Rain Garden and Bioretention Facility Effectiveness and Investment Guidance for Puget Sound Municipalities and NPDES Permittees.

Deliverable 3.1b

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Project Team: Paul Marrinan (City of Puyallup), Aaron Clark (Stewardship Partners), Bob Simmons (WSU Extension), Erica Guttman (WSU Extension), Ani Jayakaran (WSU Extension), Chrys Bertolotto (WSU Extension), Philomena Kedziorski (WSU Extension)

Outline:

- Overview of rain garden and bioretention effectiveness
- Effectiveness based on assessment data collected during this study
    - Hydrology
    - Vegetation
- Investment Guidance for Rain Gardens and Bioretention Facilities
    - Design and Planning
    - Construction and Planting
    - Assessment and Maintenance
    - Rain Gardens and Bioretention vs. Other Stormwater BMPs.

Overview of rain garden and bioretention effectiveness

Throughout the review of literature conducted as part of this project, rain gardens and bioretention facilities were found to be highly effective stormwater BMPs, often performing better than expected. In the personal experience of Stewardship Partners and WSU Extension staff, outright failure of a rain garden is quite rare, and underperformance is uncommon as well. However, as with any type of infrastructure, green stormwater infrastructure facilities can and do fail or perform below their intended level for reasons ranging from design, planning, construction, planting, and maintenance. The intended goal of this project was the creation of a standardized and easy to implement assessment protocol for rain gardens and bioretention facilities, not an analysis of the effectiveness of rain gardens and bioretention as an approach. However, our findings from the testing phase of protocol development do offer some high-level insights into factors that lead to failure and underperformance. Using the criteria created to raise red and yellow flags for maintenance attention (see appendix 6: Bioretention and Rain Garden Assessment Protocol Concern Levels from Summary Report—Deliverable 2.5), we describe below the specific types of issues detected across our 29 assessments of 14 sites during phase 1 and 82 assessments of 41 sites during phase 2, and offer suggestions for avoiding and/or remedying those issues. Detailed results of the flagging effort can be found in Appendix 7 of Deliverable 2.5: Bioretention and Rain Garden Assessment V2 Concern Analysis.

Hydrology

As was expected based on previous research and personal experience, our team found relatively few hydrologically failing rain gardens or bioretention facilities and relatively few hydrological issues of concern. Assessments of two facilities found standing water despite no measured precipitation in the previous 48 hours, and a third facility had a trace amount of water despite no rainfall in 48 hours. Two other sites were found with standing water but did not raise hydrology failure flags because of recent rainfall at those sites.

A more commonly detected hydrology issue was blocked or partially blocked inflows. Blocked inflow structures were detected in 15% of all sites assessed. Blockage of sheet flow inflows were detected in 11% of sites, indicating that sheet flow type inflows are also susceptible to blockage.

In the first round of assessments (n=29), the most frequently encountered type of blockage that was found was organic material (living and dead). Soil, sediments, litter, and rocks were also cited but were less common. In the second round of assessments (n=82), we divided organic material between living (“vegetation”) and dead (leaves, branches etc.). Overall, living vegetation was reported as the dominant type of blockage with (dead) organic material, siltation/sediment, and rock or other hardscape sharing approximately equal prevalence in blockages. Trash was a very rare form of blockage observed. We did not see much difference in the constituent blockage elements for minor (defined as less than 5% blocked), moderate (5-50% blocked), or substantial (greater than 50% blocked) inlets (Figure 1) except that in moderate blockages, living vegetation was more prevalent still than the other scenarios. While living vegetation was a frequent blockage element, we did not assess which types of plants (intended plants vs. weeds, grasses vs. ground covers, etc.) were involved. Information regarding which types of plants cause the most blockages could provide useful additional guidance.

A factor we assessed that has potential hydrology impacts was coverage of mulch. Design and maintenance guidance encourage 2-3 inches of mulch (Washington’s SWMM 2019 Draft recommends mulch as a design option up to 2-3 inches deep, but later recommends maintaining a 2-3 inch depth of mulch in all bioretention, the Rain Garden Handbook for Western Washington recommends 2-3 inches of mulch). At 96% of the sites assessed for this project mulch depth was either none or trace amounts in at least one zone of the facility. Fewer than 10% of all sites assessed meet the maintenance guidelines recommended in the Rain Garden Handbook and the SWMM.

Very few flags were raised for the following metrics: Improper overflow design; overflow blockage; erosion; liner depth; filter fabric presence; bioretention soil texture, native soil texture, or soil descriptions.

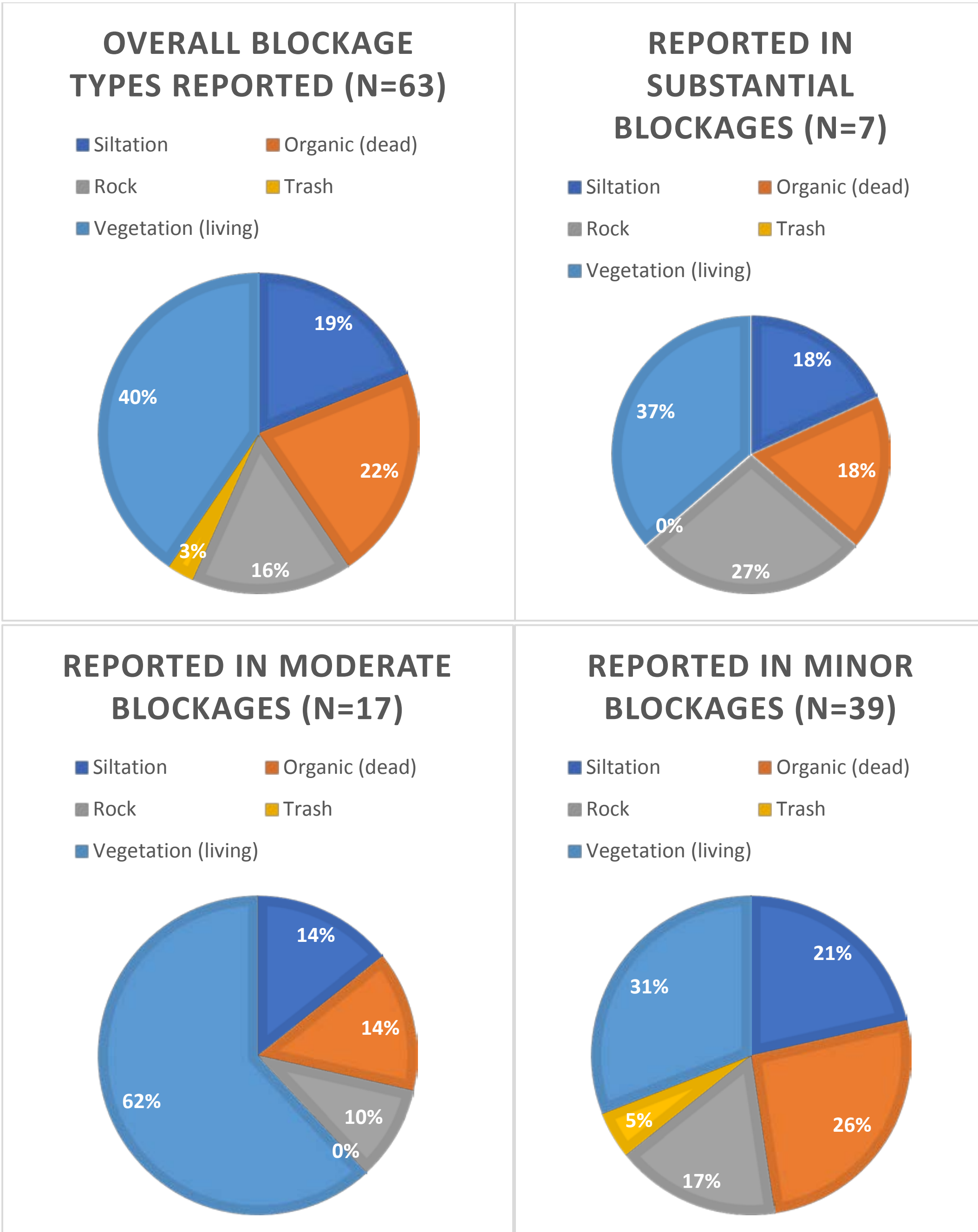

Figure 1: Types of inflow blockage reported during phase 2 Assessments. In phase 2 we divided out organic blockage types into living organic (vegetation) and dead organic (e.g. leaves and branches). Minor blockage is <5% blocked, moderate blockage if 5-50% blocked, and substantial blockage is >50% blocked.

Vegetation

Most maintenance flags raised by our assessments of vegetation were related to plant vigor. However, plant vigor scores varied greatly between different dates and times and assessment teams, including at repeated sites, so effectiveness of rain gardens and bioretention facilities to maintain plant vigor is not an effectiveness metric that we will draw any conclusions about from this study.

Of greater interest and impact to the overall effectiveness and maintenance of rain gardens and bioretention facilities is the presence of problem plants (noxious, invasive weeds). Invasive weeds were flagged as a significant concern in 17 out of 82 assessments (21%) and at 12 of 41 sites (29%). Problem plants were defined for this project as: Himalayan Blackberry, Evergreen Blackberry, Hedge Bindweed, Invasive Knotweeds, Herb Robert, Velvet Grass, Birds-foot Trefoil, Hawkweeds and Sow-thistle.

Investment Guidance for Rain Gardens and Bioretention Facilities

Design and Planning

For overall hydrology effectiveness, our findings suggest that current guidance is generally adequate for creating rain gardens and bioretention facilities that function as intended. Inflow blockages, including sheet flow-based designs, suggests that inflow designs should be studied and compared to determine which inflow designs in which contexts are most prone to blockage, and which tend to remain clear. Narrow inflows and inflows with minimal gradient or slope logically may be more prone to blockage, but that hypothesis was not tested in this study.

Based on our findings regarding inflow blockages, designing to limit potential overgrowth and leaf litter deposition in the inflow area could reduce these most common blockage types. To limit living vegetation from creating a blockage at the inlet, a perimeter surrounding the inlet area could be created that is easy to keep vegetation free, and plantings could be tailored to avoid fast spreading plant species near the inlets.

Construction and Planting

In the construction and planting phase of rain garden and bioretention facilities, there is the potential to either do harm or improve on the original design, depending on how closely the design accounted for the actual on-the-ground realities of the site. If site plans/designs are somewhat generic, then a construction and planting approach that is responsive to site conditions could improve overall effectiveness and minimize maintenance costs. For example, at a site where leaf litter from nearby trees will be a large input, enlarging inflow structures could reduce the chance of blockage (if allowed by other requirements such as transportation safety etc.). Conversely, if site plans/designs are created with careful consideration of site-specific conditions, construction and planting should exercise strong adherence to those designs. Using the same example of significant leaf litter inputs, if the inflow design has taken that information into account and sized the inflow accordingly, a construction team could do harm if that design element is not noted and followed carefully and a smaller than designed inflow is installed. Ideally, both the design/planning and construction/planting teams will take site considerations into account and communicate regularly with each other to ensure success of the installation.

Because water flow can be diverted with very small changes in grade or relatively small blockages, care for inflow construction and planting should be taken to avoid irregularities or structural elements that could catch debris. Inadvertent divergence from the necessary grade/slope can lead to water flowing the opposite direction and bypassing a rain garden, bioretention facility or other stormwater BMP. We only found one case where an inflow did not direct water into the rain garden or bioretention facility for reasons other than blockage, and it was not determined if this was a design or construction-based issue.

Assessment and Maintenance

The overall value of regular assessment of rain gardens and bioretention facilities was affirmed by this project. Most effectiveness issues identified in rain gardens and bioretention facilities can be readily addressed with straight-forward maintenance actions. Assessing inflows for blockage and subsequent removal of blockage requires relatively little time and can render a non-functioning facility fully functional. Furthermore, it is only through regular assessment of sites that patterns will emerge that may indicate a more systemic issue that requires design and construction changes.

In addition to timely removal of inflow blockages, our findings suggest two other inter-related maintenance concerns: mulch and invasive weeds. With over 90% of all assessments finding little or no mulch present in rain gardens and bioretention facilities, increasing the amount of mulch used at installation time as well as adding mulch as needed are top recommendations. Use of mulch is helpful in reducing invasive weed colonization and establishment. Adequately mulched soils are easier to remove weeds from and mulch is also helpful is retaining soil moisture, a factor that likely impacts plant vigor and plant health.

Identifying invasive weeds and removing them promptly is always recommended in landscape maintenance of any kind. Our findings suggest that this applies to rain gardens and bioretention facilities as well. Plants categorized as problem plants, invasive or noxious weeds are of particular concern because of their ability to disperse and establish quickly, so timely removal and proper disposal of potential propagules will reduce their spread both within and beyond the rain garden or bioretention facility in question.

Rain Gardens and Bioretention vs. Other Stormwater BMPs.

While this study did not compare assessment data for stormwater BMPs other than rain gardens and bioretention facilities, the overall high degree of effectiveness of rain gardens and bioretention facilities support their continued use. Every site is unique, and rain gardens and bioretention facilities are not a good fit in every case. As compared to BMPs that are not plant-based, “green infrastructure” BMPs do offer more benefits beyond stormwater management, ranging from air quality to habitat to aesthetic values. Findings from the social science assessment component of this project (Deliverable 1.3) indicate that community perceptions of rain gardens are positive. Our survey indicated that the following positive value is provided to communities by rain gardens (in descending order): cleaning water runoff; providing wildlife habitat; conserving water, beautifying neighborhoods, teaching communities about water issues, and growing plants that offset greenhouse gas emissions. The only function of rain gardens that respondents noted had some negative value was the collection of trash (Table 1). Perceptions of maintenance of rain gardens are also generally high, suggesting that community members are unlikely to file complaints about un-maintained facilities.

Table 1: Summary of Values Ascribed to Functions of Rain Gardens by Survey Respondents

Significant Value	Some Value	Neutral and Negative Values
Clean Water Runoff (88.2%)	Teach communities about water issues (45.1%)	Catch Litter (40.4%)
Provide Wildlife Habitat (49%)	Grow plants that offset greenhouse gas emissions (42%)	
Conserve Water (46%)		
Beautify neighborhoods (45.1%)		