Green Stormwater Infrastructure (GSI) on Private Property
Green Roofs

January 7, 2010

This Tip is designed to help applicants meet the requirements for green roofs associated with stormwater code compliance. Tip 535 provides design, sizing, construction, inspection, and maintenance guidelines for all projects on private property with less than 10,000 square feet of new and replaced impervious surface. Projects exceeding 5,000 square feet of new and replaced impervious surface must be stamped by a licensed engineer.

This Tip covers:
- What are green roofs?
- How are green roofs categorized?
- What are the essential components of a green roof?
- How much green roof area is necessary to meet the stormwater mitigation requirement?
- What inspections are required for GSI green roofs?
- How are inspections scheduled?
- How are green roofs maintained?
- What additional resources and contacts are available?

What are green roofs?
Green roofs are areas of living vegetation installed on top of buildings to provide flow control via attenuation, soil storage, and losses to interception, evaporation, and transpiration. The terms green roofs, ecoroofs, vegetated roofs, and roof gardens are used interchangeably. A green roof consists of a system in which several materials are layered to achieve the desired vegetative cover and drainage characteristics (see the construction detail).

Design components vary considerably depending on site constraints and the type of green roof selected.

How are green roofs categorized?
Green roofs are categorized by their depth and the materials used in their construction.

1. Intensive roofs are deeper installations, comprised of at least 6 inches of growth media (soil) and are planted with ground covers, grasses, shrubs and sometimes trees. These systems require regular landscape maintenance.

2. Extensive roofs are shallower installations, comprised of less than 6 inches of growth media and use a planting palette of drought-tolerant, low maintenance plants and ground covers. Extensive green roofs have the lowest weight and are the most suitable for placement on existing structures. Extensive systems are divided into the following:
   - Single-course systems, which consist of a single material designed to be freely draining and support plant growth, and
   - Multi-course systems that include both a growth media layer and a separate, underlying drainage layer.

Commercially available “modular” systems consist of prefabricated trays filled with growth media. Modular systems are considered multi-course systems.

The City of Seattle accepts the following types of green roofs for Impervious Surface Reduction Credit:
- Extensive single-course systems with at least four inches of growth medium for areas less than 1,000 square feet
- Extensive multi-course systems (and commercially available modular systems) with at least four inches of growth medium
- Intensive multi-course systems with six to eight inches of growth medium

Green roofs can be applied to a range of rooftop slopes; however, steeper slopes may result in re-
duced flow control performance and trigger additional 
design requirements (e.g., underlying drainage layer 
and lateral support measures). Roofs with up to two 
percent pitch provide the greatest stormwater storage 
capacity per inch of growth medium. At the time of 
publication of the Stormwater Manual, the City of Se-
attle will only provide Impervious Surface Reduction 
Credit for roofs less than 20-percent slope.

The degree of flow control provided by green roofs 
varies as a function of growth medium (soil) depth, 
growth medium composition, drainage layer charac-
teristics, vegetation type, roof slope, and other design 
choices.

What are the essential components of a 
green roof?

Waterproof membrane
A waterproof membrane shall be included in green 
roof design. Waterproof membranes are made of 
various materials, including reinforced polyvinyl 
chloride, synthetic rubber, thermoplastic polyolefin, 
high-density polyethylene, modified asphalts, and hy-
palon. Some waterproofing materials come in sheets 
or rolls and some are available in liquid form. Differ-
ent materials have different strengths and functional 
characteristics.

Root barrier
A root barrier shall be included in GSI green roof 
design. Some waterproofing membranes have root 
barrier capabilities intrinsic to the material. Modified 
asphalts usually require a root barrier, while ethylene-
propylene-diene-monomer (EPDM) and reinforced 
polyvinyl chloride (PVC) typically do not. It is sug-
gested the manufacturer be consulted to determine 
whether a root barrier is recommended for a particular 
product. Root barriers shall not contain leachable 
water quality contaminants, such as herbicides, cop-
per and zinc.

During installation, treatment to prevent root pen-
etration should not be restricted to parts of the roof 
that will be covered with vegetation, as the roots will 
extend beyond the areas in which vegetation is visible 
at the surface. Care should be taken to fully treat the 
areas at joints, borders, and seams.

Drainage layer (as applicable)
A drainage layer underlies the growth medium for 
intensive and extensive multi-course green roof 
systems. The drainage layer is designed to provide 
void spaces to hold a portion of the water that passes 
through the growth medium and to channel the water 
to the roof drain system. The drainage layer can 
consist of a layer of aggregate, or a manufactured rain 
drain mat, or boards. Many manufactured products 
include “egg carton” shaped depressions that retain 
a portion of the water for eventual evaporation and 
transpiration. For optimal flow control, an aggregate 
removal layer with a maximum total organic matter 
of one percent by mass with a saturated hydraulic 
conductivity of less than 4,500 inches per hour is 
recommended. See the SPU Technical Resources for 
updated recommendations: www.seattle.gov/dpd/
codesrules/codes/stormwater/.

Separation fabric
A non woven, geo-textile separation fabric must be 
installed between the growth medium and the drain-
age layer of multi-course systems to prevent fine soil 
and substrate components from being washed out of 
the growth medium into the drainage layer. The fabric 
must be pervious to allow water to percolate into the 
separation layer. If a manufactured drainage layer is 
used, the separation fabric is typically included. The 
separation fabric shall have permissivity sufficient to 
pass anticipated peak rainfall intensity but be suffi-
cient in retaining the growth medium.

Growth medium
Green roofs use a light-weight growth medium with 
adequate fertility and drainage capacity to support 
plants and allow infiltration and storage of water. 
Growth medium composition (fines content and water 
holding capacity) is critical to flow control perfor-
mance. The growth medium typically has a high ratio 
of mineral to organic material content and can be a 
mixture of various components including gravel, sand, 
compost, soil, or light weight aggregate material. Be-
cause of their excessive weight, particularly when wet, 
native soils are not acceptable substrates for green 
roofs. Growth media must be protected from erosion 
until 90 percent vegetation coverage is achieved.

Link to SPU’s Technical Resources by visiting: www.
seattle.gov/dpd/codesrules/codes/stormwater/.

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Vegetation

Vegetation used on extensive green roofs should be drought tolerant, self-sustaining, low maintenance, and perennial or self-sowing. Appropriate plants should also be able to withstand heat, cold, periodic rainwater inundation and high winds. Vegetation with these attributes typically includes succulents, grasses, herbs, and wildflowers that are adapted to harsh conditions.

Plants can be installed as vegetation mats, individual plugs, cuttings, or spread as seeds.

Vegetation mats: Vegetation mats are sod-like, pre-germinated mats that achieve immediate full plant coverage. They provide immediate erosion control, do not need mulch, provide the most rapid establishment for sedums, and minimize weed intrusion. They also need minimal maintenance during the establishment period and little on-going watering and weeding.

Plugs or potted plants: Plugs or potted plants may provide more design flexibility than mats. However, they take longer to achieve full coverage, are more prone to erosion, need more watering during establishment, require mulching, and require more weeding. Birds sometimes pull out plugs, in which case netting may be needed until the replaced plugs are fully rooted.

Cuttings: While cuttings may be used, they are slower to establish than mats and plugs and have a higher mortality rate.

Seeds: Seeds can be either hand broadcast or applied by hydro-seeding. Seed plantings require more weeding, erosion control, and watering than mats and plugs.

Other Planting Considerations:

In the long term, the generation of warm and cold air currents resulting from heating and air-conditioning vents on the rooftop can cause frost and drought damage to plants. Exhaust gases such as sulfur dioxide or grease from chimneys and exhausts can result in direct damage to vegetation, depending on the species. Therefore, areas that are affected by warm air, variable air currents, and exhaust gasses need to be researched carefully to determine whether they are suitable areas for planting, and to identify the type of vegetation best suited to the particular conditions.

An additional consideration is the effect of providing a green roof habitat. Habitat may be enhanced by using diverse planting and including some larger plants.

Enhancing wildlife habitat may not be appropriate for some sites (e.g., attracting birds near air fields).

Minimum requirements associated with the vegetation design include the following:

- Plans must specify that 90 percent vegetation coverage of selected plants shall be achieved within two years or additional plantings shall be provided until this coverage is met.
- Projects with more than 5,000 square feet of impervious surface will be required to submit a vegetation plan designed by a certified landscape architect.
- Vegetation must be suitable for harsh (e.g., hot, cold, dry, wet, and windy) rooftop conditions.
- Plants must not require fertilizer, pesticides or herbicides after the two-year establishment period.
- Landscape Management Plan shall be developed and implemented.

The Approved Plant List is available online at: www.seattle.gov/dpd/cityplanning/completeprojectslist/greenfactor/.

Irrigation plan

Provisions must be made for supplemental irrigation during the first two growing seasons after installation to ensure plant survival. Subsurface irrigation methods are preferred. If surface irrigation is the only method available, drip irrigation should be used to deliver water to the base of the plant. At a minimum, a water tap must be accessible for manual watering.

Any permanent irrigation system that relies on potable water should be designed to apply no more than 0.2 inches of water every 14 days from June through September, after the two-year establishment period. It is recommended that permanent irrigation systems have automatic controls, including a rain shutoff sensor.

Include sufficient irrigation in the Landscape Management Plan (See Volume 3 - Flow Control and Water Quality Treatment Technical Requirements Manual - Appendix D) including the following minimum design requirements:

- Provide irrigation during the first two growing seasons following installation and during drought conditions.
- Provided sufficient irrigation to achieve and maintain 90 percent plant coverage after the two-year establishment period.
Drain system

Drainage facilities must be capable of collecting and conveying subsurface and surface drainage to an approved discharge point. The discharge of this water will be regulated under a Side Sewer permit. To facilitate subsurface drainage, interceptor drains are often installed at a 15 to 25 foot spacing to prevent excessive moisture buildup in the media and convey water to the roof drain.

The roof outlets at green roof sites must be protected from the invasion of plant growth and the entry of loose gravel. They must be located and constructed to be permanently accessible for maintenance.

Link to SPU’s Technical Resources by visiting: www.seattle.gov/dpd/codesrules/codes/stormwater/.

Additional Considerations

Additional loading, structural, waterproofing, fire resistance, and horticultural considerations must be taken into account before incorporating green roof systems. While some of these issues are noted, related design methods and requirements are not included. The design team must include qualified professionals to address all design considerations.

Green roofs must not be subjected to any use that will significantly compact the growth medium. Unless designed for foot traffic, green roof areas that are accessible to the public shall be protected (e.g., signs, railing, and fencing).

How much green roof area is necessary to meet the project’s stormwater mitigation requirement?

In many cases, a green roof will be used in conjunction with other GSI methods to achieve the site’s overall mitigation requirements.

To manually calculate the green roof sizing, use the following table and refer to the example.
### Sizing Factor for Green Roofs

<table>
<thead>
<tr>
<th>Courses/Growth Medium depth</th>
<th>GSI Credit</th>
<th>Pre-developed Pasture Standard</th>
<th>Peak Flow control Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single-course/4-inches</td>
<td>0.59</td>
<td>0.46</td>
<td>0.71</td>
</tr>
<tr>
<td>Multi-course/4-inches</td>
<td>0.59</td>
<td>0.46</td>
<td>0.71</td>
</tr>
<tr>
<td>Multi course/8-inches</td>
<td>0.70</td>
<td>0.54</td>
<td>0.79</td>
</tr>
</tbody>
</table>

**Example:**

A 250 square feet green roof is proposed. Multiply 250 x 0.59 (assumes 4-inch growth medium depth). The roof will reduce your “effective” impervious surface by 147.5 square feet.

**What inspections are required for GSI green roofs?**

**First Ground Disturbance Inspection**

**DO NOT BEGIN EARTH DISTURBANCE PRIOR TO THIS INSPECTION**

<table>
<thead>
<tr>
<th>Builder Requirements:</th>
<th>Inspector Requirements:</th>
<th>Notes:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Have the approved building plan set onsite</td>
<td>Review approved plan set</td>
<td>If the approved set of plans are not on site, than the inspection cannot be conducted and must be rescheduled</td>
</tr>
<tr>
<td>Have knowledge of the impervious materials, areas and quantities</td>
<td>Review allowed impervious surfaces per plan</td>
<td>Changes to the approved impervious surface area may require resizing the stormwater management plan and possible plan revisions</td>
</tr>
<tr>
<td>Carefully read the Construction Stormwater Control\Post Construction Soil Management Sheet from the approved plan set and sign onsite with the Site Inspector</td>
<td>Review the Construction Stormwater Control/ Post Construction Soil Management Sheet from the approved plan set and sign onsite with the Owner or Owner’s Representative</td>
<td></td>
</tr>
<tr>
<td>Confirm setback requirements</td>
<td>Discuss setback requirements</td>
<td></td>
</tr>
<tr>
<td>Have a construction sequencing, staging and GSI protection plan prepared</td>
<td>Review GSI protection and TESC plans</td>
<td></td>
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</tbody>
</table>
First Ground Disturbance Inspection (continued)

<table>
<thead>
<tr>
<th>Builder Requirements:</th>
<th>Inspector Requirements:</th>
<th>Notes:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Determine areas to be protected from construction impacts</td>
<td>Discuss Soil Management Plan</td>
<td>Growth medium shall be protected from over-compaction during construction. Growth medium and separation fabric shall be protected from sedimentation during construction. Soil or roofing material stockpiles are not allowed on roof structures. Temporary or permanent point loads from bracing supports, equipment, and material storage shall not be permitted on drainage matting, root barrier, or waterproof membrane unless shown on approved plan set.</td>
</tr>
<tr>
<td>Install approved TESC measures including tree protection prior to start of work</td>
<td>Review TESC requirements and expectations</td>
<td>No tracking/dirt/debris allowed in ROW. Use dust control measures at all times. Establish a plan to protect growth media, and maintain this protection until 90% vegetation coverage is achieved.</td>
</tr>
<tr>
<td>Know the roof’s discharge point and the plan for connection to the drainage system</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Know the per-plan roof details: Intensive or extensive, growth medium depth, planting plan, etc.</td>
<td>Discuss the details of the per-plan roof</td>
<td>Waterproofing and structural integrity are not inspected items and are the responsibility of the builder. Root barrier and waterproof membrane shall be checked prior to placement of overlying materials. Any gouges, tears, or stretching shall be repaired in accordance with manufacturer’s recommendations. Vents and other intentional penetrations through waterproof membrane and root barrier shall be done in accordance with manufacturer’s recommendations. Flood testing and/or electro vector mapping to verify the integrity of the waterproof membrane before and after green roof materials are installed is highly recommended.</td>
</tr>
</tbody>
</table>

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## Green Roof Final Inspection

<table>
<thead>
<tr>
<th>Builder Requirements:</th>
<th>Inspector Requirements:</th>
<th>Notes:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Have the approved plan set onsite</td>
<td>Evaluate permanent erosion control</td>
<td>This inspection cannot be conducted without the approved plan set</td>
</tr>
<tr>
<td>Know the impervious square footage per plan</td>
<td>Measure required impervious surface</td>
<td></td>
</tr>
<tr>
<td>Permanently stabilize all areas surrounding the GSI</td>
<td>Confirm stabilization of the GSI areas</td>
<td></td>
</tr>
<tr>
<td>Install soil to the permitted depth</td>
<td>Ensure the soil depth matches the plan set</td>
<td></td>
</tr>
<tr>
<td>Confirm overflow connection to the approved discharge point</td>
<td>Confirm overflow connection to the approved discharge point</td>
<td></td>
</tr>
<tr>
<td>Plant the roof to achieve 90% stable and healthy vegetative cover within two years (per plan)</td>
<td>Confirm the planting is per plan</td>
<td>See approved plant list available online at <a href="http://www.seattle.gov/dpd/cityplanning/completeprojectslist/greenfactor/">www.seattle.gov/dpd/cityplanning/completeprojectslist/greenfactor/</a></td>
</tr>
<tr>
<td>Install irrigation, if needed, per plan</td>
<td>Confirm per plan irrigation is in place</td>
<td>If an irrigation system is required, it shall be on the approved plans. See Irrigation section, Page 3 of this Tip</td>
</tr>
<tr>
<td>Create a written maintenance plan for the roof</td>
<td>Review the builders maintenance plan for the homeowner</td>
<td></td>
</tr>
<tr>
<td>Provide As-Buils for the GSI, drainage, and side sewer installations on the side sewer template</td>
<td>Review As-Buils</td>
<td></td>
</tr>
<tr>
<td>Schedule additional inspections as needed</td>
<td>Assess the need for additional inspections</td>
<td></td>
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</tbody>
</table>
How are inspections scheduled?
Call 684-8900 or go online to www.seattle.gov/dpd/permits/inspections/.

- **First Ground Disturbance Inspection**: Enter the building permit number and select First Disturbance Inspection.
- **Inspection 2 Green Roof Final Inspection**: Enter the side sewer permit number and select Drainage Final if all GSI and drainage work is completed, otherwise select Drainage Cover.
- **Final Site Inspection**: Enter the building permit number and select TESC Inspection.

How are green roofs maintained?
Remove any sediment or debris from drains on a regular basis.
Test the irrigation system on a regular basis during the plant establishment period and before use during drought conditions.
Repair leaks, tears, or perforations in the membrane, or replace the membrane.
Take measures to prevent future erosion and/or undercutting. Gullies can be filled, lightly compacted, and replanted.
Maintain growth medium erosion control protection measures until 90 percent vegetation coverage is achieved.
Replace dead, damaged, or declining plants in compliance with the original planting plan or with acceptable substitutes.
Remove weeds manually. Do not use fertilizer, herbicides, or pesticides on a permitted GSI Green Roof.
Any permanent irrigation system that relies on potable water should be designed to apply no more than 0.2 inches of water every 14 days from June through September, after the 2 year establishment period. It is recommended that permanent irrigation systems have automatic controls, including a rain shutoff sensor.

What additional resources and contacts are available?
- The City of Seattle Stormwater Code, SMC 22.800
- The City of Seattle Grading Code, SMC 22.170

Key Contacts:
- DPD Drainage Desk: sidesewerinfo@seattle.gov (206) 684-5362
- Inspection Requests: http://web1.seattle.gov/DPD/InspectionRequest (206) 684-8900
- Inspection Cancelations: (206) 684-8860

Access to Information
Links to electronic versions of DPD Tips, Director’s Rules, and the Seattle Municipal Code are available on our website at www.seattle.gov/dpd. Paper copies of these documents, as well as additional regulations mentioned in this Tip, are available from our Public Resource Center, located on the 20th floor of the Seattle Municipal Tower at 700 Fifth Ave. in downtown Seattle, (206) 684-8467.

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