Report for 2004NE77B: Low-Cost Flow Estimation for Storm Water Quality BMP Monitoring

Publications

- There are no reported publications resulting from this project.

Report Follows

Research

Problem and Research Objectives:

The Environmental Protection Agency (EPA) has implemented a strategy to help reduce pollutants in municipal watersheds. The strategy requires municipalities with populations of over 10,000 to monitor storm water runoff and to reduce concentrations of specific contaminants (e.g., fecal bacteria) over a 10-year period. In order to reduce pollution, communities will have to implement Best Management Practices (BMPs). In some cases, a variety of inexpensive BMPs may substantially reduce targeted contaminants.

Monitoring storm water for the contaminants in order to show compliance with the new EPA regulations will be expensive. The relative financial burden will likely be significantly greater for mid-sized municipalities that are isolated from large metropolitan areas because access to expertise is more limited, and the tax-base is smaller. These types of municipalities are more common in less-populated states like Nebraska, but all municipalities would benefit from a reduction in the cost of monitoring BMPs.

The two parameters that must be measured to assess the impact of a BMP are contaminant concentration and mass flow rate of water. Independent of flow rate measurements, contaminant concentration measurements are considerably less useful. The volume of water flowing from a site may be small relative to that from the entire watershed, and the relative impact of the contaminant at the watershed outlet may be insignificant even if the concentration of the contaminant at the monitoring site is high. Contaminant concentration also varies over the duration of a storm, with the highest concentration likely to occur near the onset of the storm. Thus, in order to get an effective assessment of the performance of a BMP, samples may need to be collected throughout the storm. To determine the effective mass loading of a contaminant for the entire storm, the chemical samples at a site must be composited or assessed according to flow. Therefore, flow rates (at least relative flow rates) must also be measured throughout the storm to find the average contaminant concentration.

The expense associated with BMP monitoring can be reduced by reducing the cost of storm water sampling or by reducing the cost of flow measurement. The objective of this research is to investigate methods of reducing flow measurement costs.

Conventional storm water monitoring stations that feature both automatic sampling and flow measurement can be very expensive (greater than $10,000 for site modification, equipment, and installation). Such stations are impractical for monitoring most BMP sites because many of the locations where BMPs are implemented are temporary. For example, samples may be collected downstream of construction sites in order to monitor the effectiveness of erosion control BMPs, but the locations of active construction change over time. Furthermore, within any given city, numerous sites will be required to evaluate the overall storm water quality. The large number of necessary monitoring sites limits the funds available for each individual site. There is a great need for low-cost methods that municipal public works staff members can use to collect BMP data from a wide range of sites in their communities.

The goal of this study is not to improve the accuracy of flow measurements, rather, it is to find a low-cost method of measuring flow with accuracy that is sufficient for compositing concentration measurements. Therefore, accuracies of the methods studied are an important result of the current research, but the most accurate method will not necessarily be the optimal method for any given BMP monitoring study.

Methodology:

The two most common methods of measuring discharge are to develop a rating curve (stage-discharge relation) for the site of interest (FHWA, 2000), and to measure the stage upstream of a control (e.g., unsubmerged weir). In order to develop a rating curve for a site, discharge and stage measurements must be taken during a storm or there must be another way to assess the relation between stage and discharge (e.g., normal depth measurements and Manning's equation). Control sections are valuable because upstream of a control there is only one discharge for each stage, and the stage-discharge relation is often known. Unfortunately, controls are not particularly common in typical streams, and installing a control can be costly. Thus, we are focusing on methods that do not require the existence of a control. However, weirs and other flow controls are being used to assess the accuracy of alternative flow measurement methods.

We have collected a substantial amount of flow depth information over a basin in southeast Lincoln. Precipitation information is also available for this basin, and will be later used to compare flow estimation using hydrological models with flow estimation from normal depth and control measurements.

It has been difficult to instrument real storms since much of our equipment cannot be autonomously deployed. Thus, we have begun running many of our flow measurement comparisons in the laboratory. This slight change in strategy allows us to better control our experiments, and at the same time affords us some protection for some of the more expensive equipment that we are using. The laboratory exercises involve the simultaneous measurement of depth, surface velocity, and velocity profiles in a culvert. A wide range of flow conditions are being simulated in two culverts: a rectangular culvert and a circular culvert. The simultaneous measurement of depth at six locations, velocity profiles at 1 or 2 locations, and surface velocity at 1 location will allow us to assess levels of accuracy for different measurement techniques. The flow rate is also being directly measured with a v-notch weir.

Less sophisticated (and thus less expensive) methods of measuring flow rate require the measurement of flow depth. While this may seem like a simple task, logging depth measurements usually requires the installation of a pressure transducer, and accurate pressure transducer data loggers typically cost $800 or more in weather sensitive applications. Furthermore, based on our experience, installations that reduce the potential for vandalism or theft may triple the cost. Thus, as part of this project, we are also trying to develop a less costly method of logging flow depth. Incidentally, the most costly part of a pressure transducer data logger is the transducer itself. Thus, if a good alternative for measuring the depth is found, logging the measurement may be relatively inexpensive.

Summary of Progress:

Principal Findings and Significance

This project was co-funded by the Nebraska Department of Environmental Quality. Although the funds allocated through the USGS 103B grant are expended, the project is not scheduled to be completed until December of 2006. There are three preliminary findings at this time:

1. Literature has been reviewed and thus far three primary methods of measuring flow rate have been found. These methods include: stage/discharge rating curves, depth and velocity profile measurements, and using flow controls. Specific instruments for gathering relevant data include stage loggers ($300 to $1200) and ultrasonic profilers (~$4000-$6000). Depth measurements are clearly far less expensive than velocity measurements.
2. Thus far, laboratory studies and theoretical analysis have shown that normal depth measurements may be suitable for discharge estimates, but in deep non-uniform flows rating curves are insufficient because the average velocity cannot be backed out of the depth measurement.
3. If two simultaneous depth measurements are available, a rating curve is also often insufficient. The primary advantage of taking two depth measurements along the length of a culvert is to be able to use the second measurement as a way of measuring energy slope. Since the energy slope is small when the depth is significantly higher than normal depth, the second depth measurement will not be of use in this case. However, a second depth measurement may be useful for verifying normal flow or for improving accuracy if depths approach normal depth. Our assumption is that there is no way to calibrate the flow measurement methods in situ.

Uncompleted Work:

During the final stage of the project, five things have yet to be completed:

1. Precipitation and depth measurements gathered in the field will be synthesized to assess the accuracy of estimating flow from these two parameters.
2. Laboratory measurements of depth, surface velocity, and velocity profiles for a wide variety of flows and two different culvert cross sections will be completed.
3. The accuracy of using various components of the collected depth and velocity information to estimate flow will be determined and compared, and the costs associated with relevant flow measurement techniques will be assessed.
4. Alternatives for flow measurement will be discussed with project managers to collect their opinions on what methods are practical.
5. A thesis/final report comparing the advantages and disadvantages of all of the flow measurement methods will be compiled.

Publications

None yet

Information Transfer Program

Plans are to disseminate the results of this study in two ways: First, we plan to present the results at the 2007 Hydraulic Measurements and Experimental Methods Conference or at the 2007 ASCE Environment and Water Resources Institute Conference, and second, we will submit the results of our research for publication in a journal article.

Student Support

One graduate student, Mr. Chad Cecrle, was funded for five months as a graduate research assistant by this project. Thus far, Mr. Cecrle has been doing laboratory tests to determine the accuracy of different flow measurement techniques. The research done by Mr. Cecrle will be the basis of his Master of Science thesis. Thus far, Mr. Cecrle has had to become familiar with a wide range of flow measurement techniques and has collected a great deal of data in the laboratory.

Notable Achievements

References

FHWA. (2000) Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring. FHWA-EP-00-002. U.S. Department of Transportation. Federal Highway Administration. Washington, D.C., May.