



# Stormwater Management Within Green Roofing

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## ABSTRACT

Typical roof design focuses on removing water from roofs as efficiently and quickly as possible. While this design benefits the roof and building, it often adversely affects the surrounding ecology, stormwater collection, and treatment systems. Increased building density has also reduced areas of natural soils that absorb rain with the resultant increase in the volume of water flowing into municipal stormwater systems, contributing to flooding and the uncontrolled discharge of untreated waste into rivers, streams, and other bodies of water.

The link between green roofs and water control is the subject of this paper, which looks at available systems and assemblies, water retention rates of green roofs, the quality of runoff, local regulations, Leadership in Energy and Environmental Design® (LEED®) credits for green roofs, and design criteria.

Because of the expense of removing the plant growth components to make repairs to the protection layers of the roof (also raising warranty issues), a green roof should have a high-quality waterproofing/roofing system.

The amount of stormwater runoff helps determine the depth of growing media and whether the water retention system is extensive (40% of stormwater) or intensive (up to 90% of stormwater). Plants should be suitable for the local climate and to the type of green roofing system selected. The building owner must also be committed to ongoing maintenance (e.g., weeding, pruning). A specialist also needs to be consulted with regard to local conditions and regulations and how they affect green roofs.

In summary, green roofs can provide water management features that address

local authority concerns and regulations relating to stormwater management. Green roofs offer other benefits that can help to offset the added cost. Regardless of the reasons a green roof is being considered, it will be a custom design for the particular building, and the design will be based on greatly varying ranges of performance.

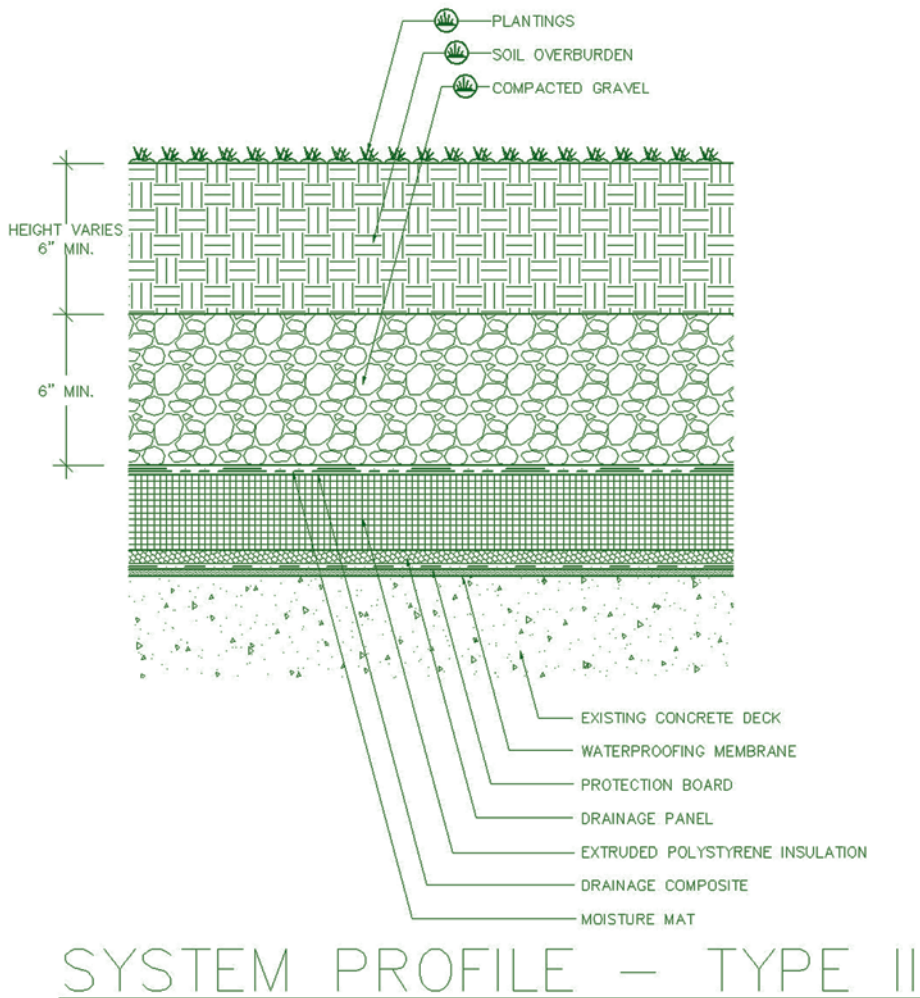
## INTRODUCTION

When rain falls on impervious surfaces (i.e., asphalt paving, roof systems), the runoff flows directly into stormwater systems and then to nearby waterways. When the rainfall is excessive, the resulting runoff strains the stormwater system, often resulting in flooding. The rain also flushes contaminants that accumulate on impervious surfaces, thus contributing to pollution of beaches, waterways, and drinking water supplies.

Green roofs are also referred to as vegetative or garden roofs (depending on the source). Green roofs are typically installed over occupied space as an area of planting on a waterproof substrate at any building level that is separated from natural ground by a man-



Photo 1 – Garden roof on a high-rise building in Boston, MA.



## SYSTEM PROFILE – TYPE II

Photo 2 – Typical garden roof cross section.

made structure. In place of traditional roof design, plazas with planted areas can also be considered green roofs.

### ISSUES TO BE ADDRESSED IN THE DESIGN OF GREEN ROOFS

The following issues must be addressed when designing a green-roof system as it relates to water control:

- Available systems and assemblies,
- Stormwater retention rates with green roofs,
- The quality of runoff with green roofs,
- Local stormwater regulations,
- Leadership in Energy and Environmental Design (LEED®) credits,
- Design criteria, and
- Recommended systems.

The green-roof industry in the United States is constantly changing; new products are coming to the marketplace, and partnerships between green-roof system manufacturers, growers, and roof membrane manufacturers are becoming more com-

mon. U.S. standards are still in the development stage. However, some standards, material requirements, and design guides are being published by various agencies and industry groups such as ASTM International, the National Roofing Contractors Association (NRCA), and others. Until recently, a substantial amount of green-roof knowledge had been developed by the Europeans. *The Guideline for the Planning, Execution, and Upkeep of Green-Roof Sites*, published by Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau (FLL 2002/2004) in Germany, is the standard to which the green-roof industry refers. The FLL guideline, first published in 1982, encompasses over 25 years of green-roof design and technology experience.

### AVAILABLE SYSTEMS AND ASSEMBLIES

Two terms describe how stormwater is handled by green roofs. “Retained” stormwater is rainwater held on the roof and not released to the storm drain system. This water evaporates and/or is used by the

plants. “Detained” stormwater is delayed on the roof by the green-roof assembly and eventually flows off the roof into the local stormwater system.

An important concept of green roofs is that the amount of stormwater that a green roof will have to handle is not consistent from storm to storm or year to year. The green-roof designer and building owner must keep in mind that weather data are shown as yearly averages of past events. Data related to yearly averages for rain volume and wind speed are typically used for roof design. So averages of past events that are not consistent are used to predict a general range of future events. Therefore, stormwater retention data or rates for various green-roof systems are presented in ranges, are typically further qualified by the weather experienced during the data-collection period, and relate to a specific green-roof assembly. For example, note the following:

- The 2002/2004 FLL guideline states that green roofs will retain from 40% to 90% of stormwater.
- The U.S. Environmental Protection Agency (EPA) indicates a 40% to 100% retainage rate.
- Toronto Region Conservation Authority (2006) published a data note that 50% to 87% of stormwater is retained.

These numbers illustrate a broad range of values. Published studies and manufacturers’ literature outline numerous qualifying factors affecting green-roof stormwater performance, such as storm frequency, intensity, and duration, as well as the type of green-roof plantings. Actual performance of a particular green roof will depend on the various components designed into the system and the weather conditions to which the system will be exposed.

Green-roof assemblies are described by the depth of their growth media (i.e., intensive/extensive), and stormwater management is directly related to depth and type of growth media and system components. Thinner green-roof systems are referred to as “extensive,” whereas deeper systems are known as “intensive.” According to FLL, annual average water retention varies from 40% for an extensive system that is 25-50 mm (1-2 in) deep (moss, sedums, and succulents) to over 90% retention for an intensive system 500 mm (20 in) or deeper (planted with lawn, shrubs, coppices, and trees). However, these retention values



*Photo 3 – Plaza/green roof assembly.*

relate to annual precipitation of 660-810 mm (26-32 in) and are further qualified by the annual precipitation in the area in which the retention values are being measured. In regions with lower annual total precipitation, water retention is higher than in regions with a high annual precipitation total.

The American Society of Landscape Architects (ASLA) publishes a table showing stormwater data from a 278.7 m<sup>2</sup> (3,000-sq-

ft) test roof located in Washington, DC. The ASLA table reports data collected for both extensive (76 mm/3 in deep) and intensive systems (457 mm/18 in deep). According to its report, stormwater runoff quantity and quality were monitored for five rain events and “for the majority of the precipitation events (50 of 65, or 77%), there was no runoff from the green roof.” (Glass and ETEC 2007: 5).

Green-roof growth media—the compo-

nents to support plant growth above the waterproofing membrane—can be described as “site-built” or “pregrown.” Site-built systems are perhaps more familiar to designers, contractors, and building owners because this has been the usual method of constructing planting areas on plazas and in planter boxes. Once the waterproofing/roofing system has been installed with various protection layers, the green-roof components are placed in layers starting



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Photo 4 – Installation of media and planting.

with root barriers, drainage, and filter fabric layers. The growth media are then placed over these components. After the growth media are prepared, the plants are installed. This site-built installation can then take up to two years to become fully “greened,” until the vegetation has taken root and the growth media will be visible. Regular maintenance is required to remove dead plants, provide replacement plants,

systems appear mature almost as soon as they are assembled. Maintenance in the form of weeding and plant replacement is still required to ensure plant growth.

With both types of assemblies, stormwater management of a particular roof is a function of plant types, media type and depth, and the water collection layer. The depth of the growth media is directly correlated to the stormwater management char-

acteristics of a particular green roof.

“Pregrown” or pallet systems arrive with fully grown plants and media in trays. As with the site-built systems, the waterproofing/roofing system, drainage, and protection layers are installed. The trays of media and plants are then placed on the prepared roof area. The trays interlock with each other, and as the plants grow, joints between trays become concealed. The pregrown

Assemblies with deeper media retain and detain higher percentages of rainwater than assemblies with shallower media. Moisture-holding sheets, similar to drainage layers, are available to provide “reservoirs” in green-roof assemblies. The FLL and ASTM standards quantify the water-retaining effectiveness of various media and water retention layers.

Critical green-roof components, with respect to stormwater management, are the plants and media. Plants use moisture, and their roots hold the media in place. Should the plants die, the media become exposed to sun and wind, resulting in the drying of the media, with the potential for it to be affected (blown away) by the wind. This can lead to a roof failure since, with many unadhered single-ply systems, the weight and continuity of the media are intended to resist wind scour and wind uplift forces.

Selecting plants for a green roof presents issues of cost, durability, and aesthetics. Plants must be acclimated to the specific building’s geographic location, wind exposures, and orientation in relation to the sun. As an exaggerated example, plants native to the Southwest are not good selections for New England. That consideration must be taken further to ensure that the plant pallet is made up of plants that will not only survive but will thrive on the specific building’s roof. Specific plant types directly affect the depth of the growth media. Larger, deep-rooted plants need more media.

#### BELOW THE MEDIA ASSEMBLIES

Eventually, rain and/or irrigation water will penetrate the plants, media, and collection layers and reach the drainage layers and waterproofing/roofing system. Even if the roof is covered with media and plants, hard pavers, ballast, or an exposed membrane, the waterproofing/roofing system is the assembly that keeps the building dry. The waterproofing/roofing components and the assembly must meet the same applicable standards and codes for drainage and performance, regardless of what is placed over the waterproofing/roofing membrane. These standards include providing positive slope-to-drain, drains properly sized for the roof area and local rain conditions, a drainage overflow system that is not dependent on the primary drainage system, and properly designed and constructed details (flashing, penetrations, or connections). When designing a green roof, one must



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include root barriers, water-retention sheets (possibly), multiple-filter fabrics, and additional protection components.

### RUNOFF QUALITY

The ASLA test roof, noted above, analyzed water-quality data for approximately 26% of the rainwater that ran off the test roof. (The other 74% was retained on the roof and did not flow to the storm system.) The published data show that the runoff pH and temperature increased; other compounds, such as phosphate, total phosphorus, total suspended solids, and total dissolved solids, also increased. The report points out that the measured levels are “within the allowed freshwater chronic concentration values promulgated by the EPA, and none of the concentrations were above the acute level” (Glass and ETEC 2007:10).

Copper, lead, and arsenic also appeared to decrease as the rain passed through the green-roof assembly. The ASLA report suggested that the decreases were caused by filtering effects of the geotextiles and roofing materials. However, one can assume that the plants and growth media also assist in filtration of compounds.

### STORMWATER REGULATIONS

As noted previously, green-roof standards are not numerous, and the prevalent standard is the FLL. Regulations governing or affecting green-roof design vary as local building codes and incentives vary. Also, language pertaining to green roofs can be found in sections

of plumbing codes that relate to roof drainage, structural codes relating to roof loads and seismic design, and roof-design codes relating to materials and wind uplift resistance. Therefore, when considering and designing a green roof, the designer and building owner will have to become familiar with the local building codes plus local incentives and guidelines.

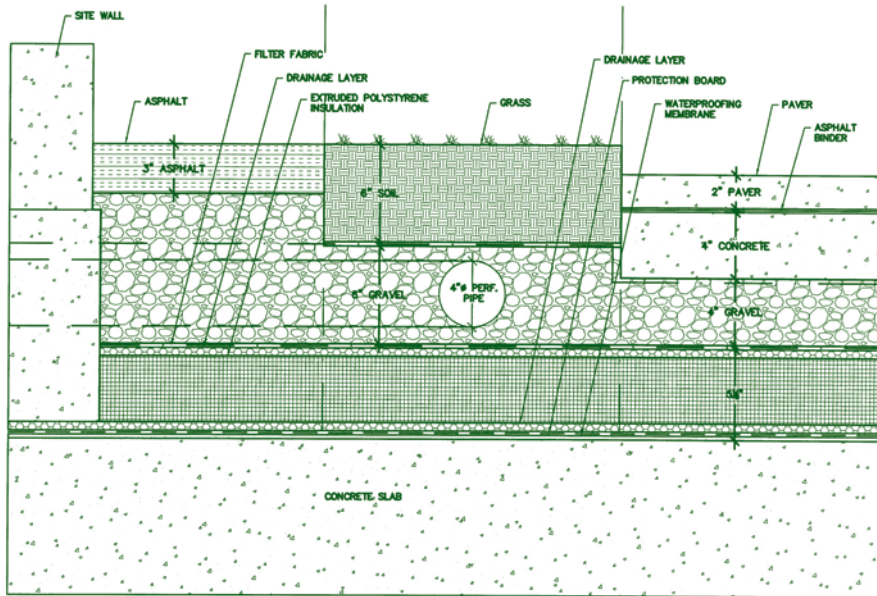


Photo 5 – Extensive green roof assembly.

The city of Boston published *Environment Department Guidelines for High-Performance Buildings and Sustainable Development*. According to the introduction, information, materials, and guidelines should be a resource for minimizing the environmental impacts potentially generated by proposed projects. The guidelines do not state particular designs that are



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GALE VARIOUS CROSS SECTIONS OF PLAZA DECK OVERBURDENS

Photo 6 – Various cross sections of plaza deck overburdens.

required. Green roofs are referred to as “eco-roofs,” and the guidelines provide a link to [www.greenroofs.com](http://www.greenroofs.com). The guidelines also link to the Massachusetts Department of Environmental Protection’s (2008) *Stormwater Management Policy and Handbook*. This very complex document does mention that green roofs may reduce the required water quality volume but notes that there is no total suspended solids credit.

Chicago, which promotes green roofs and has a green roof on its City Hall, refers to the Capital Development Board’s (2007) *Green Building Guidelines for State Construction*. These guidelines require that any

state-funded building construction meet the current new commercial construction (LEED® NC) standard or the most applicable standard of the LEED® family. As noted further on in this report, green roofs can produce LEED® points toward the overall LEED® score rating of a building.

Seattle promotes sustainable building by listing LEED® certification as a design and building guide. Seattle’s Department of Planning and Development provides a green-roof link to the city’s Green Building Web page at [www.seattle.gov/environment/building.htm](http://www.seattle.gov/environment/building.htm). According to information provided there, Seattle has an impervious surface-reduction credit for green roofs and

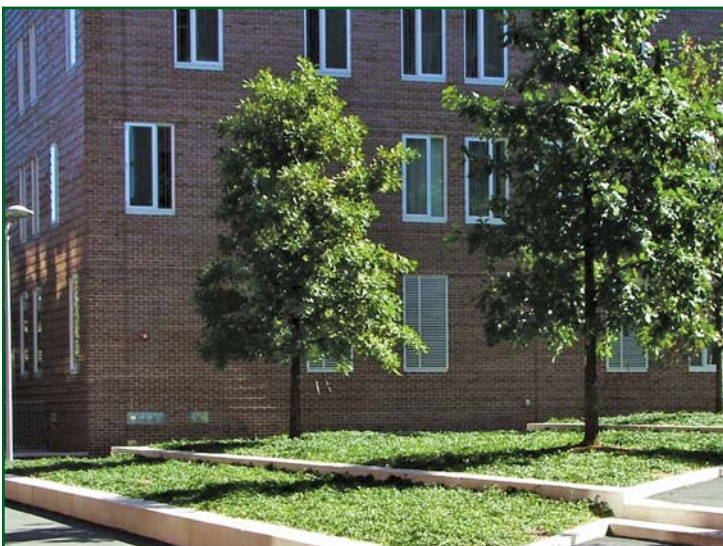


Photo 7 – Plaza deck assembly.

complex, changing, and becoming more stringent. The overall purpose is to reduce the volume of water flowing into water treatment facilities and the volume of pollutants flowing into waterways. Reducing storm flows at their sources lessens the need to rebuild stormwater treatment facilities and makes associated mitigation costs the property owners’ responsibility.

- Complex stormwater regulations should be interpreted by a specialist who understands the local conditions and regulations.
- Guidelines do not necessarily require specific building designs but do offer ideas about acceptable designs for particular building goals.
- Green roofs can provide one means to address local stormwater regulations. The issue is the wide range of stormwater management values as discussed above. The designer will have to correlate roof performance with the local requirements.

#### LEED®

LEED® design criteria and LEED® certification are becoming more prevalent in the United States. Although stormwater management by green roofs accounts for up to two LEED® points, green roofs can provide up to 26 points toward the overall LEED® score, enough to elevate a LEED® Bronze to a Silver or a Silver to a Gold. As shown below, green roofs can address many LEED® design issues:

- Sustainable site (1 point),
- Stormwater management (1 to 2 points),
- Urban heat island (1 point),
- Water efficiency (1 to 2 points),
- Energy and atmosphere (1 to 8 points),
- Materials and resources (1 to 3 points),
- Local sources (1 to 2 points),
- Recycled content (1 to 2 points),
- Rapidly renewable materials (1 point), and
- Innovation (1 to 2 points).

#### DESIGN CRITERIA

As illustrated previously, there is no one-size-fits-all green-roof design, assembly, or product. Designers need to consider the following aspects when selecting the plants:

- Cost,
- Climate,
- Required media depth,

- Maintenance required,
- Access for maintenance,
- Roof slope,
- Desired aesthetics,
- Wildlife, and
- Installation method.

Each item affects the design and, in turn, is affected by other choices. The local climate will determine the types of plants that can survive on the roof. Plant types have different soil depth requirements; soil depth will affect the structural capacity of the roof. Plant type and soil depth have a direct effect on the amount of rainwater the roof retains; thicker/deeper systems retain more water than shallower systems.

Initial ideas and plans become multiple options that are analyzed for performance and financial implications to become the custom design for the building. A design checklist should consider the following issues:

- Green roofs add significant cost beyond that of the roofing/waterproofing system. They can add to the cost of the building's structure by requiring increased structural capacity to support the heavier green roof. Seismic design considerations and added costs are additional effects of placing a heavy roof on a structure. Is this additional cost feasible?
- Will the additional cost for a green roof provide a benefit to the owner? Can the green roof be used as a selling tool for the owner? Can a green roof assist the owner in demonstrating a commitment to sustainable construction and environmental awareness?
- Are the additional LEED® points that a green roof provides desired or necessary for the project to move forward?
- Time necessary for "greening" will



*Photo 8 – Various media layers being installed.*

drive selection of the system. A site-built system will take two or more years to become fully green; a pallet system provides fully developed plants. Installing the plants at the start of the local growing season is critical, affecting the construction schedule by requiring the roof structure and roof membrane to be 100% complete at the start of the local growing season. Once the roof is complete and the plants are installed, the roof cannot be used as construction storage or working space. Providing a completed roof at the beginning of the local growing season may either force an accelerated or delayed construction schedule, both of which will adversely affect the cost of the building.

- Are there stormwater management requirements to be met at the site, and will a green roof help to mitigate the local stormwater issues? Will the additional cost of a green roof allow for a larger building footprint, or would the project be rejected by the local zoning authority unless there are means to mitigate stormwater discharge?



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- The roofing membrane and drainage system must be properly designed (as must a typical roof) and have a long expected life span. Due to the added expense of removing the green roof plants, media, drainage, and protection layers to access the roofing/waterproofing membrane system, the roofing/waterproofing system should be high quality with meticulous attention paid to details. Removing the plants, media, and protection layers to repair or replace the roof membrane is an expensive undertaking no matter when it is done. Purchasing premium waterproofing and roofing systems will also drive the initial cost of the green roof higher. However, the owner should consider that the green roof would protect the membrane and extend its useful life, offering the potential to recoup the cost over the extended life span.
- Green roofs are not “plant and forget” roofs. Maintenance is required to remove weeds, replace dead plants, or prune plants. Will the owner of the green roof accept the

need for intensive maintenance of the plants for the first two years and then regular ongoing maintenance for the life of the building?

- Is a system warranty important to the owner? If so, then the warranty requirement will drive the selection to systems that include the plants, media, and roofing membrane in one package.

#### RECOMMENDATIONS

- First, identify all local building code issues, sustainable growth and development guidelines, development incentives, and zoning requirements that may pertain to installing a green roof. Since all green roofs are custom designs, one must understand the local issues and rules that will affect the design.
- Determine if the green roof should



*Photo 9 – Thermoplastic waterproofing membrane/grid system.*

be intensive or extensive. Once the general type of system is selected, decide if a site-built or pallet assembly for the plants and media will provide the appropriate plants. This will require someone with the specialized knowledge and resources to select the types of plants that will be successful on the roof.

- The warranty issue must be part of the initial design matrix. A total system warranty requirement by the owner will drive the selection of the total assembly toward combination systems offered by waterproofing and roofing manufacturers teamed with plant and media growers and manufacturers. If multiple warranties or no warranties are acceptable to the owner, then various waterproofing/roofing membranes can be combined with different media/plant systems. In either case, the plants must be acclimatized to the local environment and weather conditions.
- Once the waterproofing/roofing membrane is covered by the green-roof system, including the media and plants, accessing the membrane to repair leaks becomes very expensive and disruptive since all the overburden must be removed to make repairs. Keep in mind that once the membrane is completed and approved, substantial construction will take place on the membrane. Therefore, do not select less than premium systems, and choose only membranes that have proven track records for performance and durability with verifiable construc-



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tion details in the same type of application. Require installation of protection layers (protection board, insulation, or drainage layers) immediately on completion of the membrane. During construction, incorporate a leak-detection monitoring system within the assembly. Electronic field-vector mapping (EFVM) can be used in lieu of flooding the roof membrane to detect leaks.

- Whenever possible, place the waterproofing/roofing membrane directly on the structural roof deck. Fully adhering the membrane to a concrete deck will limit the distance leakage can travel under the membrane. To accomplish this task and still slope the membrane to drain, the structural deck must provide the slope. Sloping the structural deck typically increases the cost of the deck but eliminates purchasing tapered insulation to go under the membrane every time the waterproofing/roofing membrane is replaced.
- Details become more critical since repairs are costly and disruptive. Therefore, do not rely on the typical details provided by membrane manufacturers. Provide and require extensive design documents that show every detail of the membrane, including all connections, terminations, and penetrations.
- Provide protection and drainage layers over the membrane, including insulation, then construct the green-roof assembly of root barriers, drainage, media, and plants. As mentioned before, the media and plant design should be done by specialists who are familiar with the local environmental requirements of the building.
- During construction, quality assurance and control become preeminent. Full-time observation of the green roof system should be provided from the time the structural deck is ready to receive the waterproofing/roofing membrane until the final plant is placed.

To summarize, green roofs can provide water management features that can address local authorities' concerns and regulations relating to stormwater manage-



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ment. Green roofs offer other benefits that can help offset the added cost of these systems. Regardless of the reasons a green roof is being considered, it will be a custom design for the particular building, and the design will be based on greatly varying ranges of performance. 

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