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Green Infrastructure Research: Rain Gardens at EPA's Edison Environmental Center

Background

Large volumes of stormwater runoff from urban or paved areas can pollute receiving waters and cause flooding and erosion. Rain gardens allow stormwater to infiltrate to underlying native soil and eventually contribute to groundwater. The resulting reduction in peak flow rates and volumes protects the physical and biological integrity of receiving streams.

Guidance on effective rain garden design is limited. In federal and state rain garden manuals, sizing criteria as a fraction of the impervious area draining to the rain garden varies widely, leaving designers with differing guidance. Sizing criteria is a critical need given the importance of avoiding flooding and overflows, while avoiding unnecessarily oversized rain gardens. Sizing considerations takes on added significance in urban settings where land area is at a premium.

An additional area of uncertainty in rain gardens involves high-quality monitoring data. Relatively few studies have measured rain garden performance and infiltration dynamics with multiple embedded instruments and replicated experimental design. Previous research has shown that rain gardens must be designed with the capacity for long-term monitoring, as retroactively equipping an existing structure is often impractical.

Research Objectives

EPA scientists are evaluating rain gardens as part of a long-term research effort examining stormwater management practices.

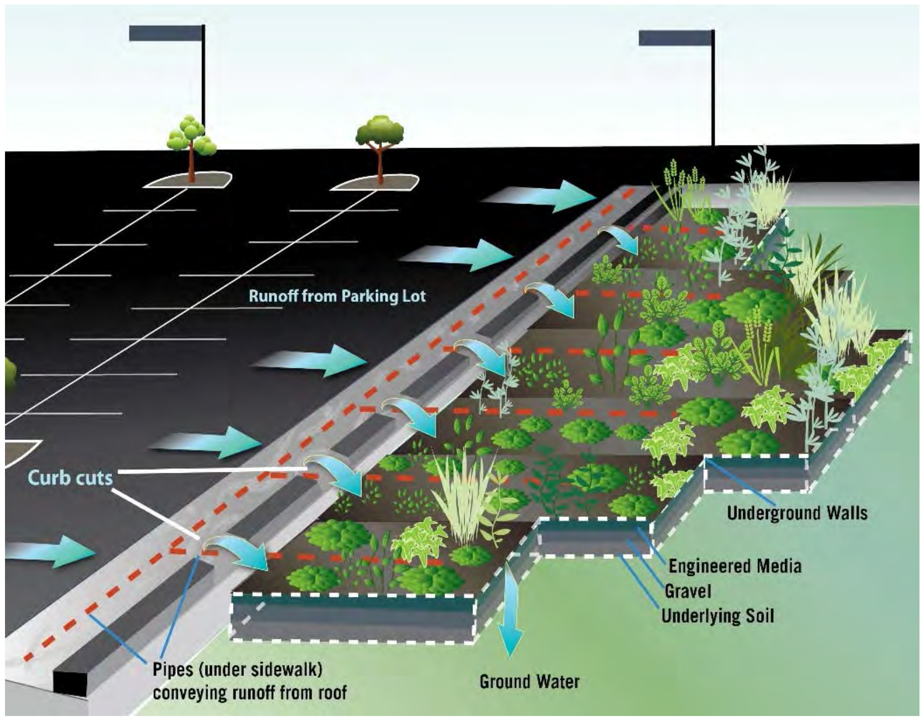

Figure 1. Rain garden design at EPA's Edison Environmental Center

EPA's research addresses two objectives: 1) quantify the hydrologic performance of rain gardens and changes with season and rain garden age, and 2) test ratios of impervious surface area to rain garden area in terms of hydrologic performance.

Approach & Methods

In October 2009, EPA finished upgrading a major parking lot at its Region 2 laboratory in Edison, New Jersey, with green infrastructure features, including a rain garden (Figure 1).

The rain garden consists of six separate cells, hydraulically isolated with plastic sheeting. The six cells receive stormwater runoff from an impervious section of the parking lot and adjoining sidewalk through curb cuts at the south end of the parking lot. Stormwater runoff from the roof of an adjacent building is collected from multiple downspouts and conveyed beneath the sidewalk in a common manifold. Another pipe distributes the roof runoff into each rain garden cell just south of the curb cuts. The drainage area to each cell is roughly equal, but the different sized rain gardens represent different percentages of their drainage areas.

The two smallest rain garden cells are 4.5%, the two medium-sized cells are 9%, and the two largest cells are 18% of their drainage areas, respectively. Each cell size is duplicated for statistical purposes. The cells were constructed with 86

June 2016 EPA/600/F-16/130

centimeters (cm) of engineered media (97% sand-sized particles) over 10 cm of gravel.

Each cell is equipped with soil water content reflectometers (WCRs) to measure soil moisture, and thermistors to measure temperature. These instruments are installed at two vertical depths at the front and rear of each cell. A cluster of piezometers and wells at various depths is located in the center of each cell.

All instrumentation contributes to quantifying the timing of the wetting front and moisture movement in the rain garden. Researchers used this data to evaluate the effectiveness of the monitoring plan.

Results

Key research results are summarized in Table 1. The WCRs successfully measured the timing of the wetting front in the rain gardens. Spatial and temporal variability outweighed any effects of rain garden cell size on wetting front rates (Stander et al., 2013).

After three growing seasons, basal area and height of shrubs were measured to quantify growth in the rain gardens. Generally, shrubs nearer the inlet (source of runoff) were larger than those farther away. The monitoring data from the WCRs supported the hypothesis that stormwater infiltration concentrated near the inlet, while areas farther from the inlet often received direct rainfall as the only water source. Therefore, rain garden design should consider plant placement and species selection relative to the proximity of the runoff source (Brown et al., 2015).

Roof runoff from a 0.64 acre area on an adjacent building was directed into the rain gardens as well, which supplemented the plants' water needs. Runoff to the rain gardens, in addition to runoff collected for non-potable usages at the facility, contributed towards a diversion of about 900,000 gallons of rainwater from the stormwater sewer system annually (O'Connor and Amin, 2015).

Table 1. Key research results from EPA's Edison rain gardens

Feature Studied	Key Results
Instrumentation	• Water content reflectometers (WCRs) quantified size and timing of the wetting front, as well as infiltration rates in the underlying soil.
Rain garden size	• Cell size does have a significant effect on WCR responses to storm events, but was not an important driver of system infiltration rates. • Oversized cells increase the likelihood that vegetation farthest from the runoff source/inlet will experience-water deficit stress.
Spatial infiltration of runoff	• Infiltration is concentrated at the inlet and does not necessarily spread evenly throughout the cell. • Nutrients (nitrogen) concentrate near the inlets.
Vegetation growth patterns	• Plants farther from the inlet experienced more frequent water-deficit stress and received limited nutrient inputs. • Plants with deeper roots are more likely to access infiltrated water in the cell; those with shallower roots will depend on direct rainfall.
Runoff collection	• About 900,000 gallons of rainwater is being diverted from the existing storm water sewer system annually. • Stormwater runoff helps limit the frequency and duration of water-deficit stress on vegetation.

Impact

The successful application of rain gardens at the Edison Environmental Center allows for technology transfer to other facilities and municipalities considering adopting green infrastructure. Results from this research are helping to inform design and implementation decisions at other rain garden sites.

These studies document a method for defining and quantifying rain gardens' hydrologic performance. Quantifying performance allows for evaluation and comparison of different rain garden designs, which enables EPA decision makers to develop national guidelines on rain garden design, construction, maintenance, and monitoring.

References

Brown, R, T. O'Connor, and M. Borst. (2015). "Divergent vegetation growth patterns relative to bioinfiltration size and plant placement." *Journal of Sustainable Water in the Built Environment*, 1(3), 04015001.

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Additional Information

EPA's Green Infrastructure Research: epa.gov/water-research/green-infrastructure-research

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