4 inches of media will increase the mortality of the plants, particularly during hot, dry weather. The green roof media can be reduced to between three and four inches if there is an irrigation plan that must be implemented after construction. If the green roof is to be irrigated, then the water supply for the green roof shall be specified in the design.

A drainage layer under the media is recommended. The drainage layer collects the water that flows through the media to prevent ponding in or on the growing media. ASTM E2398 - 11 Standard Test Method for Water Capture and Media Retention of Geocomposite Drain Layers for Green Roof Systems should be used to assess the hydraulic properties of a synthetic drainage layer. The procedure applies to a synthetic sheet, mat, or panel that is specifically designed to convey water horizontally toward a roof deck, drains, gutters, or scuppers. ASTM E2396 - 11 Standard Test Method for Saturated Water Permeability of Granular Drainage Media [Falling-Head Method] for Green Roof Systems should be used to determine the permeability of coarse granular materials used as drainage layers of a green roof system (e.g. pumice, gravel, or rock in lieu of a synthetic drainage product.

Even though the growing media is designed to retain moisture for stormwater control and plant growth, the green roof design should include provisions for roof drainage. Drainage features (inlets, gutters, pipes) should be kept free from vegetation growing over or from growing media washing into it. Blocked drains will create standing water on rooftops with unanticipated structural burden, even for conventional roofs. Vertical drainage elements must be flush with or below the roof deck. For downspout design, NCDEQ recommends consulting a roof drainage specialist because of the many factors that may influence the design.

Figure 5. Green Roof Drainage System

GREEN ROOF MDC 4: VEGETATION SPECIFICATION
The planting plan shall be designed to achieve a 75 percent vegetative cover within two years.

A 75 percent vegetative cover is required to maximize the stormwater treatment capabilities and to hold the media in place. Green roof plants bring about evapo-transpiration (ET), which is crucial to the functioning of the green roof. ET dries out the media and prepares the roof to treat the next storm. ET also is a cooling process – therefore, green roofs help to mitigate cooling costs for the building and heat island effects for the community. In addition to ET, plants intercept rainfall, hold the media in place and improve the aesthetics of the roof.

A limited number of plants can thrive in the harsh environment of a green roof with its shallow and coarse growing media, minimal fertilizer, full sun (unless shade can be provided), and high heat. Succulent plants, particularly sedums, are often grown on green roofs. They are not the only viable plants, but are often preferred due to their heartiness and their low plant height that reduces sun and wind exposure. Increasing the media depth increases the available plant

palate and the vegetation's resilience. Plants with aggressive root structures, such as bamboo, should never be specified for a green roof.

NCDEQ recommends that designers consult an expert versed in green roof vegetation in developing a vegetation plan for the green roof. Plant selection for green roofs should be based on an assessment of each individual site, and across sections of a roof.

Moran (2014) and Fu et al (2015) studied green roof plants and found that the four species with the greatest presence, survival, and overall growth were *Sedum kamtschaticum* (Weihenstephaner Gold), *Talinum calycinum* (fame flower), *Sedum sexangulare*, and *Sedum spurium* (Album Superbum).

Figure 6. From left to right: Sedum kamtschaticum (Weihenstephaner Gold), Talinum calycinum (fame flower), Sedum sexangulare, and Sedum spurium (Album Superbum)
(Fu et al 2015)

NCSU recommends planting a diversity of adapted species and varieties to increase the likelihood of plant survival. Additionally, plants should be chosen per the main function of the extensive green roof, whether it be environmental, economic, or socio-cultural. If the green roof is highly visible, well-adapted plants should be chosen with high aesthetic value.

There are a variety of planting methods to establish green roof vegetation. Spreading sedum cuttings reduces costs for both plant materials and labor. Planting plugs or root trainers allows greater design control, with the ability to create specific patterns. Large expanses of single species should be avoided to prevent obvious bare patches in the case of extensive plant death; color-blocking can be achieved with multiple species of the same color. Plants procured as plugs or pots should be no deeper than the growing media depth. Newly planted roofs should be covered by a coarse, biodegradable fiber erosion control mat to prevent wind and bird loss.

A green roof planted in situ should include a high proportion of moderate to rapidly growing plants to achieve 75 percent cover within 12 to 24 months, interspersed with slower-growing species, which are often longer-lived. Green roofs established using plugs or short root trainers are recommended to be planted at a density of approximately two plants per square foot. Large

plants and mature plants should generally not be used. Plants are best established in a juvenile state when they are most adaptable (Snodgrass and McIntyre 2010).

Some suggestions for reducing the stress to green roof plants during summer include:

- Provide structures such as photovoltaic cells to reduce exposure to sun and reflected glare.
- Provide baffles to reduce the speed and heat of wind or air conditioner exhaust.
- Layer plants vertically to decrease surface temperatures.
- Apply inorganic surface mulches to slow evaporation from the surface
- Creating small non-vegetated zones such as paver paths that shed water and not use water to minimize evaporation from the underlying substrate.

GREEN ROOF MDC 5: SLOPE
The green roof shall have a slope (or pitch) of no greater than eight percent, unless a container system designed for a greater slope is used.

Figure 7: A green roof container system
(Living Roofs)

Sloped green roofs have some advantages and disadvantages over flat roofs. An advantage is that the roof vegetation is more visible from the ground and this can improve the aesthetics. Also, being able to install a green roof on a sloped surface increases the possibilities for retrofits.

Disadvantages include the potential for loss of media and plants due to gravity. That is why a container system is required for roofs with slopes exceeding eight percent. The higher the slope of the roof, the more likely that loss of media and plants. Sloped green roofs are likely to be less effective in retaining stormwater

Recommendations

GREEN ROOF RECOMMENDATION 1: WEIGHT CONSIDERATIONS.
The roof must be strong enough to support the loads associated with construction, maintenance and ongoing loads of media, plants and water.

Weight is one of the main factors controlling the feasibility and cost of a green roof. The roof structure must support the placement of materials and foot traffic by construction and maintenance crews. For new buildings, the weight of a green roof may not be much more that of a gravel ballast-covered roof. For existing buildings (retrofit projects), the designer must adhere to the bearing capacity of the structure.

The weight of the green roof should be determined per ASTM E2397-11: Standard Practice for Determination of Dead Loads and Live Loads associated with Green Roof Systems and ASTM E2399-11: Standard Test Method for Maximum Media Density for Dead Load Analysis of Green Roof Systems. In North Carolina, dead loads shall assume completely saturated media (in lieu of the ASTM weight at the maximum media water retention). A licensed structural engineer must be consulted to evaluate the requisite structural support in accordance with the local building code.

GREEN ROOF RECOMMENDATION 2: SAFETY.
Measures should be taken to minimize the potential for dangerous falls from a green roof.

Figure 8: Fencing around a green roof
(Dr. Elizabeth Fassman)

NCDEQ recommends minimizing the potential for falls from a green roof by:

- Providing suitable exterior or interior access or elevator stops, or stairs, should be provided to allow this access.
- Providing fencing around the perimeter of the green roof.
- Using edging material as a visual cue to keep maintenance staff or visitors away from roof edges (see recommendation 3).

GREEN ROOF RECOMMENDATION 3: EDGING.
Gravel edging should be provided around the perimeter of green roofs and around any protrusions for safety and durability

Edging around green roof media and plants with inert, permeable materials such as gravel, pumice, or pavers:

1. Provides a visual cue to keep maintenance staff and any visitors off plants.
2. Provides an "emergency" drainage function in the unlikely event that the media loses permeability.
3. Provides drainage breaks on large roofs.
4. Captures substrate migration.
5. Protects metal flashing from contact with wet substrate.
6. Provides UV protection for waterproofing membrane.
7. Reduces risk of substrate slipping underneath drainage mat.
8. May reduce fire risk.

Figure 9: Gravel edging at the UNC-CH Fed-Ex Building (left, center) and at the Vancouver Convention Center (right)
(Photos courtesy of Dr. Elizabeth Fassman, University of Auckland)

GREEN ROOF RECOMMENDATION 4: DRAINAGE LAYER
For roofs with slopes of less than two percent, it is recommended to place a geotextile and a drainage layer beneath the growing media.

On flat green roofs, NCDEQ recommends providing a drainage layer and a waterproof membrane beneath the growing medium to prevent leakage. A variety of lightweight, synthetic drainage products are readily available in North America. Granular or aggregate materials may also be used for a drainage layer. The drainage layer should drain to the roof gutters and

downspouts. ASTM E23908-11, “Standard Test Method for Water Capture and Media Retention of Geocomposite Drain Layers for Vegetative (Green) Roof Systems” has been developed for evaluating synthetic drainage layers. ASTM E2396-11 “Standard Test Method for Saturated Water Permeability of Granular Drainage Media [Falling-Head Method] for Vegetative (Green) Roof Systems” can be used for granular or aggregate construction.

A geotextile should be installed over the drainage layer to prevent media migration and promote air circulation to roots. Some synthetic products have the geotextile bonded to the upper surface of the drainage material, which facilitates installation. A root barrier may be included in the geotextile.

The drainage layer is not necessary if the roof slope exceeds two percent (i.e., promotes drainage from the roof). However, it still may be a good idea to include a drainage layer because it protects the waterproof membrane from shovels or other gardening implements that might cause punctures during planting or maintenance, and providing air circulation for plant roots.

GREEN ROOF RECOMMENDATION 5: WATERPROOF MEMBRANE.
The roof should be equipped with a waterproof membrane to protect against leaks.

Waterproof membranes are required for all roofs, both green and conventional. Green roofs usually extend the life of the waterproofing membrane by blocking damaging UV rays. A waterproof membrane under a green roof typically lasts for at least 20-30 years (a conservative estimate).

The best approach is to take extra care with specification and installation of the waterproofing system as prevention is almost always less costly than repair. Several key considerations for specifying and installing waterproofing membranes are:

1. Specify at least a double-ply waterproofing membrane of high quality or a specialty green roof product, such as a heavy-duty single ply membrane with felt layer.
2. Protect the waterproof membrane throughout construction from nails, screws, or cutting implements. Consider using a drainage mat to provide a physical block for shovels or other gardening implements which could poke holes.
3. Test the integrity of the waterproofing layer in place before installing any other features. See below for suggestions on membrane testing methods.
4. Cover the waterproof membrane completely with either flashing or growing media. Any exposed membrane is susceptible to UV damage.
5. Seal thoroughly around all roof protrusions (e.g. parapets, skylights, mechanical systems, vents, etc.). For new construction, roof design should minimize protrusions when a green roof is to be built. Protrusions provide opportunities for leaks in any roof.

6. Use a commercial root barrier with the waterproof membrane. Root barriers may be physical or chemical. Some synthetic drainage mats are available with the root barrier already incorporated. Copper, due to its harmful impact on aquatic health must never be used in root barrier products.

Two methods for testing waterproof membranes for leaks are:

1. ***Flood test:*** For flat roofs only: Fill the roof with water and measure water level drop over a period of approximately 24 hours before installing the drainage layer, growing media, or vegetation. One problem with this method is that very small leaks can be missed. Also, the method can cause damage to the roof if the membrane has leaks.
2. ***Electric Field Vector Mapping (EFVM):*** EFVM is a non-destructive or invasive method, and may be performed on a sloped roof. A thin layer of water is spread over the geomembrane and a low electrical voltage is applied under the membrane. A leak is present if voltage is detected. The technology indicates the location of the breach, and may also identify future failures (e.g., small punctures which may not have yet fully penetrated the membrane surface).

GREEN ROOF RECOMMENDATION 6: ADDITIONAL BENEFITS.
Consider benefits associated with green roofs in addition to stormwater treatment.

Green roofs can cost as much as 30 percent more than traditional roofs to construct. Therefore, thy may not appear to be cost-effective if only stormwater management benefits are considered. But bear in mind that using a green roof reduces the footprint of the SCM needed to treat the remainder of the site.

In addition, green roofs extend roof life, may reduce energy demand, and provide a visual amenity, all of which have an economic value for the project. The life span of an extensive green roof can be double that of a traditional roof (up to 40 years) (Taylor 2015). Niachou et al. (2012) compared the insulative performance of 12 extensive green roofs and found that the buildings with a green roof that were also well-insulated had only a 2 percent energy savings, but the buildings with a green roof that were not also insulated exhibited an energy savings of 37 to 48 percent. Though research investigating human health effects is ongoing, Tzoulas et al. (2007) indicated that green roofs, as part of urban green infrastructures, play an important role in improving socio-economic health, community health, physical health, and psychological health.

Construction

The most important construction guideline is to engage professionals who are experienced with green roof installation, and preferably who can undertake all phases of the project from waterproofing to planting.

Once the waterproofing has been successfully found to be free of leaks or defects, the drainage layer can be installed. Synthetic drainage layers are usually very light-weight, thus if installed significantly before the growing media, extra care must be taken to ensure the materials are not blown off by wind (Figure 10). Most drainage layers do not necessarily need to be rigidly affixed to the roof structure (follow the supplier's installation guidance); in no case should any materials be allowed to puncture the waterproofing.

Figure 10. Drainage layer held in place with sand bags
(Dr. Elizabeth Fassman)

Placing the growing media installation may mechanized equipment (Figure 11). Two primary options are available for installing growing media:

1. ***Hoist cranes of one cubic yard bags.*** Cranes are usually readily on-site for new construction. As the building shell is often the first task for completion, a green roof should be installed as soon as the waterproof membrane is installed and leak-tested, thus allowing several months (to years) for plants to become established while the building interior is completed. The green roof is then "ready" when the occupants take up residency. For retrofits, the crane must be able to get close to the building. In some cases, the "reach" of the crane may be the limiting factor rather than the weight to be lifted.

   Growing media is typically sold in one cubic yard bags. Even though the media is characterized as "light-weight", a one cubic yard bag of it may weigh more than 1300 pounds. Thus, bags should not be emptied as a point load directly onto the roof unless the roof is designed to manage such a load.

2. ***Blowing or spraying growing media to height.*** Pneumatic blowers that are used to rapidly seed bare surfaces can also be used to transport growing media to a rooftop. The length of the hose may limit the height to which media can be blown, and is specific to the

service provider. Operation of blowers may be compromised in cold weather, as the system may clog (in which case bag hoists would be a preferred option). Operator safety is also a concern as a powerful blower can lift the operator off the ground.

Figure 11. Growing media installation by crane hoist (left) and pneumatic blower (right) *(Dr. Elizabeth Fassman)*

The growing media should not be mechanically compacted on low-pitched roofs; however it will settle during planting and/or within the first few rainfalls. On roofs with 10-15 degree pitch, it is suggested to lightly tamp media into place, working from the bottom of the slope towards the ridgeline. To account for settling and compaction, 10-15 percent greater depth of material should be installed prior to planting. Finished (settled) growing media depth should be checked in multiple locations across the roof. Media should be added wherever the finished (settled) depth is less than required by the plans.

On a roof slope greater than 15 degrees, horizontal strapping or other support systems must be installed to avoid slippage and slumping of the growing medium and plants. Several purpose-made batten systems are commercially available. Any erosion control measure should be waterproof, but allow for free drainage between cells created by the support system. Growing media should be filled from the bottom of the slope towards the ridgeline.

Planting may be independent of growing media installation because the timing of planting depends on the local climate and season. Planting in the NC summer may require substantial irrigation. Fall planting depends on the availability of plants and whether there is sufficient time to allow for the plants to become established before late winter. Mid-spring planting (Feb – Apr) is recommended for much of North Carolina. Green roofs constructed in the mountains are best planted between March and May. Installing growing media in advance of planting may allow wind-spread weeds to germinate.

Plant providers are likely to wait until the last possible minute to harvest plants for installation. It is not recommended to have plants sitting on site for more than two days awaiting planting. Pre-grown mats often require six months' lead time to establish before installation. During

installation, pre-grown mats should not be left rolled up for longer than 1-2 days and should be protected from sunlight. Thus, if a mat is specified, careful coordination between the mat supplier and the rest of the green roof installation team is required (if the supplier is not the installer). Ideally, the mat should arrive on-site on the day it is to be installed.

Maintenance

Consulting with a green roof plant expert during the design phase reduces ongoing maintenance burdens. The horticultural consultant should understand the limitations of growing media depth and roof exposure and design a plant palette that has an acceptable maintenance requirement, especially with respect to fertilization, irrigation and frequency of visits. Fertilizer rates should be very low (if at all) to minimize nutrient leaching; irrigation if used, needs to be designed remembering green roof growing media hold little water (are very 'droughty'), and do not allow water to 'wick' or spread far, so emitters must be close together or an underlying moisture retention mat used.

Mulch is not generally used on roofs as it adds weight and nutrients and can blow away. Low maintenance regimes are particularly suited to roofs that are difficult or expensive to access. Some plants require maintenance to maintain aesthetics, where larger grasses may require annual trimming or stripping to reduce fire risk. The horticultural consultant should visit the roof site at least during the design process to check shading, areas where wind concentrates, and access.

The greatest maintenance demands for green roofs are usually during plant establishment. Irrigation needs are likely high during establishment in North Carolina. In the absence of significant rainfall, weekly watering may be required during summer and early autumn until plants are established. During establishment, frequent (at least monthly) inspections are recommended to ascertain the need for weeding. Weed management is largely governed by the time taken to achieve a dense, weed-resistant plant cover. Rapid cover can be achieved by including some plants with high growth rates (as well as long-lived plants), high planting density, and reducing plant stress during establishment (i.e., using hardened-off plants[1] and managing moisture deficit). Generally, once the desired plant cover reaches 60 – 75 percent of the surface area, weeding requirements will be minimal.

Plant condition will vary throughout the year dependent on climate conditions and stress condition of the plants. The variability of a green roof system should be conveyed to clients, to present an accurate description of green roof aesthetics through the year and to manage client expectations. Without some maintenance, the proportion of grasses is likely to increase over time (three to five years) on most roofs.

[1] The growing environment of a rooftop is quite harsh. Plants grown inside (e.g. a nursery or green house) should be moved outside at least a few weeks in advance of green roof installation to encourage climate adaptation. Plant seedlings or plugs should be raised in green roof growing media.

Maintenance contracts for routine care of the vegetative cover frequently can be negotiated with the installer. Active communication, and likely training, between the horticultural consultant and the maintenance provider is strongly encouraged; the aesthetics and plant species on an extensive green roof are usually very different from ground-level gardens or landscaping.

Easy access to gutters, drains, spouts, and other components of the roof drainage system should be designed. Foreign matter, including leaves and litter, should be removed promptly. Twice-yearly inspections of the drainage system are recommended.

Figure 12: Common Weeds on North Carolina Green Roofs
(left) Creeping Jenny likes the hot microclimate of gravel edging.
(right) Spotted spurge invades the growing media whose planting has been delayed.
(Dr. Elizabeth Fassman)

Sample Inspection and Maintenance Provisions

The person responsible for the green roof system is required to keep a signed and notarized Operation and Maintenance Agreement and inspection records in a known set location. These records must be available upon request.

Important inspection and maintenance procedures:

- The plants will be watered during extended periods of dry weather. In North Carolina, watering is suggested (at a minimum) after 2 weeks without measurable rain, or if ambient temperatures exceed 100ºF for more than 3 consecutive days.
- Low addition of slow-release fertilizer may be applied during establishment, and while plants are actively growing. Once plants are established, fertilizer addition is unlikely needed and typically not recommended.

The rooftop runoff management system will be inspected **once a quarter**. Inspection activities shall be performed as follows. Any problems that are found shall be repaired immediately.

SCM element:	Potential problem:	How to remediate the problem:
The plant materials	Weeds are present.	Remove the weeds by hand. For repeat growth of the same weed, systemic weed killer may be applied to the single plant using a Q-tip or paint brush**. In no case** should weed killer be sprayed.
	Vegetation is dead or diseased.	Try to determine the cause of the problem (may wish to consult an expert). Correct the problem and replace the plants. An alternative species may be required.
The growing media	Ponding occurs after the first few rain events.	If not washed before mixing and installation, some aggregates may create a thin surface crust. The crust may be removed by light tilling and should not recur. If it does, consult with the supplier.
	Persistent ponding occurs.	Check the particle size distribution of a sample(s) from the area susceptible to ponding. The sample should be representative of the full substrate depth. If particles less than 1 mm diameter exceed 5% by mass, excessive fine particulates are likely the problem. Consult with the supplier; however, the media may need replacement.
	Substantial loss of material over time.	Can result because of excessive organic matter (>20% by volume) in the media. Check with consultant to assess whether reduced media depth compromises stormwater retention, and hence permit compliance. Check with horticultural consultant regarding implications on plant health. Plants should not be sustained by regular fertilizer addition. If needed (and feasible), amend with additional media.
Gutters, drains and spouts	Clogging has occurred.	Remove leaves, debris, and other foreign matter and dispose of in a manner that will not impact streams or the BMP. Inspect permeable edging and clear if needed.
	Damage has occurred.	Repair or replace the damaged conveyances.