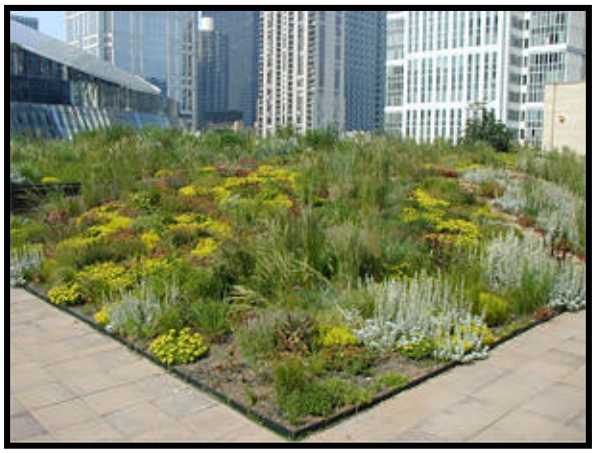


GR

Green Roofs

Description

Green roofs can be effectively used to reduce stormwater runoff from commercial, industrial, and residential buildings. In contrast to traditional asphalt or metal roofing, green roofs absorb, store, and evapotranspire precipitation, thereby acting as a stormwater management system and reducing overall peak flow discharge to a storm sewer system. Furthermore, conventional roofing can act as a source for numerous toxic pollutants including lead, zinc, pyrene, and chrysene (Vane Metre and Mahler, 2003).

Green roofs have the potential to reduce discharge of pollutants such as nitrogen and phosphorous due to soil microbial processes and plant uptake. Green roofs usage would reduce the volume of stormwater entering local waterways resulting in less in-stream scouring, lower water temperatures and better water quality. Green roofs can reduce the volume of stormwater discharged into combined sewer system, thus preventing combined sewer system overflows and the discharge of sewage into local waterways.

Green roofs offer additional benefits including reduction of urban heat island effects, increased thermal insulation and energy efficiency, increased acoustic insulation, and increased durability and lifespan compared to conventional roofs.

Green roofs are classified as extensive, semi-intensive, or intensive. Generally, extensive green roofs have six inches or less of growing medium, whereas intensive green roofs have greater than 6 inches of substrate. Semi-intensive green roofs can be defined as a hybrid between intensive and extensive green roofs, where at least 25 percent of the roof square footage is above or below the 6 inch threshold. Extensive green roofs provide many of the environmental benefits of intensive green roofs, but they are designed to be very low-maintenance and are not typically designed for public access. Semi-intensive and intensive green roofs are designed to be used by the public or building tenants as a park or relaxation area. However, they also require greater capital and maintenance investments than extensive green roofs. Intensive green roofs are particularly attractive for developers, property owners, and municipalities, in areas where land prices command a premium, but property owners want to provide some of the amenities associated with parks.

Selection Criteria

Green roofs can be applied to new construction or retrofitted to existing construction. They are applicable on residential, commercial, and industrial or mix use buildings and are easily constructed on roofs with up to a 20 percent slope.

Ultra-Urban Areas

Green roofs are ideal for ultra-urban areas because they provide stormwater benefits and other valuable ecological services without consuming additional land. In a 2005 modeling study of Washington DC, Casey Trees and Limno-Tech found that green

roofs on 20 percent of buildings over 10,000 square feet could add an additional 23 million gallons of storage and reduce outflow to the storm sewer or combined sewer systems by an average of just under 300 million gallons per year. According to the authors, this would reduce the annual number of CSO events in DC by 15 percent.

Stormwater Retrofit

A stormwater retrofit is a stormwater management practice (usually structural) put into place after development has occurred, to improve water quality, protect downstream channels, reduce flooding, or meet other specific objectives. Green roofs are a useful tool for retrofitting existing impervious area associated with building footprints. The construction of most existing flat-roofed buildings is such that they can accommodate the weight of an extensive green roof without structural modifications. Although retrofitting existing structures with green roofs can be more complex and expensive than on new facilities, technological advances are bringing that cost down.

Design Considerations

Green roofs can be installed during initial construction or placed on buildings as part of a retrofit. The amount of stormwater that a green roof mitigates is directly proportional to the area it covers, the depth and type of the growing medium, slope, and the type of plants selected. The larger the green roof area, the more stormwater mitigated. Green roofs are appropriate for industrial and commercial facilities and large residential buildings such as condominiums or apartment complexes. Green roofs can also prove useful for small residential buildings under some circumstances. For instance, green roofs are commonly used on single family residential structures in Germany and other European countries. Single family residential structures, like all buildings with green roofs, must be able to support the loading from a saturated roof. Furthermore, the green roofs should be easily accessible and residents should understand the maintenance requirements necessary to keep the roof functional.

A building must be able to support the loading of green roof materials under fully saturated conditions. These materials include a waterproofing layer, a soil or substrate layer, and a plant layer. Plants selected need to be suited for local climatic conditions and can range from sedums, grasses, and wildflowers on extensive roofs to shrubs and small trees on intensive roofs.

Green roofs can be designed to be either intensive, semi-intensive, or extensive green roofs. The type of design chosen will depend upon loading capacity, budget, design goals, and stormwater retention desired. There will also be variations in the type of green roof selected depending upon climate, types of plants chosen, soil layer depth desired and feasibility and other design considerations. Green roofs can be constructed layer by layer, or can be purchased as a system. Some vendors offer modular trays containing the green roof components.

Maintenance

Immediately after construction, green roofs need to be monitored regularly to ensure the vegetation thrives. During the first season, green roofs may need to be watered periodically if there is not sufficient precipitation. After the first season, extensive green roofs may only need to be inspected and lightly fertilized approximately once per year. The roofs may need occasional weeding and may require some watering during exceptionally dry periods. If leaks should occur in the roof, they are relatively easy to detect and fix. Intensive green roofs need to be maintained as any other landscaped area.

This can involve gardening and irrigation, in addition to other roof maintenance. Green roofs are less prone to leaking than conventional roofs. In most cases, detecting and fixing a leak under a green roof is no more difficult than doing the same for a conventional roof.

Limitations

Green roofs need to have drought tolerant plant and native species or an irrigation system to sustain vegetation. The slope of green roofs can range from 0 to 40 degrees. In new construction, buildings should be designed to manage a potentially increased load associated with the green roof. When designing green roofs for existing structures, engineers must take the load restrictions of the building into account.

Green roofs have been shown to be effective at removing some pollutants and reducing peak flows associated with storm events. As a general rule, developers can assume that extensive green roofs will absorb 50 percent of rainfall (Stephen Peck, 9/1/2005, personal communication). In a modeling study, Casey Trees and Limno-Tech (2005) assumed that extensive green roofs absorbed two inches of rainfall and intensive green roofs stored 4 inches of rainfall. Due to evapotranspiration and plant uptake, this storage is assumed to recharge once every 4 days. A study by Moran (2005) found that monthly stormwater retention rates varied between 40 percent and 100 percent on two green roofs in the Neuse River watershed, North Carolina. The study showed a decrease in peak flow runoff and total stormwater runoff, and a gradual and delayed release of the stormwater that was ultimately discharged. The reduction of peak flow discharge potentially mitigates stream channel scouring, resulting in improved aquatic habitat and lessening the risk of downstream property damage and flooding.

Penn State Green Roof Research Center has also noted a decrease in both total stormwater runoff and peak flow discharge. The graphs below show both the decrease in total discharge and peak flow run-off from roof area associated with three green roofs. In this 1+ inch storm event, the green roofs captured approximately 25 percent of total runoff compared to the conventional roofs. Over the period from May 23, 2003 to June 1, 2003, 2.21 inches of rain fell, of which the green roof detained 1.05 inches (~47 percent). The center noted that the spring of 2003 was wet and cool.

References

Casey Trees Endowment Fund and Limno-Tech, Inc. 2005. Re-greening Washington DC: A Green Roof Vision Based on Quantifying Stormwater and Air Quality Benefits. http://www.caseytrees.org.

Green Roofs for Healthy Cities. 2005. http://www.greenroofs.org.

Roofscapes, Inc. 2007. http://www.roofmeadow.com/

Jones, R. C. and C. C. Clark. 1987. Impact of Watershed Urbanization on Stream Insect Communities. Water Resources Bulletin **23**(6): 1047-1055.

Mentens, J., D. Raes, and M. Hermy. 2005. Landscape and Urban Planning.

Scholz-Barth, K., 2001. Green Roofs, Stormwater Management from the Top Down. Environmental Design and Construction. http://www.edcmag.com.

Van Metre, P.C. and B.J. Mahler. 2003. The contribution of particles washed from rooftops to contaminant loading to urban streams. Chemosphere **52**: 1727 - 1741.

Figure 1
Typical Green Roof Components

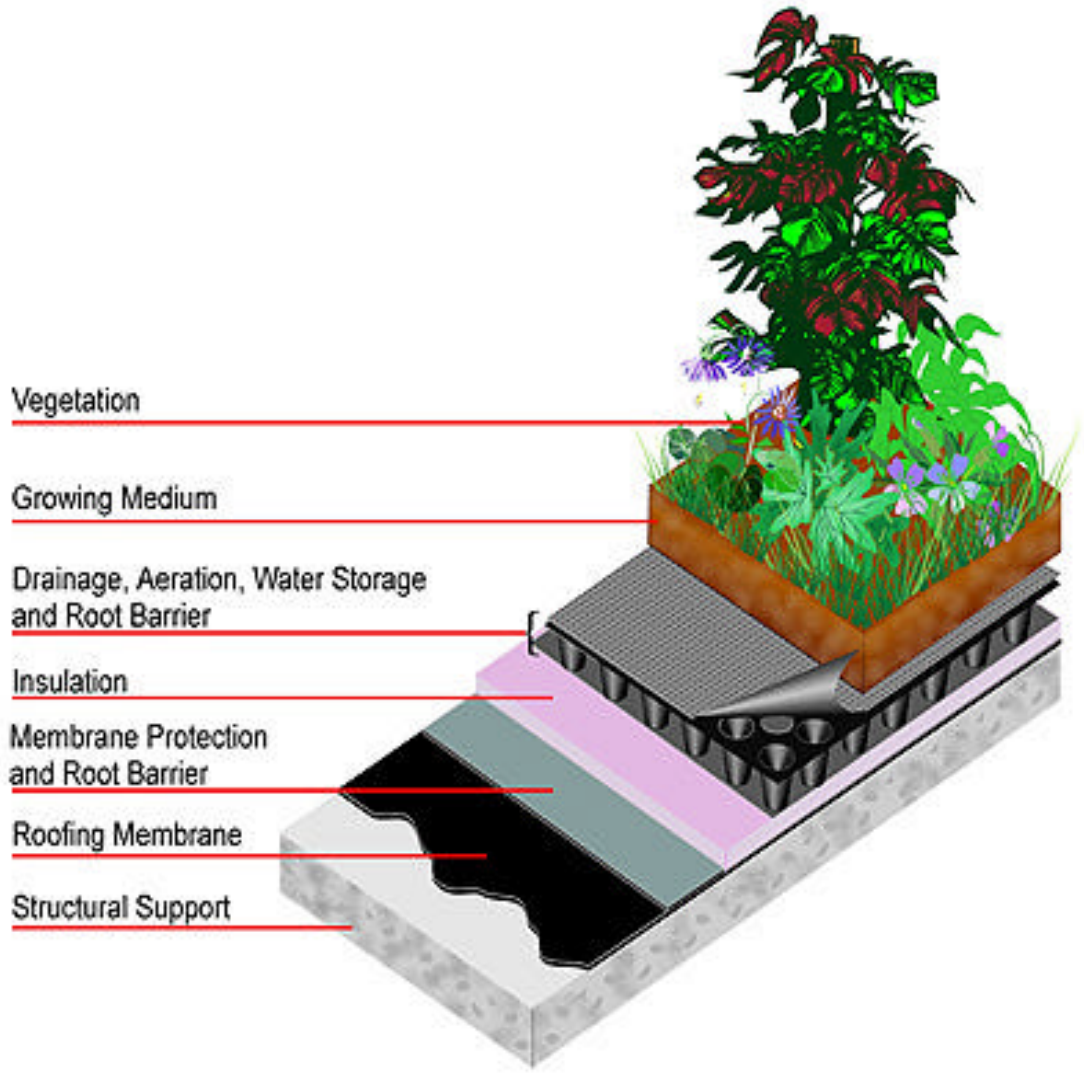
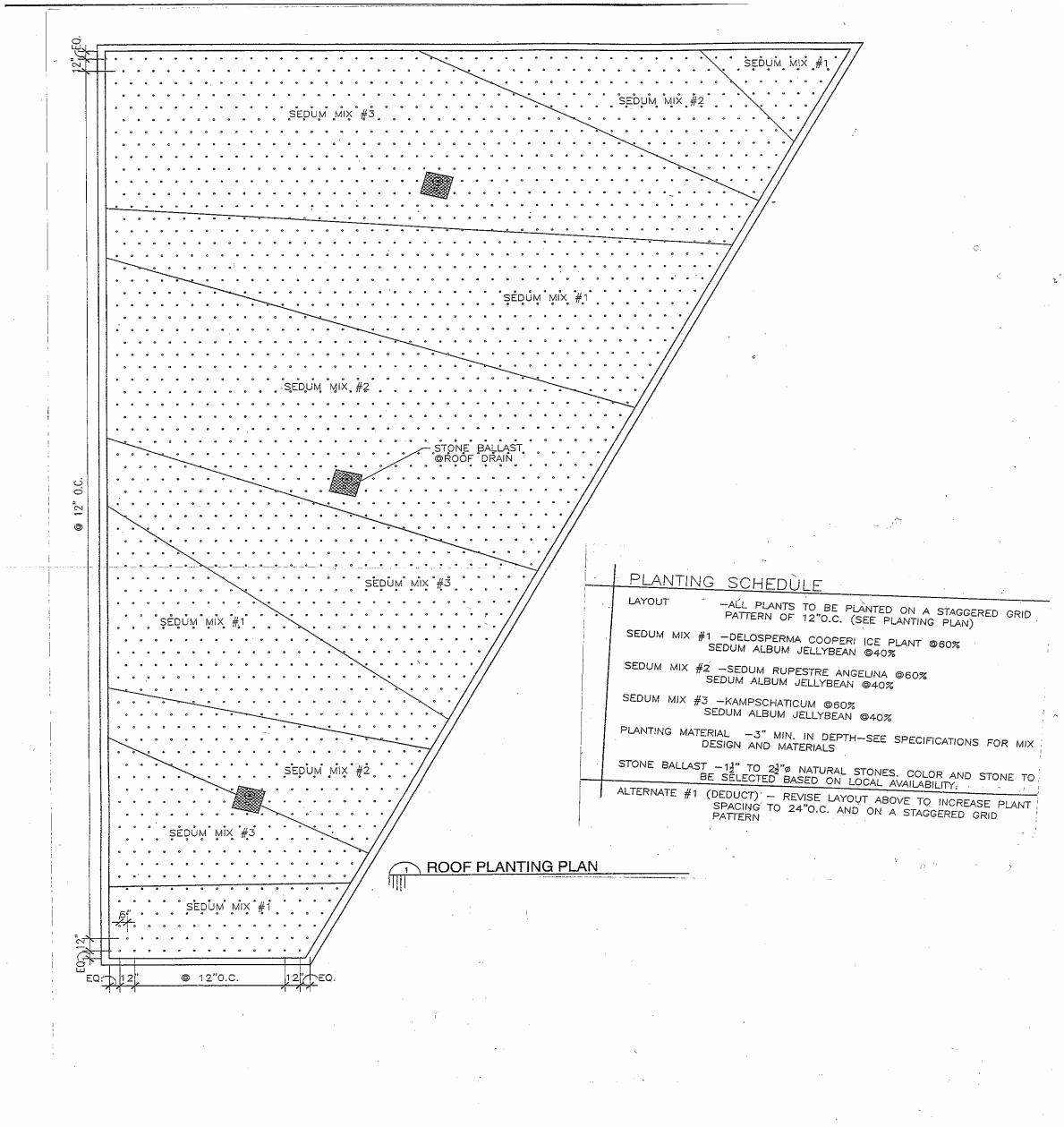
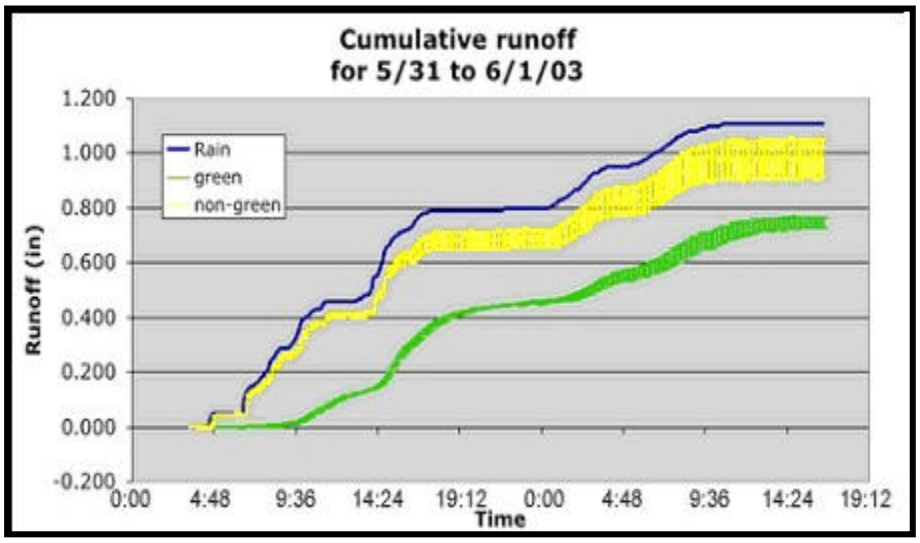


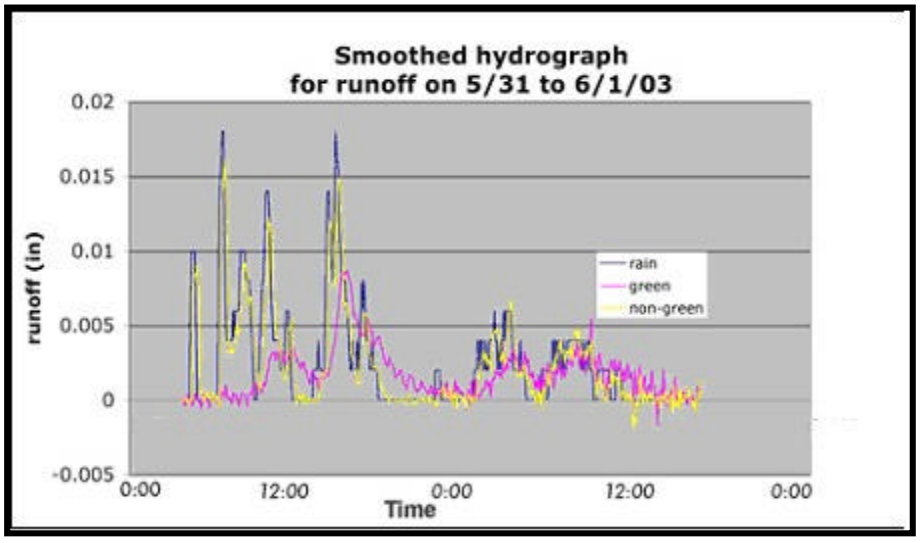
Figure 2
Roof Garden Planting Plan



Figures 3 - 4

Graphs are courtesy of Penn State Green Roof Research Center, Rock Springs, PA. They are based on data from 3 buildings with green roofs and three with traditional roofing.





Photos 1 - 2
Green Roofs