Development of an Online Performance Calculation Tool for Bioretention Projects in Seattle, WA, USA

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Highlights

- Presents online tool that calculates annual load reductions based on monitored flow data and laboratory results for bioretention systems to support Integrated Stormwater Management.
- In the absence of monitored data, performance is estimated using modeled data to allow for analysis of conceptual designs and built systems without available monitoring data.
- Allows for scenario analyses and assessment towards reaching regulatory water quality goals.

Introduction

The City of Seattle (City) manages stormwater through a combined sewer system and a municipal separate storm sewer system (MS4), both of which are permitted under the National Pollutant Discharge Elimination System (NPDES) by the Washington State Department of Ecology (Ecology), the state regulatory agency. While the storm sewer system serves approximately two-thirds of the city, discharging approximately 13 billion gallons of stormwater to receiving waters in and around the city during an average year, the City has historically contributed limited resources toward addressing water quality impacts of discharges from the City's MS4, focusing instead on CSO discharges. Ecology determined that stormwater runoff was a main pathway through which toxic pollutants enter Puget Sound (Ecology, 2011) and may contribute more than 50 times as much flow and 30 times as much solids loading to the Lower Duwamish Waterway, a major Seattle receiving water, compared to CSO discharges (Ecology, 2013).

To address stormwater-related impacts to receiving waters, the City developed an "Integrated Plan" (City of Seattle, 2015). This Plan allows the City to implement stormwater control projects that will significantly benefit water quality in receiving water bodies, while deferring lower-benefit CSO projects. The Integrated Plan is composed of three major projects. One project—Natural Drainage Systems (NDS) Partnering—includes the installation of bioretention stormwater management systems along City roadways. The bioretention systems manage flow and provide water quality treatment of urban runoff, thereby decreasing flow volume and pollutant loads to City receiving waters.

For regulatory acceptance of the City's Integrated Plan approach, the City agreed to demonstrate that the stormwater projects provide water quality benefits beyond those that would be achieved by the CSO projects alone. To assist in demonstrating success, post-construction monitoring is required from several NDS Partnering projects, the data from which can be used to estimate performance of other similarly implemented facilities and track progress toward achieving goals defined and accepted by Ecology.

This paper discusses the development of a simplistic tool to track, estimate performance, and allow scenario analyses to determine the number of stormwater investments through implementation of bioretention systems necessary to meet regulatory load reduction and volumetric goals.

Methodology

Pollutant Load Model

To evaluate stormwater projects considered in the Integrated Plan, a Pollutant Load Model (PLM) was developed in 2013 to determine the pollutant load reduction goals for each watershed. The model used

land use information for existing conditions and predicted load reductions, based on literature, and associated benefits for each proposed project. A separate cost-benefit analysis for the NDS Partnering projects was completed using present-value costs of the proposed projects based on costs per unit of pollutant load reduced compared to benefits. The projects were then scored and ranked, considering other factors including performance risk, project flexibility, relationship with other agencies, water quality load reduction, other positive environmental outcomes (in alignment with the City's Green Goal by reducing stream flow and/or add green space and habitat), and others.

The development of the PLM was completed in previous efforts to determine the necessary load reduction goals for pollutants of interest (e.g., PCBs, metals, bacteria, solids, and nutrients) for several City sub watersheds. The PLM determined annual averages of volume treatment and pollutant load removals that must be met through NDS Partnering projects. The target date for complete project implementation is 2025 with proven success (monitored) shown by 2029.

Online Monitoring and Load Estimation Tool

A website containing two complementary tools was developed to calculate and track estimated load reductions achieved through bioretention implementation as part of the NDS Partnering. This webtool is collectively known as the Seattle Public Utilities (SPU) *Green Stormwater Infrastructure Performance Calculator (GSIPC)*, and it consists of the *Monitoring-based Load Reduction Calculator (MLRC)* and the *Project Performance Estimator Tool (PPET)*. Both tools estimate load reductions from BMPs based on calculations represented in the diagram in **Figure 1**. In **Figure 1**, arrows represent loads, and circles represent flow divergences or convergences. For a given drainage area, a certain percentage of the pollutant load (comprised of a volume and pollutant concentration) will enter an NDS Partnering project for treatment, while the remaining load will bypass the system. Load reduction within the NDS Partnering project is achieved by both volume reduction (which is assumed to remove all pollutants associated with that volume of water) and water treatment through the BMP (e.g., filtration), which reduces the pollutant concentration of the remaining volume of water. The difference between the total watershed runoff load and the combined discharge load from the BMP, including treated effluent and bypassed volume, represents the load reduction associated with the NDS Partnering project.

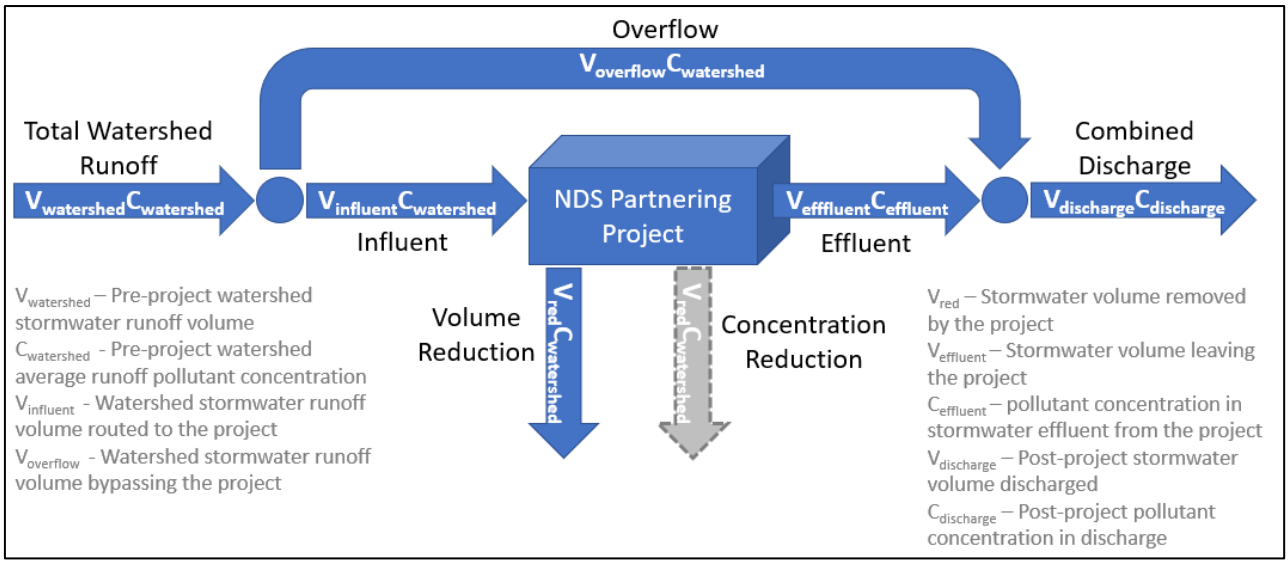

Figure 1. Conceptual diagram of load reduction calculations used by the SPU GSIPC. Adapted from Appendix F of the Integrated Plan (City of Seattle, 2015).

The *MLRC* tool can be used to estimate load reductions in existing NDS Partnering projects based on actual monitored data for each bioretention system. The tool allows users to parameterize the drainage area to the stormwater project and enter or upload monitoring data for single or multiple events. Data upload forms are designed to be compatible with EDDs (water quality data as received from laboratory analysis) to facilitate easy data upload. It also supports manual entry or bulk upload of Geographic Information Systems (GIS) data including land uses for pervious and impervious areas.

These monitoring data are used alongside watershed runoff estimates (generated from land use in the drainage area) to calculate and display a water balance performance summary (influent, effluent, and overflow volumes), event mean concentrations (EMCs) for pollutants of interest, and influent, effluent, and overflow loads for pollutants of interest each monitored location. The tool allows users to choose if load reductions are calculated assuming no pollutant export from BMPs or allowing pollutant export if supported by monitoring data. No pollutant export was an assumption used in the development of the Integrated Plan, and so this option would support regulatory reporting. The MRLC provides downloadable tabular and graphical summaries by event and determines annual load reductions.

The *PPET* allows users to use applicable monitoring data entered in the *MLRC* tool (e.g., for a similar stormwater project) or apply modeling input data based on the approach used in the PLM to estimate load reduction of existing—but not yet monitored—and potential future projects. As more data are collected as part of the NDS Partnering Project, more data will be available in the PPET to apply to new and existing facilities, and users will rely less on modeled data.

Results and Discussion

The tools were successfully developed and are undergoing testing and validation to provide simplistic tracking of right-of-way bioretention system performance. The tools provide performance estimates using monitored and/or modeled data with output of estimated long-term annual load reduction, estimated annual bypass load, estimated annual volume reduction, and collective performance for all systems entered into the tool database (**Figure 2**).

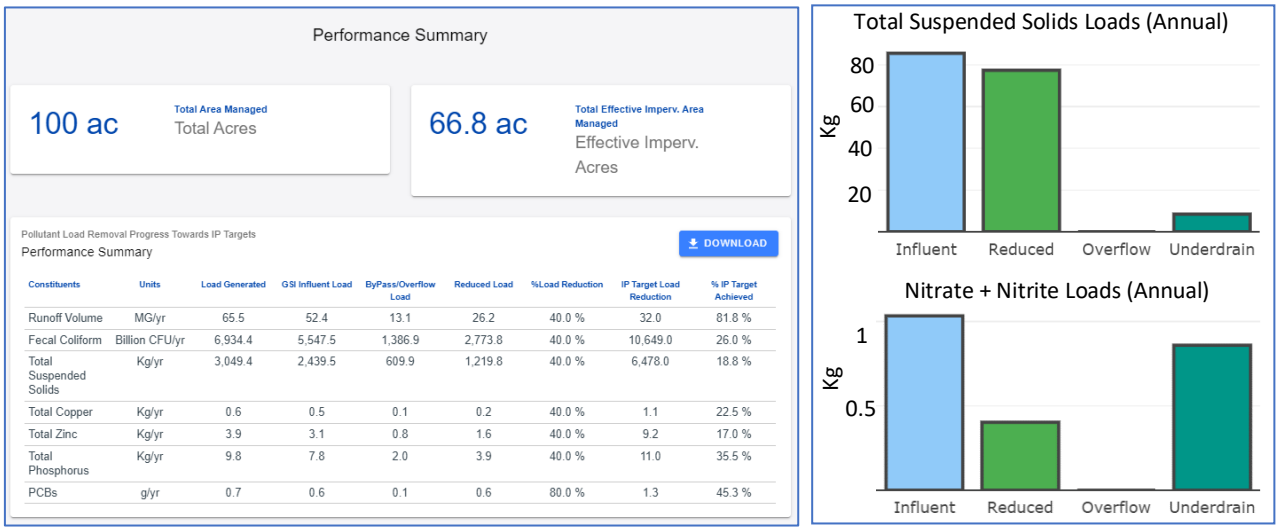

Figure 2. Example performance summary of the PPET for a conceptual bioretention system (left). Graphical output of scaled annual influent, overflow, and underdrain loads of total suspended solids and nitrate + nitrite based on monitoring data using the MRLC tool. Reduced loads are those infiltrated or retained by the bioretention systems.

Conclusions and Future Work

The tools developed for the City of Seattle provide an easy-to-use tracking and performance estimation platform to understand and report progress towards meeting regulatory load reduction requirements. The tools can also be used to predict project performance based on modeling or monitored information, aiding in determination of necessary investments in stormwater management.

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