Evaluation of an Agricultural Stormwater Cascade System

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INTRODUCTION

With the recent promulgation of the Chesapeake Bay TMDL (Total Maximum Daily Load), inputs of sediment, nitrogen (N), and phosphorus (P) to the Bay must be reduced throughout the entire Bay watershed. Agriculture, urban, and wastewater treatment discharges are all included in the TMDL requirement. Although advances have been made, agricultural land use remains the overall largest source of N and P to Bay waters. As rain falls on agricultural land, becoming runoff, nutrients and sediment from field and other areas, especially from row crops, are mobilized and transported to the Bay and its tributaries.

Processes to reduce and/or treat stormwater runoff continue to be developed, refined, and implemented in agricultural areas. These processes are commonly known as Best Management Practices (BMPs) and include technologies such as swales and buffer strips. While these practices can be effective when implemented and maintained, they commonly result in taking valuable cropland out of production. Additional tools are needed to address the agricultural runoff challenge.

High Impact Environmental (HIE) of Chestertown, MD, has developed a swale/basin technology (herein titled: Agricultural Stormwater Cascade System, ASCS) to address runoff from field crop areas. A prototype practice installed at HIE anecdotally has shown significant potential in runoff control, with runoff discharge only occurring during large rain events (maybe greater than 1 or more inches). Smaller rainfall events are fully captured and attenuated by the practice. The net result is reduced runoff and nutrient loads to the local Chesapeake Bay tributary.

PROJECT GOALS AND OBJECTIVES

The goal of this proposed MIPS research project is to provide research and development support for the ASCS. With detailed performance information, HIE can move the practice to market, providing new business for HIE and an offering an additional agricultural BMP for addressing one of the most important issues in Chesapeake Bay water quality.

TECHNOLOGY DESCRIPTION

The technology is a series of basins constructed in a agricultural grassed swale. The basins are approximately 30 ft wide, 50 ft long and about 2-3 ft deep (Figure 1). As runoff from agricultural fields is directed into the swale, instead of simple conveyance, the basins provide for water storage. This storage can promote several mechanism of water and pollutant reduction in the system, including infiltration, evapotranspiration (ET), sedimentation, and denitrification. As a result, runoff is reduced and water quality is improved. Research on this system is necessary to

Figure 1. Photos of HIE agricultural runoff cascade treatment technology. Top: Filled basin. Middle: dry basin. Bottom: Existing outlet structure.

provide reliable performance information to allow the technology to be expanded to other agricultural areas.

Treatment Mechanisms

The ASCS consists of a series of 4 basins also a swale flow path. The basins collect, store, and possibly treat the stormwater runoff as it is concentrated from the field areas. The expected primary mechanism of operation is runoff reduction through storage, evapotranspiration (ET), and infiltration. By reducing runoff, not only are S, N, and P kept on the field site, but also erosive flows are kept from the nearby streams. Mechanisms for pollutant removal may also exist. Sediment can be removed via sedimentation. A large fraction of phosphorus is bound to sediment, so sediment reduction will result in P reduction. While minimal or no nitrogen removal is expected, possible zones of denitrification or vegetative uptake may exist which would reduce total N loads.

WORKPLAN

The study site will be instrumented to evaluate input and output water and pollutant loads. Other measurements and sampling will occur to support input/output data and to evaluate treatment mechanisms operating in the facility.

Instrumentation will include a commercially-available calibrated flume installed with an automated sampler at the input to the BMP. Flow depth in the flume will be measured and water quality samples will be taken at selected storm events using automated sampling equipment, such as the ISCO 6750 with bubble meter. Similarly, a wooden vee-notch weir will be installed at the outlet of the facility, also with a depth monitor and water sampling capability. Two water depths probes and 2 staff gages with cameras will be installed in the four basins. A redox probe and a temperature probe will be installed in the first basin and may be moved to other basins during the duration of the study to continuously characterize water conditions. A recording tipping bucket rain gauge will be installed with one of the samplers.

The target is to collect hydrologic (flow) data in as many storm events as possible. This will necessitate HIE assisting with instrumentation, ensuring that all is working correctly and that batteries are changed out and charged as necessary. A goal of at least 10 water quality measures is set, with more desired, as weather will permit. The site will be prepared for sample collection, collecting either a single flow-weighted composite or multiple discrete samples during specific times in a storm/runoff event. Input and output samples will be collected by HIE, stored in an iced cooler, to be picked up by UMD personnel as soon as possible. Water quality samples will be taken back to the environmental engineering laboratory at UMD for determination of pH, TSS (sediment), TP (total phosphorus), DP (dissolved phosphorus), SRP (soluble reactive phosphorus), TN (total nitrogen), Nitrate, and possibly others. In addition, approximately every 2 weeks, grab samples of water and sediment will be taken from basins in the ASCS that have standing water. The grab samples will be collected using clean bottles attached to an extension pole.

The grab water samples will be characterized via the same parameters as above. The collected sediment will be extracted to determine Total P (likely via a Melich III) and possibly a measure of TN. Other parameters to be measured include water depth in the basins, via probe or camera staff guage. Evapotranspiration will be estimated from the basins via standard equations, such as Blaney Criddle, which is very simple, yet can be relatively accurate.

All setups and measurements will follow strict QA/QC, including cleaning glass and plasticware, sample collection and preservation, certified analytical standards, analytical standards checks, and error analysis.

Data Handling

The total pollutant mass (M) present in each storm event will be calculated as:

$$M = \int_{0}^{T_d} QC\,dt \qquad (1)$$

where Q is the measured stormwater flowrate and C is the pollutant concentration for each sample during the event. T_d is the event duration. The interval between samples is dt. In cases where the concentration of a pollutant is below the laboratory analytical detection limit, a value equal to one-half of the detection limit will be used for calculation and statistical purposes.

The event mean concentration (EMC) is calculated similarly as:

$$EMC = \frac{\int_0^{T_d} CQdt}{\int_0^{T_d} Qdt} \qquad (2)$$

The EMC represents the concentration that would result if the entire storm event discharge were collected in a single container. EMC weights discrete concentrations with flow volumes; therefore it is generally used to compare pollutant concentrations among different events.

Annual pollutant loads (kg/ha/yr or lb/ac/yr) will be calculated by normalizing the input and discharge pollutant mass by the ratio of average total annual rainfall:rainfall measured during sampling, and dividing by the drainage area.

$$L = M\,(P_a/P)/A \qquad (3)$$

Performance efficiency for the ASCS will be evaluated based on percent pollutant mass removal efficiency, effluent pollutant concentrations, and probability exceedence distributions with appropriate water quality targets. Performance will be related to storm characteristics. Also, the distribution of storms studied (intensity, duration) will be compared to expected storm distributions for Maryland.

As appropriate progress reports will be filed describing progress to date on the project. At the end of this project a final report will be completed that will include Complete write up of methods, QA/QC, results, discussion of data that will include discussion of removal mechanisms and controlling design parameter that may affect performance, and suggested impact of results on the agricultural non-point source pollution of the Bay.

As more is learned and understood about the technology, it will also be evaluated for possible design modifications that can be implemented that may improve reduction of runoff volume, sediment, N and P through different treatment mechanisms or enhancing existing mechanisms.

Risk Factors

This proposed project does offer several very specific challenges. First, as with all stormwater research endeavors, the results will be dependent on capturing runoff from specific rainfall events. Adequate and relatively predictable rainfall is necessary to complete this project. The distance of the HIE site to College Park presents challenges that we think can be overcome through multiple visits to the site and through very close communication between the UMD research team and HIE. HIE can address site issues directly, communication about rainfall occurrence, and store and preserve water quality samples immediately after monitoring events.

Project Benefits

The net impact of this project will be quality performance information on a promising agricultural BMP. With this information, HIE can begin to market this technology in other areas of Maryland and the Chesapeake Bay watershed. If successful an additional tool will be available for improving water quality of the Bay and its tributaries.

About the Research Team

This work will directly support 1 MS student for 1 year. This student will have a BS degree in Civil/Environmental Engineering or closely related fields. This project will be part of his/her MS Thesis. Also, undergraduate students will be supported to assist in laboratory and sampling studies.

Allen P. Davis is an environmental engineer with experience in environmental and water chemistry. For over a decade, he has been investigating sources and treatment of pollutants in urban stormwater runoff with a focus on low impact practices, particularly bioretention. He is a registered professional engineer in Maryland.