ENVIRONMENTAL LIMITATIONS TO VEGETATION ESTABLISHMENT AND GROWTH IN VEGETATED STORMWATER BIOFILTERS

By

Greg Mazer
Graduate Research Assistant

Center for Urban Water Resources Management

Department of Civil and Environmental Engineering

University of Washington, Box 352700

Seattle, WA 98195

EXECUTIVE SUMMARY

Runoff from urbanized landscapes is an increasingly common source of surface water degradation. It carries a variety of pollutants including sediments, nutrients, metals, synthetic organic toxins, and pathogens. Where storm sewers transport runoff directly to downstream water bodies, pollutants bypass filtration by vegetation and soils. The result is decreased water quality.

Acknowledging this problem, both federal and local governmental agencies throughout the country have required construction of low cost, in-pipe or end-of-pipe stormwater filtration facilities. One such facility increasingly employed in the Puget Sound region is the biofiltration swale (also called bioswale or biofilter).

Bioswales are open channels possessing a dense cover of grasses and other herbaceous plants through which runoff is directed during storm events. Aboveground plant parts (stems, leaves, and stolons) retard flow and thereby encourage particulates and their associated pollutants to settle. The pollutants are then incorporated into the soil where they may be immobilized and/or decomposed. Despite some experimental evidence to the contrary, herbaceous cover is commonly considered to predict treatment efficiency.

Over 100 bioswales have been constructed in King County over the past ten years to treat runoff associated with residential, commercial and light industrial development. A recent survey by King County Water and Land Resources Division found most swales to be vegetationally depauparate. Water level fluctuation, long-term inundation, erosive flow, excessive shade, poor soils, and improper installation are the most common causes of low vegetation survival. The relative importance of these limiting factors may vary widely from swale to swale. This study was designed to identify those factors that most influence vegetation establishment and growth, so that recommendations can be made to improve future biofiltration swale design and performance. The presumed relation between vegetation abundance and bioswale performance was also investigated.

Environmental conditions were examined for eight biofiltration swales in King County, Washington, to determine the relative importance of the various factors influencing vegetation establishment and growth. Three of these swales were regraded, retrofitted with new soil, and hydroseeded in September 1996. A nested two-factorial greenhouse experiment tested the response of four turfgrass species, commonly seeded in bioswales, to four moisture regimes (three inundation schedules plus a control).

Of the three retrofitted bioswales, only one (SAY7) accrued an abundance of vegetation deemed adequate for effective biofiltration. Vegetation and organic litter biomass there was comparable to that of the three other evaluated swales that also supported high herbaceous cover (at Discovery Elementary School, Pine Lake Park, and the Center for Urban Horticulture), although these swales were seeded 3-9 years ago. Virtually no hydroseeded grasses established at the two other retrofitted swales (SAY8 & SAY9) due to particularly long inundation durations after seeding, a consequence of the local soils and hydrologic regime. However, some volunteer wetland plant species grew in less erosive and shallower areas of these sites.

The proportion of time that each swale was inundated at or above 2.5 cm depth proved to be the variable that was most closely correlated with plant and organic litter biomass ($r^2 = -0.92$). For those plots that experienced summer drought, vegetation biomass was strongly dependent on adequate soil depth ($r^2 = 0.74$). Field monitoring revealed other factors that locally limit bioswale vegetation growth, such as springtime base flow velocity and excessive shading by trees. In contrast, bioswale biomass was *not* well correlated with certain hydraulic variables, such as the rate at which runoff is introduced over the surface of the swale, that *are* important in determining sedimentation potential and thus pollutant removal. As a result, the condition of swale vegetation may not reflect a facility’s actual pollutant-removal effectiveness.

In the greenhouse experiment, the "wet" treatment (long-term inundation of seeds) produced equally poor germination amongst all grass species. For each of the other three moisture treatments, *Festuca arundinacea* (Tall Fescue) accrued significantly more biomass, and *Agrostis alba* var. *stolonifera* produced significantly more leaf blades, in comparison to the other species. These greenhouse results were consistent with field observations in retrofitted swale SAY7, where Tall Fescue established more quickly than the other seeded species while *Agrostis alba* var. *stolonifera* achieved nearly equivalent abundance within one year. Both field observations and greenhouse experiments clearly demonstrate that persistent inundation severely limits germination and establishment of those grasses typically seeded in biofiltration swales.

Several shortcomings of current bioswale design and construction are evident from this study. First, the factor that most critically determines vegetation success (inundation during germination) is not acknowledged by present design or construction guidelines. Second, current design guidelines permit flows at overly high rates that can overwhelm the vegetation or circumvent filtration via channeled flow. Finally, factors that contribute to eventual success but that vary widely on a site-by-site basis can only be addressed by careful evaluation and construction, but most bioswales are constructed without incentives to install high-quality stormwater runoff facilities that are suited to the requirements of individual site characteristics.

The results of this study suggest that bioswales design standards should be modified to restrict the permitted inflow discharges to much lower maximum values than at present, and that implementation guidelines should ensure that proper moisture conditions for germination are achieved. Given the multiple challenges to constructing and maintaining functionally satisfactory biofiltration swales, however, construction of alternative stormwater facilities with less critical requirements should be investigated. Carefully designed constructed wetlands, for example, may provide conditions conducive to sediment deposition more readily, offer more effective immobilization and/or greater biological uptake of contaminants, and concurrently create refuge for native flora and fauna.

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