Memo

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TO	Bob Spencer, Tracy Tackett – Seattle Public Utilities	DATE	February 29, 2008
FROM	Brian Taylor	PAGE	1 OF 4
PROJECT	**SPU Storm Code Review, Seattle, Washington**	PROJECT #	92561.50
SUBJECT	Draft – Green Roof Media Recommended Specifications		

SCOPE

Magnusson Klemencic Associates (MKA) has prepared the attached recommendations for vegetated roof media (Attachment 1) at the request of the City of Seattle Department of Public Utilities (SPU) for incorporation into upcoming stormwater manual revisions. These recommendations are appropriate for vegetated roof systems ("green roofs") seeking to obtain stormwater flow control credit. This memorandum provides background information for City staff.

It is beyond the scope of these recommendations to instruct readers in the selection and design of vegetated roof systems and materials; selection and design is to be done by experienced practitioners. Rather, these recommendations identify the specific requirements of growing and drainage media that must be met in order for the vegetated roof installation to receive **stormwater flow control credit** as described in the City of Seattle drainage code. It is the responsibility of the vegetated roof designer, and beyond the scope of these stormwater-related requirements, to ensure that the media used in the vegetated roof system will support and sustain the plants used in the installation.

These recommendations are provided to fulfill flow control requirements; requirements to fulfill water quality objectives are not addressed.

BACKGROUND

VEGETATED ROOF SYSTEMS

Green roofs are distinguished by their depth and the courses used in their construction. "Intensive" green roofs are 6 inches to 2 feet deep; planted with ground covers, grasses, shrubs, and even trees; and require regular landscape maintenance. "Semi-intensive" or "simple intensive" roofs are generally 6 inches to 2 feet deep and use a limited planting palette of grasses, ground cover, and shrubs that require little attention. "Extensive" green roofs are 2 inches to 6 inches deep; use a planting palette of drought-tolerant, low-maintenance ground covers; and are designed to create an expansive natural-appearing landscape. Extensive green roofs have the lowest weight, are most suitable for placement on existing structures, and can be constructed using "modular" trays filled with growing media.

A distinction is also made between single-course and multi-course green roof systems (FLL, 2002). Many European green roofs are single-layer systems that consist of a single media designed to be free-draining yet support vegetative growth (Philippi, 2006). In the United States, however, most commercially available systems use a multi-course design that includes both a growing media and a separate, underlying drainage layer. The multi-course approach enables more robust planting palettes. Many designers and most of the roofing companies that provide green roof systems believe that additional protection is provided to the roof's waterproof membrane by using the separate drainage layer, a factor that seems to drive the use of multi-course over single-course systems to date in North America (Phillippi, 2006; Carey, 2006).

VEGETATED ROOF STORMWATER CONTROL FACTORS

Attachment 2 provides a description of green roof hydrologic processes. The ultimate stormwater control performance of a green roof system is determined by many factors, including the following (Taylor & Ganges, 2007):

- Rainfall intensity and climate
- Type of vegetated system
- Roof pitch
- Drainage layer materials
- Drainage layer configuration and thickness
- Presence and spacing of interceptor drain channels
- Growing media properties and thickness
- Water retention mats and boards
- Roof micro-climate and solar exposure
- Density of plant cover
- Species of plants used

The attached criteria are for the engineered drainage and growing media.

Drainage mats and boards are frequently used in multi-course systems. These generally provide a free-draining open area for collected water to flow to the roof drain. Many also provide "egg carton"-shaped cups that can retain a portion of the water collected for eventual evapotranspiration. MKA's research suggests that these boards/mats do not provide sufficient moisture storage to affect peak runoff rates in Seattle; drainage mats and boards should be sized and installed in accordance with the manufacturer's recommendations and are not specified in the attached recommendations.

The stormwater control effectiveness of media used in a vegetated roof system is primarily determined by how much moisture the media can hold, both permanently and temporarily, and by the rate that temporarily held moisture (beyond the media capacity) drains from the vegetated roof assembly to the roof drain(s). Retained water is typically held within the media until evapotranspiration diminishes the moisture level to the field capacity of the media. Excess water is detained within the media assembly as it travels downward to the impermeable layer and then laterally through the drainage layer to the roof drain.

The media parameters that influence the volume and rate of drainage are the porosity, permeability (also called the saturated hydraulic conductivity), field capacity, and maximum water capacity. The media particle-size-distribution (gradation) and the material properties of components used in the media are the predominate factors that determine these physical hydraulic parameters for a specific system configuration.

Organic content is a factor that influences the hydraulic performance of the system indirectly. Overall, there is still debate in the green roof community regarding the maximum acceptable/desirable level of organic content; MKA believes additional data are needed before constraining the organic content in media by stormwater code-related requirements. The influence and effects of the organic material on the system performance will be reflected in the testing for the design requirements and properties described in the recommendations.

PERMANENCE AND LONGEVITY

For a vegetated roof system to provide stormwater flow control, the media must resist wind and water erosion and stay in place on the roof. Therefore, while it is not a specific media material specification, MKA emphasizes that stormwater flow control credit should only be awarded for vegetated roof systems that provide erosion control matting and maintain erosion control practices until plant coverage exceeds 90 percent.

Organic cycling may diminish the media thickness over time, depending on the type of organic material used, how rapidly it is broken down and taken up by vegetation, the rate it is replenished by plants, and the amount incorporated into the media. Until additional data are available to inform the requirements in the attached recommendations, MKA recommends that the media thickness be measured during regular maintenance inspections of the vegetated roof and corrective actions be taken when necessary to maintain design depths.

Please contact me if you have any questions or comments regarding these documents.

BLT/dah

Attachments:

1. Proposed Vegetated Roof Media Requirements to Receive Stormwater Flow Control Credit
2. Description of Green Roof Hydrologic Processes

ACKNOWLEDGEMENT

MKA thanks Mr. Charlie Miller of Roofscapes Incorprated for graciously providing his time and input.

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Attachment 1
Proposed Vegetated Roof Media Requirements to Receive Stormwater Flow Control Credit

SPU Storm Code Review
Seattle, Washington

February 29, 2008

The following recommendations are appropriate for vegetated roof systems ("green roofs") seeking to obtain stormwater flow control credit. It is beyond the scope of these recommendations to instruct readers in the selection and design of vegetated roof systems and materials; selection and design is to be done by experienced practitioners. Rather, these recommendations identify the specific requirements of growing and drainage media that must be met in order for the vegetated roof installation to receive **stormwater flow control credit** as described in the City of Seattle drainage code. It is the responsibility of the vegetated roof designer, and beyond the scope of these stormwater-related requirements, to ensure that the media used in the vegetated roof system will support and sustain the plants used in the installation.

These recommendations are provided to fulfill flow control requirements; requirements to fulfill water quality objectives are not addressed.

VEGETATED ROOF MEDIA REQUIREMENTS

Table 1 identifies the acceptable ranges of specific media properties and attributes that must be met to comply with the vegetated roof flow control credit requirements. Table 1 also identifies testing protocols used to determine the media properties. The drainage code provides additional requirements for vegetated roof systems that also must be met to receive the flow control credit. The green roof designer of the vegetated roof system must verify compatibility of the media properties for the specific horticultural goals, including but not limited to plant establishment, plant survival, nutrient availability, and organic content.

As an additional resource for designers, Table 2 shows suggested media properties that, when met, should yield a media that approximately conforms to the Table 1 requirements.

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Table 1. Minimum Requirements for Engineered Media for Vegetated Roofs to Receive Flow Control Credit

Water Retention Parameters	Units	Determination	Drainage Media for Multi-Course System	Growing Media for Single-Course System (Depth ≤ 6 Inches)	Growing Media for Multi-Course System (Total Depth ≤ 6 Inches)	Growing Media for Intensive Green Roof System (Total Depth > 6 Inches)
Total Pore Volume (A)	vol. %	ASTM E2399	25% min.	30% min.	45% min.	45% min.
Maximum Water Capacity[1] (B)	vol. %	ASTM E2399	—	25% to 65%	35% to 65%	45% to 65%
Water Permeability[2]	cm/s	ASTM E2396-05	0.3 to 3.2	0.1 to 1.0	0.002 to 0.1	0.002 to 0.1
	in/min		7 to 75	2.4 to 24	0.05 to 2.4	0.05 to 2.4
Air Content at Max. Water Capacity	vol. %	Difference: (A) - (B)	—	4% min.	4% min.	4% min.
Total Organic Matter	mass %	Loss on Ignition	1% max.	—	—	—

1. Designers are encouraged to use media with high maximum water capacity for improved stromwater control capacity.
2. Also called saturated hydraulic conductivity. Designers are encouraged to use media with permeability at the low end of the ranges shown for improved stormwater control capacity.

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Table 2. Suggested Design Properties for Engineered Media for Vegetated Roofs[1]

Property	Units	Determination	Drainage Media for Multi-Course System	Growing Media for Single-Course System (Depth ≤ 6 Inches)	Growing Media for Multi-Course System (Total Depth ≤ 6 Inches)	Growing Media for Intensive Green Roof System (Total Depth > 6 Inches)
Particle Size Distribution		ASTM D422[2]				
d ≤ 0.02 mm	mass %		—	—	—	10% max.
d ≤ 0.063 mm	mass %		—	7% max.	15% max.	20% max.
d ≤ 0.2 mm	mass %		—	—	25% max.	10% to 35%
d ≤ 0.5 mm	mass %		—	20% max.	15% to 42%	19% to 60%
d ≤ 2 mm	mass %		2% max.	50% max.	43% to 72%	40% min.
d ≤ 4 mm	mass %		—	25% to 80%	—	—
d ≤ 6 mm	mass %		30% max.	44% to 100%	70% min.	70% min.
d ≤ 10 mm	mass %		80% min.	77% min.	—	100%
d ≤ 15 mm	mass %		100%	100%	100%	—
Water Retention Parameters						
Total Organic Matter	mass %	Loss on Ignition	0%	4% max.	6% max.	6% max.

1. Suggested properties are for information and use by the designer and are not subject to City review. For additional design suggestions, refer to "Guideline for the Planning, Execution and Upkeep of Green-Roof Sites," Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau (FLL), Bonn, Germany, 2002 (English version, 2004)

2. ASTM C-136 may be used for drainage media.

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MEDIA TESTING AND ACCEPTED PRODUCTS

Vegetated roof media shall be tested to verify conformance with the requirements of Table 1. The following is a list of soil laboratories familiar with testing requirements for vegetated roof media.

- Pennsylvania State University - Agricultural Analytical Services Lab, University Park, Pennsylvania. Telephone: 814-863-0841. Website: www.aasl.psu.edu
- Soil Control Lab, Watsonville, California. Telephone: 831-724-5422. Website: www.greenrooflab.com
- British Columbia Institute of Technology (pending verification)
- Washington State University - Cooperate Extension Service (pending verification)

As of February 2008, the approximate cost of testing a 5-gallon sample is less than $300.

Based on the available information, media on the following list comply with the requirements for the flow control credit. Other media will be accepted so long as test results verify the hydraulic design parameters are within acceptable ranges.

Accepted Media:

- Roof-lite™ (available from Swanson Bale & Mulch, Longview, Washington)
- Roofscapes Incorporated (specific blends to be determined)
- American Hydrotech (pending verification)
- Greengrid (pending verification)
- Garland Greenshield (pending verification)

Attachment 2
Description of Green Roof Hydrologic Processes

SPU Storm Code Review
Seattle, Washington

February 29, 2008

GREEN ROOFS FOR STORMWATER MANAGEMENT

The stormwater management benefits of vegetated roof covers (green roofs) have frequently been cited as a compelling reason to promulgate the greening of urban rooftops (Scholz-Barth, 2001; Peck, et al., 1999). The most commonly reported stormwater benefits of green roofs are reduction in flow volumes and reduction in peak runoff rates due to flow attenuation. International research has demonstrated the benefits offered by green roofs; however, efforts to quantify and monitor the benefits achieved in specific climatic regions of the United States have only begun in recent years. While green roof stormwater benefits have been quantified for some climatic areas, there has been little information available on the performance of these systems in Seattle until very recently (Taylor and Gangnes, 2004). While there are a number of established green roofs in Western Washington and Seattle, the first Puget Sound basin stormwater performance data known to exist were collected by MKA from 2005–2006 as part of the Seattle Greenroof Evaluation Project (SGREP). These data confirmed the stormwater control potential of green roofs in Seattle. The City of Seattle implemented a separate monitoring program in 2006 to collect runoff data from several full-scale green roof installations.

BASIC TYPES OF GREEN ROOFS

Global interest in green roofs has been growing in recent years as cities look for innovative practices that can enhance the environmental sustainability of urban environments. For various reasons, green roofs have been promoted and successfully implemented on a wide scale in Germany over the past several decades. The experience gained and academic research conducted in Germany informed the development of the "Guidelines for the Planning, Execution and Upkeep of Green-Roof Sites – Roof-Greening Guidelines," by the Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau (The Landscaping and Landscape Development Research Society, hereafter "FLL"), which are intended to be "recognized rules of technique" that "present a yardstick for precise and faultless technical behaviour" (FLL, 2002). Because there are no comprehensive, uniform international or U.S. standards[1] for roof greening practices, the FLL is often regarded as the state-of-the art for establishing green roof design standards.

[1] ASTM has developed several standards for testing green roof materials but does not provide the same level of comprehensive guidance as that found in the FLL guidelines.

Green roofs are generally classified by the depth and planting scheme (FLL, 2002). "Intensive" green roofs are 6 inches to 2 feet deep; planted with ground covers, grasses, shrubs, and even trees; and require regular landscape maintenance. "Semi-intensive" or "simple intensive" roofs are generally 6 inches to 2 feet deep and use a limited planting palette of grasses, ground cover, and shrubs that require little attention. "Extensive" green roofs are 2 inches to 6 inches deep; use a planting palette of drought-tolerant, low-maintenance ground covers; and are designed to create an expansive natural-appearing landscape. Extensive green roofs have the lowest weight and are most suitable for placement on existing structures. Extensive green roofs are the focus of the remainder of this memorandum.

The FLL distinguishes between single-course and multi-course green roof systems. Many European green roofs are single-layer systems that consist of a single media designed to be free-draining yet support vegetative growth (Philippi, 2006). In the U.S., however, most commercially available systems use a multi-course design that includes both a growing media and a separate drainage layer. The multi-course approach enables more robust planting palettes. Many designers and most of the roofing companies that provide green roof systems believe that additional protection is provided to the roof's waterproof membrane by using the separate drainage layer, a factor that seems to drive the use of multi-course over single-course systems. (Phillippi, 2006; Carey, 2006)

OVERVIEW OF TYPICAL GREEN ROOF COMPONENTS

North American green roofs are frequently constructed as layered systems (Dunnett and Kingsbury, 2004), as illustrated in Figure 1 below. The bottom layer is a waterproof membrane that is installed onto the roof deck. Roof insulation may be placed either above or below the waterproof membrane, depending on the architectural roof design for the project. A root barrier is typically installed as the next layer in order to reduce the chance of root penetrations into the waterproof membrane. A drainage layer that promotes free drainage is placed next, for collecting seepage from the green roof and conveying it to the roof drain. The drainage layer is usually either a fabricated drainage product or a layer of sand- to gravel-sized aggregate with high hydraulic conductivity. Light-weight aggregates such as expanded slate or pumice often are used to reduce roof loads. A geotextile fabric is usually placed on top of the drainage layer to prevent the migration of fines from the growing media into the drainage layer. The final layer is comprised of growing media and plants.

The growing media layer is the heart of a green roof system since it comprises most of the volume of the green roof "veneer," enables plants to grow and survive harsh rooftop conditions, and provides substantial stormwater benefits (Miller, 2003). Growing media are engineered "soils" that are designed to achieve specific goals for rainwater retention and provide appropriate growing conditions for the green roof vegetation. The depth of the media depends on the desired functions of the green roof, the load-bearing capacity of the structure, the desired plants, and the cost of the media.

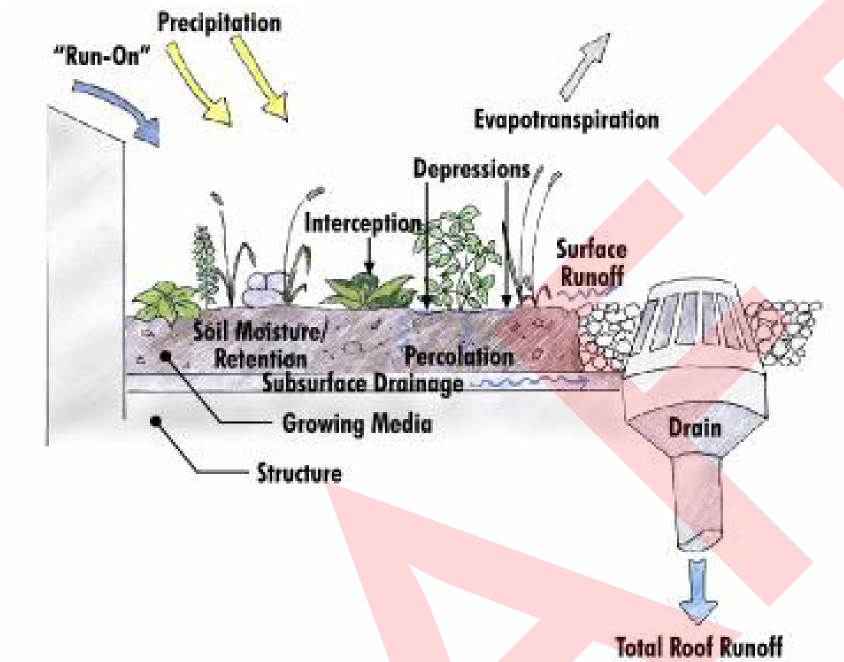

Figure 1. Typical Green Roof Section and Hydrologic Processes
Source: Taylor and Gangnes, 2004

Most mix designs of growing media consist of primarily mineral aggregates with small amounts of organic material. The media are mostly mineral because organic soil materials installed in green roofs tend to decompose and dissipate over time. Lightweight aggregates such as expanded slate or pumice often are incorporated to reduce roof loads. Hydraulic qualities that enable plantings to establish themselves and survive the harsh rooftop environment are a primary consideration in the growing media design, such as a resistance to moisture removal as the media dries, which can be configured to facilitate the vegetation adapting to dry roof conditions (Miller, 2003). In "Moisture Management in Green Roofs," Miller noted the following:

> The ideal green roof media will combine many features that are typically mutually exclusive in nature:
>
> - Efficiently absorb and tenaciously retain water
> - Be readily drained
> - Offer a high void ratio (air volume), even when approaching saturation
> - Exhibit moderate to high effective surface area
>
> As a result, green roof media is almost always a manufactured 'soil-less' material. (Miller, 2003)

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The growing media are planted with species suitable to rooftop environs. The plants are typically drought- and wind-tolerant in order to accommodate the exposed setting (Dunnett and Kingsbury, 2004). Plants that can thrive in nutrient-poor shallow substrates are most suitable. Succulent ground covers such as the Sedum family of plants have proven to be especially well-suited for green roofs; these plants absorb moisture during rainstorms and store it for use during dry periods.

Drainage for multi-course green roofs can be provided in several ways. Many green roof vendors use a rigid drainage "board" comprised of a molded sheet, usually plastic, shaped to provide both moisture storage "cups" and an underlying void space that provides for free flow of drainage of water that seeps through upper green roof layers. Geotextile and root barrier fabrics are often adhered to the molded sheet to provide material separation (filtration to restrict fines to the growing media layer) and root control. The second drainage approach used in multi-layer systems is to provide an aggregate drainage layer. Typical aggregates include pumice, gravel, expanded slate/clay, and recycled brick. A third approach is to use a drainage fabric or mat placed beneath a filter fabric that provides for clear drainage to the roof drain. Unlike a drain board, a drain mat/fabric is more flexible but does not provide storage "cups" to retain moisture for plant uptake between storms.

Modular green roofs systems, including tray systems, also are widely used. These are similar to multi-course systems; the growing media and filtration layer are provided within a tray or module, while the drainage layer function is provided in a clear-space between the tray and the roof membrane. The bottom of trays/modules are typically shaped to provide clear drainage channels so there is no need for an aggregate layer or drain board/mat. Holes in the tray (e.g., 1/4 inch diameter at 8 inches on center) allow excess moisture to drain from inside the tray to the drain channels.

Additional components may be included as part of the green roof assembly but are not always required. Irrigation systems may be needed depending on the planting scheme, and are highly recommended by MKA to prevent Seattle's summer drought from harming plants. Erosion-control fabrics are used to prevent the media from erosion and wind scour until plant coverage and root structure is adequate to prevent movement of the growing media material. On sloped roofs, baffles may be employed to prevent the media from migrating (sliding) down the roof. On high roofs, steel cables or nets may be integrated to hold the green roof in place during high winds.

GREEN ROOF HYDROLOGIC AND DRAINAGE PROCESSES

The veneer of growing media and plants affect the hydrologic cycle of buildings with green roofs. The green roof plants absorb moisture from the soil and transpire water to the atmosphere. The growing media absorb and retain moisture that may later be taken up by plants or evaporated through solar heating of the media. Excess moisture that is not retained in the growing media percolates through the media and then flows through the drainage layer ultimately to the roof drain, after which point the flow becomes building runoff. The net effect is that initial portions of rainfall are retained until the moisture-retaining capacity of the growing media is satisfied, upon which point "breakthrough" occurs and water begins to seep through the media into the drainage layer.

It is worth noting that for typical green roofs—designed using engineered growing media—excess precipitation almost always becomes seepage flow through the media rather than surface "runoff." This percolation and lateral flow of the seepage can extend the time before which rain becomes runoff (in comparison to a conventional roof), attenuating the flow of runoff from the building.

The macro-level drainage strategy used when designing green roofs is to (1) provide permeable engineered media to reduce surface runoff and retain moisture, and (2) allow water that percolates through the media to flow laterally to a drain. Hydrologic processes in the media layer(s) are discussed below. The lateral flow of water takes place in the drainage layer of multi-course systems, or throughout the media profile of a single-course system. Interceptor drains are typically installed as needed on larger green roofs to limit the lateral flow to 12 to 25 feet. These interceptors may control the overall depth of water while conveying seepage flow to the roof drain location.

Various soil-moisture processes are at play in the growing media of green roofs. These same processes can also occur within aggregate media when it is used for the drainage layer. There are several categories of moisture storage in soils and green roof media (Miller, 2003; Gregory, et al., 1999):

- Hygroscopic water is defined as water unavailable to plants and not drainable by gravity; the only practical way to remove this water is by oven-drying. The upper limit of this portion of soil-moisture storage is referred to as the "wilt point" and is typically 8 to 15 percent by volume in green roof growing media. (Miller, 2005).

- Moisture exceeding the wilt point of the media is held in pores and soil voids that are available to plants but does not drain by gravity. This typically is called the "field capacity" in the green roof industry and typically is reported as the "Maximum Water Content" (MWC) based on FLL or ASTM testing procedures and is often 40 to 50 percent for green roof growing media. The effective field capacity (difference between MWC and the wilt point) of green roofs is estimated to be between 15 and 40 percent by volume (Miller, 2005), depending on the media.

- The final component of moisture storage, drainable water (also called transient storage), is water that is delayed as it flows downward through the green roof media (Miller, 2003); this is usually reported as porosity, voids, or percent-air at MWC. This is a very significant parameter because it represents an "active" storage reservoir of moisture in the soil profile that alternates from absorbing rainwater and being withdrawn through evapotranspiration processes.

The type and composition of the drainage layer also affects the runoff characteristics (Miller, 2003). Many commercially available drainage products for green roofs consist of three-dimensional mats or "drain boards" that incorporate small molded-plastic cups intended to hold water within the drainage layer (Dunnett and Kingsbury, 2004). This type of system may provide additional moisture for plant roots, but does not provide enough storage to substantially affect stormwater runoff except for small storms (Miller, 2002). However, aggregate drainage layers, such as fine pumice, can slow the flow of runoff as water migrates laterally to the interceptor/roof drain (Miller, 2003); this significant observation was observed in MKA's green roof evaluation plots.

The plants of a green roof also play a role in retaining moisture and reducing runoff (Uhl, et al., 2003), especially for low intensity storms, but this effect has not been quantified for Pacific Northwest conditions

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in the available literature. MKA staff have observed that some plant species have leaves shaped to intercept rainwater, with collected moisture visibly present for hours following storms. Additional research is needed to better quantify the specific role of plant uptake and interception in the overall hydrologic regime of green roof systems.

Roof slope is another factor that could affect the amount and rate of green roof runoff. Most roof flow paths are on the order of 30 to 60 feet; at this scale, runoff will collect rapidly at any slope if unimpeded. The affect of slope on roof discharge was evaluated for monitored roof plots in Germany (Uhl, et al., 2003); roof pitch did not substantially affect retention or peak rates of discharge.

Because of these different water storage and hydraulic processes, green roofs have capacity to both retain water (reducing runoff volume) and detain runoff (reducing runoff peak flow rate) from a roof. The effectiveness of a specific green roof at achieving stormwater management goals depends on the climatic zone where the system is installed and on the factors identified above: single- or multi-course construction, growing media properties, type of drainage layer, drainage layer properties, slope of roof, and properties of specific plant species.

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