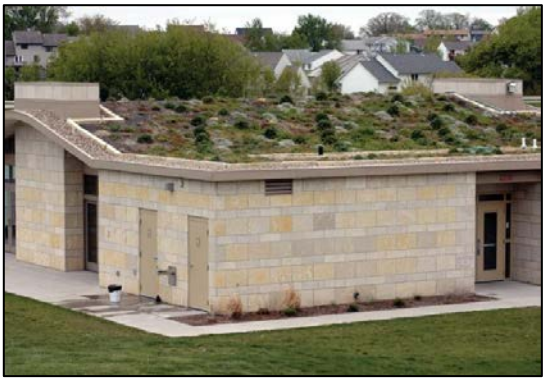
Design Standards Chapter 17- Green Roof Systems

Chapter 17 Green Roof Systems



BENEFITS Low = <30% Medium = 30-65% High = 65-100%			
	Low	Med	High
Nitrogen	✓		
Phosphorous	✓		
Metals		✓	
Energy Efficiency		✓	✓
Volume Reduction		✓	✓

Description: A green roof is a stormwater management practice that incorporates vegetation, growing medium, filter fabric, drainage panels, gravel, insulation, and geotextile layers to reduce runoff from an impervious roof surface. There are three main types of green roof systems, extensive, semi intensive or intensive, primarily defined by the depth of growing medium. Typical green roof characteristics:

Extensive Green Roof: 2-6" of growing medium; limited plant diversity (primarily sedum species); works well for building retrofits or new construction; may require irrigation for roofs that contain less than 4" of growing medium Semi Intensive Green Roof: 6-12" of growing medium; great diversity in plant selection; work well for new construction or major renovations
Intensive Green Roof: 12" or more of growing medium; nearly infinite diversity in plant selection; well suited for new constructions

Typical uses:
- Reducing stormwater runoff in urban areas where rooftops comprise a high percentage of impervious surfaces.
- Flat roofs or roofs with up to a 25% slope installed on both new and existing roofs

Advantages/Benefits:
Benefits of green roofs are well documented through research, utilities and occupant feedback. The benefits listed below may not be realized on each green roof project and should be verified through calculations, energy modeling and site specific conditions.
- Reduces stormwater runoff
- Well suited for space-limited sites
- Increases the life expectancy of the waterproof membrane
- Mitigates the urban heat island effect and improves air quality
- Reduction in cooling loads
- Provides aesthetically-pleasing functional green space in ultra-urban areas
- Provides habitat for birds and beneficial insects

Disadvantages/Limitations:
- Building capacity to support structure
- Access to the rooftop
- Installation costs

Maintenance requirements:
- Weeding, especially during the first two years
- Supplemental irrigation may be necessary
- Verify plant coverage and maintain soil fertility
- Keep drains clean.

A. Overview

1. **Description:** A green roof is a stormwater management practice that incorporates vegetation, growing media,

filter fabric, drainage layers, gravel, insulation, and geotextile layers to reduce runoff from an impervious roof surface. Green roofs have been used in Europe for over seventy-five years but are relatively new in North America (see Figure C17-S1- 1). Unlike the impervious properties of a traditional roof, green roofs promote retention and evapotranspiration of precipitation. Thus, a green roof can be used in place of a traditional roof as a way to limit impervious site area and manage stormwater runoff.

In addition to the three basic types of green roofs, there are two primary delivery and installation methods: in-situ and modular systems. In-situ or "built" up systems are constructed through a series of layers that are built up on the roof deck using materials that arrive on site in bulk. The roof is then vegetated by plugs, cuttings or pre grown mats. Modular systems or "trays" are individually placed on a rooftop in small 2'x4' plastic units filled with growing media and pre grown plants set on top of the waterproofing membrane and root barrier.

a. The typical saturated weight of a green roof is 7 lbs per square foot per inch of growing medium. Therefore a 4" extensive green roof weighs approximately 28 lbs per square foot. An existing rock ballast roof may be structurally sufficient to hold a 10-15 lbs/square foot green roof as ballast typically weigh about 10-15 lbs/square foot.

(a) An extensive green roof installed on the 70,000 square foot roof of the Des Moines' downtown library in 2005.

(b) A semi-intensive green roof at Cedar Rapids Public Library completed in 2013.

(c) A 4,700 square foot modular extensive green roof installed at Genesis Medical Center in Davenport in 2010.

(d) An extensive green roof installed on the 3,000 square foot roof of the North Ridge Park Pavilion in Coralville in 2003.

Figure C17-S1- 1: Examples of green roof applications in Iowa.

2. **Green Roof Components:** Most green roof systems are generally composed of similar components, although each green roof may not contain each component. This includes the following:
   a. Roof Deck,
   b. Leak Detection (if necessary)
   c. Waterproof Membrane
   d. Root Barrier
   e. Protection Layer

f. Drainage Layer
g. Filter Fabric
h. Growing Media
i. Wind Blanket
j. Plants
k. Ballast
l. Roof Drains
m. Irrigation System (if necessary)

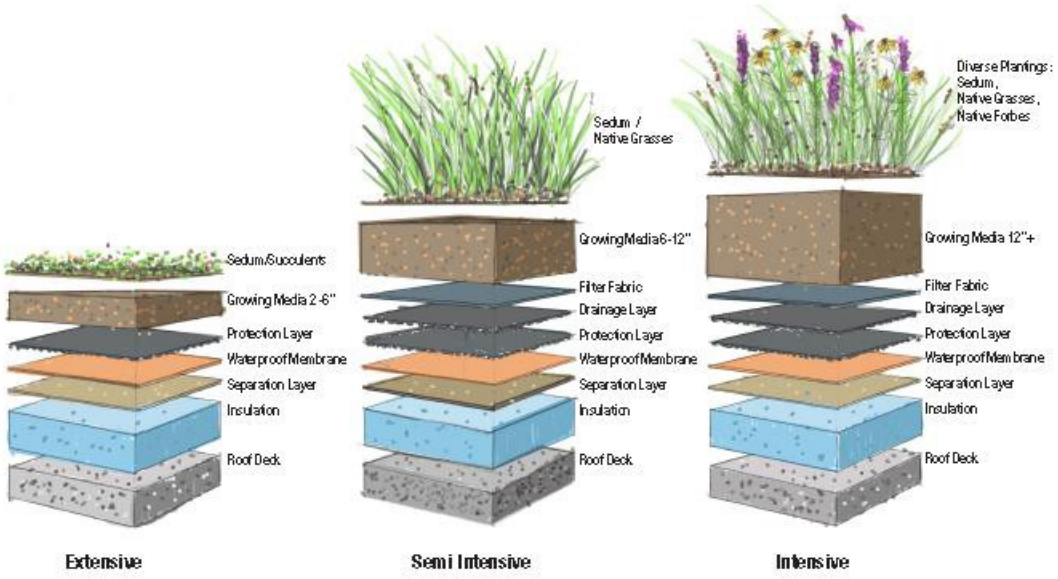


Figure C17-S1- 2: Typical arrangements of layers in extensive, semi-intensive and intensive green roof systems.

Table C17-S1- 1: Green Roof Components

Roof Deck	The load capacity of the building's roof structure must be taken into account when considering the design and installation of a green roof. Green roof systems can vary in weight depending on the space's program and design, but typically weigh about 7 lbs per square foot per inch of growing media. For example, a 4" extensive green roof typically weighs 28 lbs per square foot and a 12" intensive system will weigh about 84 lbs per square foot.
Leak Detection	It is recommended that the waterproof membrane be checked for leaks prior to adding additional layers. Leak detection systems are used on many green roof systems and typically consist of moisture sensors arranged in a grid fashion.
Waterproof membrane	The waterproof membrane protects the building from water infiltration and serves as the primary point of protection between the green roof system and interior building improvements.
Root Barrier	The root barrier protects the waterproofing membrane from root intrusion. This product is typically composed of a Poly-Vinyl Chloride membrane that is field welded together.
Protection Layer	The protection layer provides a uniform surface on top of the waterproofing membrane to protect the system from abrasion and penetration.
Drainage Layer	The drainage layer may be either a lightweight granular media or a synthetic layer that is set beneath the planting media. The drainage layer provides a balance between water retention and root aeration.
Filter Fabric	Filter fabric prevents fine soil particles from passing into the drainage layer of the green roof system.
Growing Medium	The primary purpose of growing media is to support plant growth and provide storage for stormwater. Growing media is typically composed of expanded clay, shale or lava rock.
Wind Blanket	The wind blanket provides temporary erosion control when placed over loose laid growing media to prevent materials from blowing or washing away. It typically bio or photo-degrades over a two year period.
Plants	Ideally plants chosen should be drought resistant and require no watering after their initial establishment. Sedum species are the predominant plants used for extensive green roof systems. Semi-Intensive systems can begin to support a limited number of native prairie plants found in shallow soils above bedrock.
Ballast	Ballast is used to provide a free draining path to roof drains, hold down waterproofing membranes and provide membrane coverage in areas that do not positively support vegetation.
Roof Drains	Roof Drains are placed in low points to help remove excess stormwater that moves laterally through the drainage layers.
Irrigation System	Some extensive green roof systems require permanent irrigation in order to comply with the manufacturer's warranty. Irrigation is not necessary if proper plants are selected.

3. **Applications for stormwater management and pollutant removal.**
   Green roofs have historically been used across the United States to reduce stormwater runoff. In addition, other benefits include extending the lifetime of the roofing membrane, reducing cooling loads, mitigating the urban heat island effect, and providing habitat. Unlike conventional roofing, green roofs promote retention and evapotranspiration of precipitation. The plants, growing media, and drainage layers absorb and store stormwater, significantly reducing the release rate and volume over an extended period.

   a. **Water quantity.** The greatest benefit of green roofs is the ability to reduce runoff. The ability to retain stormwater is determined by the growing media depth and porosity. Additional consideration should be given to the drainage layer, including the depth and size of the panel or the aggregate used.

      In general, the annual reduction in stormwater runoff generally varies depending on the type of green roof system, drainage layers, roof slope, plant species, and the intensity and duration of the rainfall. Water that is retained in the substrate will evaporate or evapotranspire back into the atmosphere. Green roofs are most effective when not saturated, but even when saturated by rainfall, runoff is delayed. This can significantly delay and reduce peak flows prior to producing runoff. In urban areas, this is a significant benefit when existing storm sewers are at capacity. (EPA/600/R-09/026, 2009)

   b. **Water quality.** Installation of green roofs is a source reduction strategy. They are typically used as part of a

treatment train. They reduce the runoff that would normally be discharged on-site which can transport pollutants to storm sewers and/or receiving waters. Depending on the depth of the growing media, some roofs may be able to manage the water quality volume that falls on the media surface.

Studies show there may be an initial increase in nutrient loads from green roofs due to the composition of materials in the original growing media. Applications of fertilizers and pesticides to ensure plant growth can also be detrimental to water quality. However, when native Iowa plants are used, fertilization is not necessary. It is also important to note that although the runoff concentrations of pollutants can be higher in green roof effluent, total pollutant loading is typically lower due to reduced total runoff volume. Research conducted by Hathaway et. al. (2008) indicates that up to 64% of recorded precipitation was retained in study green roofs and average peak flows were reduced by up to 75% during the study period.

Decreasing the temperature of stormwater runoff is especially important for systems discharging to natural streams, rivers, or lakes containing aquatic life. Buffering pH as shown in Figure C17-S1- 3 is also an important treatment characteristic especially in areas subject to acid rain.

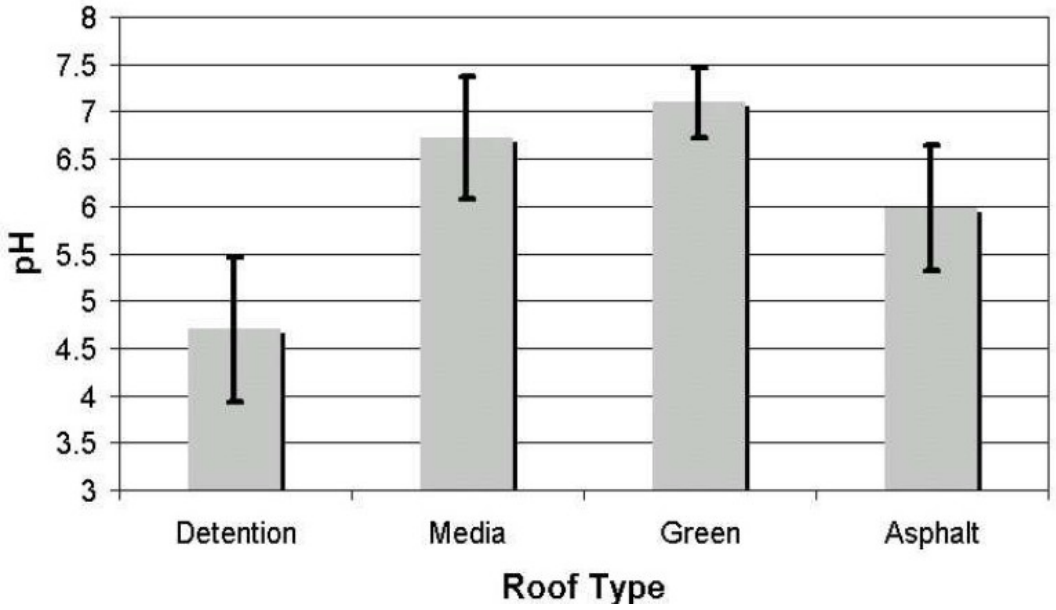


Figure C17-S1- 3: Average pH in runoff from different roof types
Source: Berghage, et.al, EPA/600/R-09/026, 2009

4. **Additional Environmental Benefits.** In addition to improving stormwater management by reducing runoff and improving water quality, green roofs have also been shown to provide several other environmental benefits.

    a. **Extended Lifetime of Waterproofing.** Green roofs protect the waterproofing membrane from ultraviolet rays and extreme temperature swings. Green roof systems can double the lifetime of the waterproofing system, significantly reducing the waste stream and reducing lifecycle costs.
    b. **Air Pollution.** Green roof vegetation can remove air pollutants by taking up gaseous pollutants through their stomates (e.g. CO_2), intercepting particulate matter with their leaves, and breaking down certain organic compounds in their plant tissue or in the growing media.
    c. **Urban Heat Island Reduction.** Green roofs reduce the urban heat island effect by mitigating the ambient air temperature heat fluctuations that are typically associated with black, grey or other dark colored roofing systems.
    d. **Cooling Load Reduction.** When used adjacent to rooftop units, the ambient air temperature is cooler than the air pulled off of a typical black, grey or dark colored roofing system.
    e. **Noise Reduction.** The vegetation and growing substrate on green roofs absorb sound waves to a greater degree than a hard surface roof. Green roofs have been shown to reduce noise pollution and can even reduce

noise levels on the inside of a building.

f. **Wildlife Habitat.** May provide habitat for birds and insects.

5. **Application and feasibility.** Green roofs can be installed on many different types of roofs, from small slanting roofs to large commercial flat roofs, but provide the greatest benefit within ultra- urban environments. They are also an ideal option for new buildings, especially those that place a premium on open space. Many existing buildings can be retrofitted if structurally reinforced.

   a. **Feasibility:**
   - Microclimate: The rooftop microclimate must be considered. Factors like solar radiation, exposure to extreme wind, and shade all will impact the success of an installation.
   - Structural capacity of roof – A licensed structural engineer should conduct a structural analysis to determine if a roof can support the additional live and dead loads that are associated with a green roof.
   - Slope – When a green roof reaches a 2:12 pitch, consideration must be given to hold growing media in place. Green roofs that exceed a 3:12 pitch should use a high strength mechanically fastened mesh to prevent media slippage and erosion.
   - Height – A wind blanket, ballast and other means to hold down a green roof should be considered when a green roof is installed more than 3 stories above the ground or if exposed to extreme winds. ANSI/ PRI RP14
   - Roof Access –Access must be provided for maintenance of the rooftop. The design should consider safety, access and egress requirements.
   - State and local building and fire codes – Consult local planning and zoning authorities in your municipality.

B. Design Methods

1. **Initial design considerations and preliminary investigation.** The most complete and well- established set of green roof standards and guidelines are the "Guidelines for the Planning, Construction, and Maintenance of Green Roofing." These guidelines are published by the German organization Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau (FLL) and are commonly referred to as the German FLL Guidelines.

2. In addition to FLL guidelines, the green roof industry in North America has developed further guidance, specific to North American design and construction procedures. A sampling of these codes and standards include the following organizations:
   a. International Building Code (IBC)
   b. American Society for Testing and Materials (ASTM)
   c. National Roofing Contractors Association (NRCA)
   d. Whole Building Design Guide (WBDG)
   e. American National Standards Institute (ANSI)

   Before choosing a green roof system, consideration must be given to a number of factors that will impact the design. Table C17-S1- 2 identifies a series of initial design considerations that should be evaluated.

Table C17-S1- 2: Initial Design Considerations

Local Requirements	Green roofs must be designed in accordance with applicable city, state, and federal building codes. Prior to beginning the design, the owner and design team should meet with the local code officials, including fire departments.
Structural Support	The structural support of a building must be sufficient to hold the weight of a green roof. A structural engineer or architect must verify that the roof will support the weight of the green roof system.
Quality Control	The green roof system should be designed to manage the Water Quality Volume (WQv) as defined in Chapter 2, section 1 of the Iowa Stormwater Management Manual (Unified Sizing Criteria) – green roof runoff can be routed into additional practices such as rain gardens to meet WQv requirements.
Quantity Control	The green roof system should be designed to safely convey large storm events through internal or external drainage systems.
Waterproofing System	Consideration must be given to the type of waterproofing system and the manufacturer's long term maintenance and warranty requirements. Each manufacturer has unique warranty requirements that must be met with the system's design.
Wind Uplift	Careful consideration should be given to the design wind speed for systems that are not adhered or mechanically attached to the roof deck. ANSI/ PRI RP14.
Public Access	If the green roof will be accessible to the public, consideration must be given to accessibility and occupancy requirements.
Plant Materials	Plants must be drought tolerant and able to withstand extreme temperatures. Extensive green roofs are primarily planted with sedum species, while semi-intensive and intensive green roofs are able to support a limited number of native plants.
Maintenance	Maintenance varies depending on the green roof design; the owner and designer should develop a maintenance plan that complies with the manufacturer's warranty. NOTE: some manufacturers require maintenance to be completed by a 3rd party contractor during the initial green roof establishment period.

3. **Design of green roof components.** The longest existing **s**tandards for green roof design and construction are the German FLL Guidelines. Recently, the number of guidelines available from North American organizations continues to increase (see Table C17-S1- 3). The green roof standards that are currently available from ASTM International include:

   E2396 Standard Test Method for Saturated Water Permeability of Granular Drainage Media (Falling-Head Method) for Green Roof Systems
   E2397 Standard Practice for Determination of Dead Loads and Live Loads Associated with Green Roof Systems
   E2398 Standard Test Method for Water Capture and Media Retention of Geocomposite Drain Layers for Green Roof Systems
   E2399 Standard Test Method for Maximum Media Density for Dead Load Analysis of Green Roof Systems (includes tests to measure moisture retention potential and saturated water permeability of media, total porosity, and air content of media)
   E2400 Standard Guide for Selection, Installation, and Maintenance of Plants for Green Roof Systems

   The green roof standards that are currently available from the American National Standards Institute (ANSI) include:

   ANSI/SPRI RP-14 Wind Design Standard for Vegetative Roofing Systems
   ANSI/SPRI VF-1 External Fire Design Standard for Vegetative Roofs
   ANSI/GRHC/SPRI VR-1 2011 Procedure for Investigating Resistance to Root Penetration on Vegetative Roofs

   The materials needed for green roofs will vary depending on factors such as media thickness, intended uses, and desired appearance.

Table C17-S1- 3: Available guidelines and standards for green roof design components

Attribute	North American Reference	German FLL Guidelines
System and Compatibility	ANSI/Single Ply Roofing Industry(SPRI) VF-1 (Section 3)	Chapters 1, 5, 6, and 7
Application	ANSI/SPRI VF-1 fire and wind standard is for roof slopes up to 2:12	Chapters 5, 6, and 7
Wind	ANSI/SPRI VF-1 (Section 3)	Chapters 2 and 6
Fire	ANSI/SPRI VF-1 (Sections 4 and 5)	Chapters 2 and 6
Filtration	N/A	Chapters 2 and 9
Design Loads	IBC 1607.11.22, IBC 1607.11.3,	Chapters 1, 2, 5, and 6
Surface Loads and Material Properties	N/A	Appendix 1, Tables 13 to 16
Waterproofing	NRCA (Chapter 5), WBDG 075564, IBC (Chapter 15)	Chapters 2 and 5
Root Barriers	NRCA (Chapter 6)	Chapters 6 and 7
Drainage Materials and Construction	NRCA (Chapters 6 and 7), WBDG 073363	Chapter 8
Management of Surface Flows	N/A	Chapters 7 and 8
Management of Subsurface Flows	WBDG 073363	Chapter 8, Appendix 2
Growth Media Depth and Material/Composition	WBDG 073363	Chapters 2, 7, and 10
Managing Growth Media, Permeability, and Erosion	WBDG 073363	Chapter 10, Appendix 2
Vegetation Selection	ASTM E 2400, WBDG 2.2	Chapter 3
Depth of Growth Media	ASTM E 2400	Chapter 7
Vegetation Installation	ASTM E 2400, WBDG 073363	Chapters 2, 7, 11, and 12
Watering	ASTM E 2400	Chapter 7
Weeding, General Care, Warranty	ASTM E 2400, NRCA (Section 10-11)	Chapters 11 and 13

Source: Dvorak, B. 2011. Comparative analysis of green roof guidelines and standards in Europe and North America. Journal of Green Building 6:2:170-191.

a. Roof Deck. The load capacity of the building's roof structure must be taken into account when considering the design and installation of a green roof. Green roof systems can vary in weight depending on the space's program and design, but typically weigh about 7 lbs per square foot per inch of growing media. For example, a 4" extensive green roof typically weighs 28 lbs per square foot and a 12" intensive system will weigh about 84 lbs per square foot. The load bearing capacity of the roof structure is critical for the support of soil, plants, water, snow, and any people who will be accessing the green roof (for maintenance or recreation). For retrofit projects, an architect, structural engineer, or roof consultant can determine the condition of the existing building structure and what might be needed to support a green roof. Alterations might include additional decking, roof trusses, joists, columns, and/or foundations.

Flat roofs (or those with a pitch of up to 2%) are easiest to install and least complex. Those with steeper slopes usually require the addition of cross-battens to hold drainage layers in place as well as more soil erosion control.

b. Leak Detection. This is an optional layer that an owner may consider for risk management. There are several products on the market today that create a low voltage electrical field below the waterproofing membrane.

The technology has historically been used in roofing, landfill or other applications where there is significant risk if a leak would occur.

c. Waterproof Membrane. The waterproof membrane protects the building from water infiltration and serves as the primary point of protection between the green roof system and interior building improvements. A qualified professional should be consulted to help determine the type of waterproofing system to be used. Once a waterproofing system is determined, the green roof design should be approved by the waterproofing manufacturer certifying full compliance with the warranties. There are two commonly used types of waterproofing systems – sheet and liquid applied.

- Sheet Applied Membranes –typically installed over the roof deck on top of insulation and vapor control layers. Typical products include:
  i. Thermoplastic Polyvinyl Chloride: composed of PVC resin reinforced with fiberglass. Membranes can be adhered or loose laid. Seams are welded together with heat, creating a uniform, waterproof surface.
  ii. Modified Bitumen: composed of styrene-butadiene-styrene creating a modified rubber surface, typically coated with protective granules and reinforced with fiberglass.

- Liquid Applied Membranes – typically installed over a cementitious substrate directly on the roof deck. Typical products include:
  i. Rubberized Asphalt: composed of asphalt, rubber and resins applied as a hot liquid and reinforced with a compatible fabric.
  ii. Polyurethane Elastomers: a urethane based product that is spray applied creating a monolithic surface without reinforcing.

d. Root Barrier. The root barrier protects the waterproofing membrane from root intrusion. This product is typically composed of a PVC or HDPE membrane that is field-welded together creating an impenetrable surface. Consideration should be given to use the waterproofing manufacturer's standard sheet specifically designed to retard root growth.

e. Protection Layer. The protection layer is typically placed over the waterproofing membrane to protect the waterproofing system from abrasion and penetration during installation. This product comes in many types ranging from polypropylene fabrics, to drainage panels with an integrated compression hybridized with drainage panels,

f. Drainage Layer. The drainage layer provides conveyance of excess water in green roof systems and maintains continuous flow under compressed and saturated conditions.

- There are two types of drainage layers commonly used in green roof systems: clean gravel or recycled plastic composite. The type, size and thickness of the drainage layer will vary depending on the depth of growing media and desired stormwater management outcomes. Aggregate Drainage layers are typically composed of ⅜"-¾" clean aggregates meeting the following requirements:
  i. Abrasion resistance (ASTM-C131-96): ≤25% loss
  ii. Soundness (ASTM-C88 or T103 or T103-91): ≤5% loss
  iii. Porosity (ASTM-C29): ≤25% loss

- Plastic Composite drainage layers come in numerous designs. Consideration should be given to the weight, water holding capacity and flow rate. Typical products look like an "egg carton" or "dimple board" with holes punched to allow water to move through the system.

g. Filter Fabric. Filter or separation fabric shall allow root penetration, but prevent the growth medium from passing through into the drainage layer. The fabric should be a non-woven polypropylene geotextile.

h. Growing Medium. The growing medium in green roofs should be a lightweight mineral material and coincide with the waterproofing manufacturer's recommendations.

i. Wind Blanket. The wind blanket provides temporary erosion control when placed over loose laid growing media to prevent materials from blowing or washing away. It typically bio or photo-degrades over a two year

period.

j. Plants. Plant selection for green roofs is governed by local climate and design objectives.

- Green roof vegetation should be perennial or self-sowing and be able to withstand heat, cold, and high winds.
- Once established, the selected plantings should be self-sustaining, tolerant of drought conditions, and thoroughly cover over 90% of the growing medium.
- The root size and depth, height of the roof, exposure to wind, snow loading potential, orientation to the sun, and shading by surrounding buildings should all be considered when choosing green roof plant material.
- *Sedum sarmentosum* (also known as star sedum, gold moss, stringy stonecrop, or graveyard moss) and *Sedum hispanico* are known to be invasive and should be avoided.
- For extensive green roofs, a combination of sedums (at least 12 different species), native prairie forbs and grasses are recommended (see Table C17-S1- 4).

Table C17-S1- 4: Examples of green roof plant material.

4 Inches Soil Minimum	8 Inches Soil Minimum
Allium Schoenoprasm ‘Chives’	Delosperma Nubgineum ‘Basutoland’
Sedum Acre ‘Aureum’	Echinacea Purpurea ‘Purple Coneflower’
Sedum Album ‘Coral Carpet’	Sporobolus Heterolepis ‘Prairie Dropseed’
Sedum Reflexum ‘Green Spruce’	Opuntia Humifusa ‘Prickly Pear Cactus’
Sedum Sexangulare	Bouteloua Curtipendula ‘Side Oats Grama’
Sedum spurium ‘Fuldagut’ Sedum Spurium’John Creech’	Talinum Calycinum ‘Flameflower’
Sedum Spurium ‘Roseum’	Sempervivum Silverine ‘Hen and Chicks’
Sedum Spurium ‘Vodoo’	

k. Ballast. Ballast provides a free draining path to roof drains, holds down loose laid waterproofing membranes and provides membrane coverage in areas that do not positively support vegetation.

l. Roof Drains. Roof Drains are placed in low points to help remove excess stormwater that moves laterally through the drainage layers. Consideration should also be given to overflow scuppers or supplemental roof drains.

m. Irrigation Systems. The majority of green roofs installed do not need permanent irrigation if there is at least 4 inches of modified soil and proper plants are selected. It is recommended that extensive green roof systems be designed so that an irrigation system is not necessary.

- If an irrigation system is necessary (e.g. an intensive green roof), the irrigation system pipes should not be placed directly on the waterproof membrane, but on a protection board or among the growing medium to avoid damage to the system from pressure and pipe movement.

In addition to design guidelines and specifications, there are also references available for testing the different components of green roofs (see Table C17-S1- 5). The German FLL Guidelines include industry standard tests for the weight, moisture, nutrient content, and grain-size distribution of growing media. FLL also certifies laboratories to conduct critical tests, such as root penetration resistance of waterproofing membranes. Laboratories in the United States are now offering a full range of FLL tests for green roof materials.

Table C17-S1- 5: Available standard tests and practices for evaluating green roof components

Attribute	North American Reference	German FLL Guidelines
System and Compatibility	IBC 104.11.2 2009, WBDG 1.7	Chapter 16
Wind	ANSI/SPRI RP-14,	Chapter 6
Fire	ANSI/SPRI VF-1,	Chapter 16
Density	ASTM E 2399	
Design Loads	ASTM E 2399	N/A
Surface Loads and Material Properties	ASTM E 2397	Table 7
Waterproofing	Varies by Type	N/A
Root Barriers	ANSI/GRHC/SPRI VR-1	Appendix 3
Drainage Materials and Construction	Varies by Type	Chapter 16 and Appendix 2
Management of Subsurface Flows	ASTM E 2396, ASTM E 2398	Appendix 2
Growth Media Depth and Material/Composition	ASTM E 2399	Chapter 16
Managing Growth Media, Permeability, and Erosion	N/A	Appendix 2
Vegetation Installation	WBDG 073363	80% coverage of planted area with specified plant material after 12-15 months, No gaps in vegetation over 2.5 m^2 allowed
Weeding, General Care, Warranty	WBDG 073363	Chapter 16

Source: Dvorak, B. 2011. Comparative analysis of green roof guidelines and standards in Europe and North America. Journal of Green Building 6:2:170-191.

4. **Green Roof Sizing Calculation.** The following design procedure assumes that the designer has completed preliminary investigations, and understands the design components of a green roof. It is recommended that these calculations be completed as early as possible in the design process, so that adequate room is reserved for stormwater management as site design development continues. Calculations can be adjusted as final site design is completed.

Water Quality Volume Management

Calculations to determine the WQv treatment provided by a green roof are typically based on the amount of pore space present within the system. When using a proprietary green roof system, a designer should review the manufacturer's design guidelines to determine the percentage of pore space that is expected to be present within the different elements of the system.

For the purposes of conceptual or preliminary design, research completed by Hunt (2007) demonstrated that green roofs can provide 0.2 inches of storage volume per inch of media depth. Based on this, the following table lists the available storage volume based on media depth.

Table C17-S1- 6: Storage Volume Based on Media Depth

Media Depth (in)	Storage Volume (in)
2	0.4
4	0.8
6	1.2
8	1.6
10	2.0
12	2.4

From this relationship, it can be seen that 6 inches of media depth will likely be required to fully manage the rainfall volume of the 1.25" WQv storm event.

More detailed calculations should be performed as part of final design, using manufacturer's information regarding pore space for proprietary products, or an assumed void space in other cases.

5. WQv design example

A green roof has been designed for part of a 2,200 square foot rooftop. The green roof will cover 2,000 square feet of the roof. The runoff from the other 200 square feet of the rooftop is directed to the green roof. The proposed system will have a 4-inch soil media layer, and a 2-inch drainage layer which is designed to retain water prior to its discharge to the roof drain system. Given the proposed design, evaluate if the proposed green roof design satisfies site Water Quality Volume (WQv) requirements.

Step 1: Calculate the Water Quality Volume (WQv) using the equation defined in Chapter 2, section 1 of the Design Standards.

$$WQ_v = \frac{(R_v)(A)(P)}{12}$$

Where:
R_v = site runoff volume coefficient = $0.05 + 0.009(I) = 0.05 + 0.009(100) = 0.95$
I = the percentage of impervious area draining to the site
A = site drainage area [square feet] = 2,200 square feet
P = design rainfall depth (90% cumulative frequency depth) = 1.25 inches

$$WQ_v = \frac{(0.95)(2200ft^2)(1.25in)}{12} = 217.7ft^3$$

$$\boldsymbol{WQ_v = 217.7ft^3}$$

Step 2: Calculate the drainage layer and soil media storage volume.

The equation for calculating the storage volume of a green roof is as follows:

$$Storage\ Volume = V_{SM} + V_{DL}$$

$$V_{SM} = A_{GR} \times D_{SM} \times n_{SM}$$

$$V_{DL} = A_{GR} \times D_{DL} \times n_{DL}$$

Where:
V_{SM} = volume of the soil media [**in cubic feet**]

V_{DL} = volume of the drainage layer [**in cubic feet**]*
A_{GR} = green roof surface area [**in square feet**]
D_{SM} = depth of the soil media [**in feet**, based on design]
D_{DL} = depth of the drainage layer [**in feet**, based on design]
n_{SM} = porosity of the soil media (use manufacturer's recommendation, or assume ≈ 20%)
n_{DL} = porosity of the drainage layer (use manufacturer's recommendations, or assume ≈ 25%)

$$V_{SM} = A_{GR} \times D_{SM} \times n_{SM}$$

$$V_{DL} = A_{GR} \times D_{DL} \times n_{DL}$$

Where:
A_{GR} = green roof surface area = 2,000 square feet
D_{SM} = depth of soil media = 4 inches = 0.33 feet
D_{DL} = depth of drainage layer = 2 inches = 0.17 feet
n_{SM} = porosity of soil media = 0.20
n_{DL} = porosity of drainage layer = 0.25

$V_{SM} = (2000ft^2)(0.33ft)(0.20) = 132.0ft^3$
$V_{DL} = (2000ft^2)(0.17ft)(0.25) = 85.0ft^3$

$Storage\ Volume = V_{SM} + V_{DL} = 132.0ft^3 + 85.0ft^3 = 217.0ft^3$

$$\boldsymbol{Storage\ Volume = 217.0ft^3}$$

*Note: The volume within the drainage layer should only be counted within this calculation if it is design to retain that volume prior to its release to the roofdrain system.

Step 3: Determine if the green roof satisfies the Water Quality Volume (WQv) requirements.

WQv = 217.7 ft^3
Green Roof Storage Volume = 217.0 ft^3

WQv Volume should equal or exceed the Green Roof Storage Volume Provided

217.7 ft^3 ≈ 217.0 ft^3

These values are essentially equal. The difference is less than a cubic foot of runoff. This is so close, that the WQv could be considered as satisfied. Other options would be to slightly increase the depth of soil media, or pair the green roof system with another BMP (rain barrel, bioretention cell, etc.).

Stormwater Modeling (TR-55 Hydrographs)
Stormwater models can be adapted to calculate surface runoff from a green roof by using revised curve numbers (CNs) and times of concentration. When using NRCS TR-55 software to model runoff generated from a green roof, it is recommended to use the following curve numbers, based on available storage volume within the green roof system (measured in inches of depth).

Table C17-S1- 7: Green Roof Curve Numbers

Storage Volume (in)	Curve Number**								
	WQv	1-yr	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	500-yr
0.4	93	94	94	94	94	95	95	95	95
0.8	83	90	90	90	91	91	91	91	92
1.2	62	84	85	86	87	87	88	88	88
1.6	62	77	79	82	83	84	84	85	85
2.0	62	69	73	76	79	80	80	91	82
2.4	62	55	64	71	75	76	76	78	79

**Calculated based on using TR-55 to estimate runoff volume in inches from a standard roof (CN=98), then subtracting the storage volume to define the revised runoff volume. Then, CN is calculated using Equation C3-S5- 5, for the various events using the largest value of rainfall depth for the various regions within Iowa.

Equations included within NRCS TR-55 to calculate times of concentration based on sheet flow, shallow concentrated flow and channel flow are not applicable to green roofs. However, delays have been observed in the arrival times for peak rates of runoff from green roofs during a variety of studies. To consider this effect, it is recommended to calculate the time of concentration for a green roof as the time it takes rainfall to pass through the soil media layer, at a rate of 4 inches per hour (i.e. a green roof with 8 inches of soil media would have an assumed time of concentration of 2 hours or 120 minutes).

C. Construction

1. **Pre-Installation Meeting.** A pre-installation meeting with the design and installation contractor is critical to the success of a green roof.
   a. Contractors should be trained and certified for green roof installations and have a thorough understanding of the overall system being installed.
   b. Contractors must be aware of the roof access points, load bearing points, material storage requirements, mode of transportation of materials to the jobsite, and scheduling of materials.

2. **Installation.**
   a. The installation of the green roof system is the most important aspect of any green roof project. This design guide makes reference to many of the different supporting elements of the green roof for the purposes of creating a successful project. This design guide does not cover the installation or specification of the roof deck. Consultation with a qualified Architect and/or structural engineer is recommended.

   b. Leak Detection. Install leak detection grid on membrane substrate immediately under membrane and immediately prior to installation of membrane. The installation process should adhere to the leak detection system manufacturer's requirements.
      - Test the entire membrane after waterproofing installation
      - Flood the roof with water prior to each test.
      - Verify that roof drains, flashings and other appurtenances are watertight.

   c. **Waterproof Membrane.** Correct and meticulous application of the waterproof membrane is essential to the viability of the rooftop. This design guideline does not cover the installation of the waterproofing membrane. Consultation with a qualified Architect or roofing professional is recommended. Follow manufacturer's requirements for installation.

   d. **Root Barrier.** The root barrier is often integrated into the waterproofing membrane. If the manufacturer's system requires a separate root barrier, place the membrane over the waterproofing membrane separated by a protection layer as required by the manufacturer.

e. **Protection Layer.** Install the protection layer over the membrane or separation layer. Seams should be welded air tight. Follow manufacturer's specifications.

f. **Drainage layer.** Drainage layers shall be placed directly over the waterproofing membrane protection layers.
- Start the installation at the low points on the roof, typically at the roof drains.
- Connect drainage panels together using manufacturer's connections strips or zip ties.
- Trim panels to fit closely around drains.
- Cover the panels with the integrated fabric or filter fabric.
- The drainage layer should be tested to ensure water drains properly from the roof.

g. **Filter Fabric.** Install according to the insulations manufacturer's specifications.
- Cover filter fabric with growing medium as work progresses.

h. **Growing Medium.** Growing media shall be placed carefully to avoid damage or displacement of other materials such as walls, paving, protection layer, filter fabric, and waterproofing membrane.
- Place growing media at a 1 inch greater depth than final grade.
- Compaction shall be performed with a 200-300 lb. landscape roller to achieve 50-60 % compaction as determined by ASTM D1557. Areas inaccessible by the landscape roller shall be hand tamped to achieve 50-60 % compaction as determined by ASTM D1557.
- After compaction remaining growing medium shall be placed at 1 inch greater than final grade and thoroughly watered or jetted over entire area. Low settled areas shall be filled with additional soil and re-wet to achieve uniform prescribed final grade.

i. **Wind Blanket.** Install wind blanket and secure in accordance with manufacturers requirements.

j. **Plant Material.**
- Install plants within approved planting schedule.
- Establish vegetation in the spring or summer for best results – sedums can be established from fresh cuttings that are broadcast onto the growing medium, plugged or through vegetated mats
- Set out and space plants, mark locations, outline areas and distribute individual species, seed or vegetated mats as indicated on plan drawings.
- Contractor installing plant material shall not damage the protection layer or any other green roof component below the protection layer during the planting process. Any damage to the protection layer or any component below the protection layer must be immediately reported to the Architect and protection layer installer for inspection, and must be fully repaired by the contractor at no additional cost to the owner, following the Architect and protection layer installer's instructions.

k. **Ballast.** Install ballast edge as indicated on the drawings. Place gravel carefully to avoid damage and displacement of aluminum edging, walls, filter fabric, protection layer and waterproofing membrane.

l. **Roof Drains.** Install access box at locations shown on Drawings. Install top of boxes level with the finish elevation of growing medium.

m. **Irrigation Systems.** Install per manufacturer's instructions.

Figure C17-S1- 4: Installation of modular tray system green roof.
Source: East Side Recycling Center, Iowa City, Iowa, 2011

D. Maintenance

All green roof components, including plant material, growing medium, filter fabric, drainage layer, waterproof membranes, and roof structure should be inspected for proper operations, integrity of the waterproofing, and structural stability throughout the life of the green roof.

Achieving plant coverage greater than 95% is the single most important aspect to create a thriving, healthy rooftop. During the first two years, green roofs should receiving regular watering during establishment, approximately 1" per week. A typical green roof planted with plugs will achieve 50% coverage during the first growing season and should be fully covered after the second growing season.

During the first two years, a green roof should be inspected monthly during the growing season. Maintenance activities include weeding, supplemental planting and vegetation assessment. After the initial inspection maintenance should occur one to two times a year after vegetation has been established. Maintenance activities include weeding, filling in bare spots with plugs or seeds, and replacing any media that has eroded. Plant material should be maintained to provide 95% plant cover.

During the growing season, supplemental irrigation or fertilizing with a slow release NPK fertilizer may be necessary. Irrigation may also be needed during extended periods of hot, dry weather. Irrigation, although not recommended, can be accomplished either through hand watering or automatic sprinkler systems if necessary during the establishment period.

Table C17-S1- 8: Green roof maintenance guidelines

Activity	Schedule
• Ensure the drains are working properly. Drain inlet pipe should be cleared when soil substrate, vegetation, debris, or other materials clog the drain inlet. Sources of sediment and debris may be identified and corrected. If necessary, prune plants away from roof structures. • Plant material should be maintained to provide 90% plant cover. Weeding should be manual with no herbicides or pesticides used. Weeds should be removed regularly and not allowed to accumulate. • Irrigation, although not recommended, can be accomplished either through hand watering or automatic sprinkler systems if necessary during the establishment period.	As needed
• Growing medium should be inspected for evidence of erosion from wind or water. If erosion channels are evident, they can be stabilized with additional growth medium similar to the original material	Quarterly
• Inspect drain inlet pipe and containment system.	Annually
• Maintain a record of all inspections and maintenance activity.	Ongoing

Note: The design of green roofs is not limited to the examples shown within this text. Successful stormwater management plans will combine appropriate materials and designs specific to each site.

E. References/Further Resources

1. ANSI/SPRI RP-14 Wind Design Standard for Vegetative Roofing Systems. ANSI/SPRI VF-1 External Fire Design Standard for Vegetative Roofs.
2. ANSI/GRHC/SPRI VR-1 2011 Procedure for Investigating Resistance to Root Penetration on Vegetative Roofs.
3. ASTM E2396-05 Standard Test Method for Saturated Water Permeability of Granular Drainage Media (Falling-Head Method) for Green Roof Systems.
4. ASTM E2397-05 Standard Practice for Determination of Dead Loads and Live Loads associated with Green Roof Systems.
5. ASTM E2398-05 Standard Test Method for Water Capture and Media Retention of Geocomposite Drain Layers for Green Roof Systems.
6. ASTM E2399-05 Standard Test Method for Maximum Media Density for Dead Load Analysis of Green Roof Systems.
7. ASTM E2400-06 Standard Guide for Selection, Installation, and Maintenance of Plants for Green Roof Systems.
8. ASTM E631-06 Standard Terminology of Building Constructions
9. ASTM C29/C29M-07 Standard Test Method for Bulk Density (“Unit Weight”) and Voids in Aggregate
10. ASTM E2114-08 Standard Terminology for Sustainability Relative to the Performance of Buildings
11. ASTM WK7319-New Standard Guide for the Use of Expanded Shale, Clay or Slate (ESCS) as a Mineral Component in Growing Media for Green Roof Systems (std. still in development)
12. Barr Engineering Company. 2003. Minnesota Urban Small Sites BMP Manual: Stormwater Best Management Practices for Cold Climates. Metropolitan Council Environmental Services. St. Paul, Minnesota.
13. Berghage, R, D Beattie, A Jarrett, C Thurig, F Razaei, and T O’Connor. Green Roofs for Stormwater Runoff Control. US Environmental Protection Agency, Washington, DC, EPA/600/R-09/026, 2009.
14. City of Indianapolis: Stormwater Design and Specification Manual: 4.1 Green Roofs.
15. Design Guidelines and Maintenance Manual for Green Roofs in the Semi-Arid and Arid West. Dvorak, B. 2011. Comparative analysis of green roof guidelines and standards in Europe and North
16. America. Journal of Green Building 6:2:170-191.
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18. Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau. Bonn, Germany.
19. Green Roofs for Healthy Cities (http://www.greenroofs.org/).
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21. New York State Stormwater Management Design Manual: 5.3.8 Green Roofs. Philadelphia Stormwater Manual v2.0:

7.1 Green Roofs.
22. Rowe, BD, 2011. Green roofs as a means of pollution abatement. Environmental Pollution 159: 2100 2110.