Center for TMDL and Watershed Studies

CENTER FOR TMDL AND WATERSHED STUDIES

At the Center

VOLUME 3 ISSUE 1 JANUARY 2007

INSIDE THIS ISSUE:

Incorporating Channel Degradation and Restoration into Watershed Models

The Center's breadth of expertise and scope of water quality related research and outreach expanded recently with the completion of a project that focused on improving the accuracy and efficiency of watershed-scale sediment modeling as it relates to stream channel restoration.

Sediment yield prediction is an important component in the development of watershed management strategies and Total Maximum Daily Load (TMDL) studies where sediment is identified as a stressor. Studies have shown that sediment from streambanks can account for as much as 85% of watershed sediment yields. Excessive channel degradation reduces water quality through increased turbidity and the transport of sediment-bound pollutants. According to the EPA, sediment is the fourth leading cause of water quality impairment nationwide. While considerable effort has been directed toward reducing erosion from agricultural and urban lands, a major source of sediment - stream bank erosion - has received little attention. In watersheds where stream bank erosion is an issue, the quantity of sediment contributed by stream bank erosion and the potential effects of stream restoration efforts on sediment yield need to be assessed to develop and implement accurate, effective TMDLs.

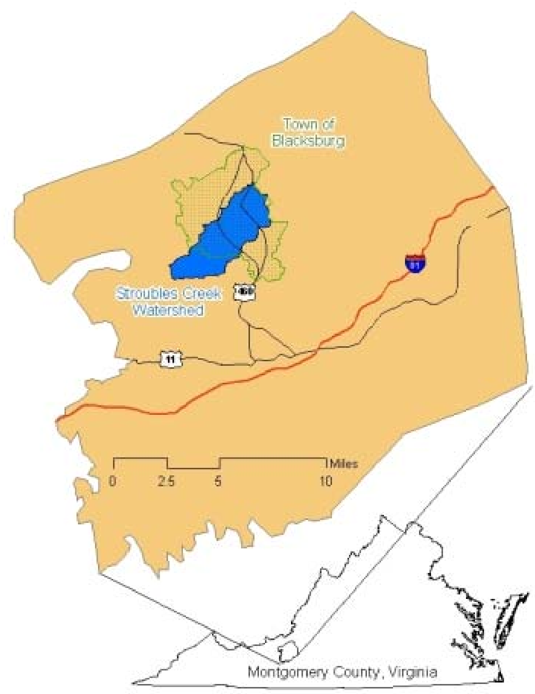

Figure 1: Location of Stroubles Creek Watershed

Watershed modeling software is essential in the development of TMDL studies. The software helps researchers simplify complex watershed systems and allows them to determine the sources of impairment and the reductions required to meet water quality standards. For TMDL studies where sediment is identified as the pollutant causing the water quality impairment,

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detailed process-based models are often avoided due to the extensive input data/parameterization requirements. The required data simply do not exist or collecting it is prohibitively expensive. Hydrologic models such as the Generalized Watershed Loading Function (GWLF), Soil and Water Assessment Tool (SWAT), and CONservation Channel Evolution and Pollutant Transport System (CONCEPTS), include channel degradation sub-models. The channel degradation routines used in these models vary from highly empirical to predominately process-based. Little research has been done to compare model predictions of stream bed and bank degradation to field measurements.

The goal of this cooperative Center/EPA project was to summarize existing models and software that evaluate sediment contributions to streams due to channel degradation from streambed scour and streambank retreat and provide guidance on selecting the most appropriate tool for sediment modeling analysis. The resulting model selection guidance document can be found on the Center's Stream Restoration page at http://www.tmdl.bse.vt.edu/uploads/File/pub_db_files/VTBSE_Channel_Modeling_Guidance_Document.pdf. In addition to describing various modeling tools, the Center conducted a case study to compare three sediment modeling packages of varying complexity (GWLF, SWAT, and CONCEPTS) with one another and field measurements of channel degradation.

The case study focused on the Stroubles Creek watershed, in the Town of Blacksburg, Virginia (figure 1). The objective of the study was to compare predicted sediment loadings from in-stream sources as predicted by GWLF, SWAT, and CONCEPTS. Model comparisons were also contrasted with channel degradation estimates derived from a system of erosion pins and scour chains. A TMDL was completed for this watershed in 2003 based on an aquatic life impairment which determined the impairment was caused by excess sediment. Urban land and residential areas cover 46% of the watershed, located mainly in the upstream portion of the watershed. Forested areas, which make up 28% of the watershed, are located mainly in the downstream reaches. The remaining 26% is agricultural land.

Stream bank erosion is a complex cyclic process involving erosion of the bank toe followed by geotechnical bank failure. Methods used to model bank erosion vary widely. The relatively simple watershed-scale, lumped-parameter GWLF model, calculates channel and bank erosion based on an empirical relationship that is a function of stream discharge, percent of developed land in the watershed, watershed animal density, area-weighted average curve number, area-weighted average K-factor from the USLE equation, and average watershed slope. Another commonly used watershed-scale model, SWAT, is more process-based and incorporates sediment transport capacity, the erodibility of the channel materials, and vegetative cover. Recently, the USDA Agricultural Research Service (ARS) developed a reach-scale model (CONCEPTS) that calculates toe scour, bank failure, and sediment transport to determine changes in stream form.

Project results indicated that there was no significant agreement found between the model predictions and the measured retreat, based on erosion pin measurements. In addition, sediment loading varied considerably between models. For more information on the project and case study or to download the final report visit the Center website (http://www.tmdl.bse.vt.edu/stream_restoration/).

Opequon Targeted Watershed Grant

A Chesapeake Bay Targeted Watersheds Grant "Effective Strategies for Reducing Nutrient Loads in the Opequon Creek Watershed" was recently awarded to faculty associated with the Center. The Opequon Creek watershed lies in Frederick and Clarke Counties, VA and Berkley and Jefferson Counties, WV. The Targeted Watershed Program will provide $1,000,000 in funds which is supplemented by another $350,400 through partners contributions. A broad-based partnership, including Virginia Tech, West Virginia University, the Frederick-Winchester Service Authority, as well as federal, state and local governments, community groups and business interests, will use proven and innovative best management practices to accelerate nutrient reduction in the Opequon Creek Watershed.

The Opequon faces a combination of agricultural and urban nonpoint source loads and a wastewater treatment plant that is in urgent need of expansion capacity. Best management practices to be implemented include: creating or enhancing ten wetlands – including floodplain and pocket wetlands; creating six water quality swales; and, installing 32,000 feet of stream fencing. The project expects to reduce annual nitrogen pollution to Opequon Creek by 108,000 pounds, and annual phosphorous pollution by 13,500 pounds. The project will result in a plan for the Frederick-Winchester Service Authority to obtain nutrient offset credits for wastewater treatment plan expansion. This project builds on existing Center efforts in the Opequon Creek watershed. In 2003 the Center completed 5 TMDL studies in the watershed and in 2006 the finalized the TMDL implementation plan for the watershed.

Modeling Workshop for TMDL Implementation Plans Development

In October, the Center held a 2 and ½ day workshop entitled "Modeling Workshop for TMDL Implementation Plan Development." The overall goal of the workshop was to provide personnel from Virginia's two state agencies responsible for the TMDL program (the Departments of Environmental Quality and Conservation and Recreation) with the necessary tools and instruction for implementation plan development. The workshop objectives were to provide TMDL Project Managers with the knowledge and skills:

1. to perform selected modeling tasks associated with developing TMDL Implementation Plans and

2. to more ably communicate with stakeholders about model-related matters.

Since many different private contractors are used to develop the TMDLs within the State of Virginia, detailed methodology can vary somewhat. Therefore, many of the TMDL managers needed a greater understanding of the TMDL development modeling process. The workshop included seven sessions. Five sessions focused specifically on water-quality modeling and included thirteen hands-on computer-based modeling exercises. The modeling sessions included evaluating data from DEQ for existing TMDLs, exploring GWLF and exploring HSPF. Some exercises that were part of the GWLF sessions included running the model, exploring model inputs and outputs, the reference watershed approach that uses a calculated area adjustment, and representing BMPs in GWLF. Exercises on the HSPF included running and debugging the model, setting up output files needed for implementation planning, and incorporating BMPs into the model to reach the TMDL target load.

Workshop participants work through one of the hands-on exercises with the help of Center personnel.

The remaining sessions focused on the implementation planning process and stakeholder involvement. This workshop material was generated based on the Center's experience in developing 3 TMDL implementation plans addressing 11 TMDLs. Our expertise and experience within the implementation planning process has evolved through each IP and those experiences were delivered throughout the workshop.

Workshop participants completed self-assessment evaluations for each session. Results showed that the participants' believed that their knowledge about each of the 5 model-related topics was significantly greater post-workshop than pre-workshop. Further, the participants believed the workshop "expanded [their] perspective of the roles and responsibilities of the various parties involved in developing a TMDL implementation plan". Lecture and modeling exercise resource materials developed for the workshop were assembled in a 366-page binder containing annotated PowerPoint presentations and exercises.

Recent Center Meetings and Presentations

Hall, K.M., B.L. Benham, K.M. Brannan and R.W. Zeckoski. Assessing Alternative Fecal Coliform Bacteria Direct Deposit Modeling Approaches. Presented at the 2006 Virginia Water Science and Technology Symposium, Virginia Tech, Blacksburg, VA.

Hall, K.M., R.W. Zeckoski, K.M. Brannan and B.L. Benham. Effect of FTABLE Generation Method on Instream Fecal Bacteria Concentrations Simulated Using HSPF. Presented at the 2006 Virginia Water Science and Technology Symposium, Virginia Tech, Blacksburg, VA.

Recent Center Publications

Kim, S.M., B.L. Benham, K.M. Brannan, R.W. Zeckoski, and J. Doherty. 2007. Comparison of Hydrologic Calibration of HSPF Using Automatic and Manual Methods. Water Resources Research. In Press.

Wagner, R., T. Dillaha, and G. Yagow. 2006. An Assessment of the Reference Watershed Approach for TMDLs with Biological Impairments. Water Air Soil Pollut. http://dx.doi.org/10.1007/s11270-006-9306-8. (published online December 2006, print release follows in two or three months)

Upcoming Conferences

Fourth Conference on Watershed Management to Meet Water Quality and TMDLs (Total Maximum Daily Load) Issues: Solutions and Impediments to Watershed Management and TMDLs. March 11-13, 2007. San Antonio, TX.

Presentations:

Assessing Alternative Fecal Coliform Direct Deposit Modeling Approaches. Hall, K.M., B.L. Benham, K.M. Brannan, and R.W. Zeckoski.

During dry weather, flow in low-order, upland streams is often minor and may stop completely. Under 'low-flow' conditions fecal bacteria directly deposited in the stream dominate in-stream bacteria loads. When developing a Total Maximum Daily Load (TMDL) to address a bacterial impairment in an upland, rural watershed, direct deposit (DD) sources (livestock and wildlife defecating directly in the stream) often drive the source-load reductions required to meet water quality criteria. Due to limitations in the application of existing watershed-scale water quality models, under low-flow conditions the models can predict unrealistically high in-stream fecal bacteria concentrations. These erroneously high simulated concentrations manifest in the TMDL in the form of bacteria source reductions that are much more severe than what may actually be needed to meet applicable water quality criteria. This study used Hydrological Simulation Program-FORTRAN (HSPF) to compare three low-flow direct deposit simulation methods; DD Stage Cut-off is a function of livestock behavior, while Flow Stagnation and Stream Reach Surface Area address DD through model representation. The study uses two Virginia watersheds where bacteria impairment TMDLs were previously developed and where evidence of low-flow conditions were encountered. A modified version of the Climate Generation (CLIGEN) program was used to stochastically generate climate inputs for multiple model simulations. Daily average in-stream fecal bacteria concentrations, predicted using each method, were compared to the Virginia single-sample water quality criteria for fecal coliform (400cfu/100mL). Violations of the fecal coliform criteria were used as the response variable. A factorial experimental design was used to represent different levels of source reductions for each DD method. The violation rates of each reduction level – DD method were compared using One-Way-ANOVA.

Comparison of HSPF Simulated In-Stream Fecal Bacteria Concentration Using FTABLEs Generated with Field Survey and Digital Data. Hall, K.M., R.W. Zeckoski, K.M. Brannan, and B.L. Benham

The Hydrological Simulation Program-FORTRAN (HSPF) describes discharge from a stream reach based on function tables (FTABLES) that relate stream stage, surface area, volume, and discharge. In this study, five FTABLE scenarios were compared to assess their effect on daily average in-stream fecal bacteria concentrations predicted using HSPF. Four "field-based" FTABLE scenarios were developed using detailed cross-section surveys collected at predefined intervals along 14 reaches in the study watershed. A fifth "digital-based" scenario was developed using digital elevation models (DEMs) and Natural Resource Conservation Service (NRCS) Regional Hydraulic Geometry Curves. The Kolmogorov-Smirnov two-sample test was used to compare daily average in-stream fecal bacteria concentrations simulated with HSPF using the five FTABLE scenarios. The daily average fecal bacteria concentrations produced by the five FTABLE scenarios were not statistically different ($p = 0.95$). While the FTABLE scenarios compared here did not produce statistically different fecal coliform concentrations, the daily average in-stream fecal bacteria concentrations simulated using the digital-based scenario were higher than those simulated using the field-based scenarios. When developing a bacterial impairment Total Maximum Daily Load (TMDL) in Virginia, simulated daily average in-stream fecal bacteria concentration can not exceed the single-sample water quality criterion (400 cfu/100ml). Thus, higher simulated concentrations will yield more water quality criteria violations. As a result, if a TMDL were developed using the digital-based FTABLE scenario it would require greater bacteria source load reductions than one developed using the field-based scenarios.

Implementation Planning – Lessons Learned from 3 Watersheds in Virginia. Yagow, G., B.L. Benham, M.L. Wolfe, C.D. Heatwole, and R.W. Zeckoski.

Although the Clean Water Act and subsequent TMDL rules stop short of requiring implementation of TMDL plans, implementation is clearly the implied intent of the legislation in order to achieve our water quality improvement goals. (Cont'd on next page.)

Upcoming Conferences Cont.

Some states, such as Virginia, have passed additional legislation that explicitly requires implementation within all watersheds where EPA-approved TMDLs have been developed. This past year, in compliance with Virginia's mandate, the authors have facilitated the development of implementation plans in three sets of TMDL watersheds in Virginia – Abrams/Opequon Creeks, Big Otter River, and Stroubles Creek. This paper details lessons learned throughout the public participation process and will draw parallels between our experience and EPA's draft "Handbook for Developing Watershed Plans to Restore and Protect our Waters". The lessons learned will include discussion on the use of focus groups, the importance of good facilitation, the use of existing watershed groups, using maps as a focusing tool, the need and the role of education for all planners and stakeholder participants, and considerations on moving from planning to implementation.

TMDL implementation plan development for a rapidly urbanizing watershed in Northern Virginia. Wolfe, M.L., B.L. Benham, F. Dukes, S. Morris, A.Collins, T. Borisova, and G. Yagow.
The Center for TMDL and Watershed Studies at Virginia Tech led development a TMDL Implementation Plan (IP) for the Opequon Creek watershed, which includes portions of Virginia's Clarke and Frederick counties and encompasses the City of Winchester. The IP addresses impairments on five stream segments in the watershed. Three segments have both benthic and bacteria impairments, while two segments have bacteria impairments. Urban and agricultural nonpoint sources are cited as causes of the impairments, with urban being the primary cause in a large portion of the watershed. TMDLs were developed previously for three segments. The other two segments were listed as impaired after the other TMDLs had been developed. One important feature of the IP development process was the intensive public participation process involving a Resource Team (comprised of personnel from three universities, two state agencies, and a local watershed group), a Steering Committee (representatives from local government, watershed groups, and watershed residents); and two Working Groups (urban and rural). Through facilitated sessions, the working groups identified potential corrective actions and the Steering Committee prioritized the actions with respect to likelihood of adoption of and other characteristics. These actions were then quantified using spatial data analysis and watershed modeling. The IP includes a date of expected achievement of water quality objectives; the types and quantities of necessary corrective measures; measurable goals; and the associated costs and benefits of addressing the impairments. While many of the potential benefits are difficult to quantify, through analyses of responses to a survey mailed to watershed residents, the value of two specific benefits, improved aquatic life (game fish population) and the safety of swimming and wading, resulting from improved water quality within the watershed was estimated to range from $2.0 to $2.75 million.

Water Quality and Economic Benefits of Livestock Exclusion from Streams: Experiences from Virginia. R.W. Zeckoski and B.L. Benham.
Producers across Virginia are voluntarily participating in stream exclusion practices that reduce the time livestock spend in streams. Evidence from the literature suggests that stream exclusion practices can be both environmentally and economically beneficial to the producer. Studies have shown that the health and productivity of livestock increase with stream exclusion. The goal of this project is to collect information from producers across Virginia who have implemented stream exclusion practices to determine what factors affect the decision to implement stream exclusion practices and what costs and benefits producers associate with stream exclusion. The project accomplished these goals through interviews with 19 producers from varied regions of Virginia. Through these interviews, we found that producers with stream exclusion practices commonly experienced an increase in cattle weight gain (beef operations) or milk production (dairy operations) and decrease in disease. Common factors positively influencing the decision to install a stream exclusion practice include information provided by local agency personnel, a desire to take advantage of off-stream waterers and interior fencing that could be installed as part of a stream exclusion cost-share project, and a concern for the environment. A major complaint of the producers was the noxious vegetative growth in the riparian area; they hypothesized this was a main reason that many producers did not participate in stream exclusion practices. Overall, the interviewed producers were happy with the systems they had implemented and recommended stream exclusion to their peers.
Workshops:

Modeling Strategies for Implementation Planning. Yagow, G., B.L. Benham, R.W. Zeckoski, and K.M. Brannan.

This full day workshop will provide participants with hands-on exercises and demonstrations of modeling strategies that can be used during development of implementation plans to achieve load reduction TMDL goals. This workshop will provide participants with: an overview of the Implementation Planning (IP) process, assessing IP data needs from a developed TMDL, accounting for spatial and temporal data differences, planning for BMP implementation, cost benefit analyses, and milestones and other measures of progress. Workshop participants will maximize their workshop experience if they bring along a laptop loaded with ArcGIS and Microsoft Excel, though laptops are not required, as procedures will be demonstrated with a computer projector and participants will be supplied with workshop notes and spreadsheet files with demonstrated examples.

(Cont'd on next page)

Upcoming Conferences Cont.

Using the Bacteria Source Load Calculator (BSLC) for TMDL Development. R.W. Zeckoski.

The Center will offer a half-day hands-on computer workshop on the use and application of the Bacteria Source Load Calculator (BSLC) at the ASABE TMDL conference in March. The BSLC is an open-source software product developed by Center personnel and available on our website at: http://www.tmdl.bse.vt.edu/bslc/. It is designed to take simple inputs of animal and land use information and produce formatted input files for use in the Hydrological Simulation Program - FORTRAN (HSPF). Attendees will learn to conduct pre-processing tasks needed to quantify fecal bacteria sources prior to input to the BSLC; use the BSLC to create input files for HSPF; and analyze BSLC output and assess implications for TMDL studies.

Update on Current TMDLs

Lick Creek: The first public meeting for the Lick Creek bacteria and aquatic life (VA general standard) TMDLs took place on November 28, 2006 in Dante, VA. Because Lick Creek does not have a continuous hydrology gage, HSPF model parameters were calibrated for the nearby Crane's Nest River. That hydrology calibration was successfully completed at the end of October. The calibrated parameters were transferred to the Lick Creek HSPF model and were confirmed using the limited hydrology data available in Lick Creek. Between the TAC meeting in September and the first public meeting in November we worked on our population estimates for the watershed. We are currently working on the water quality calibration of the HSPF model for Lick Creek. The aquatic life impairment continues to progress with sediment and organic matter identified as the primary stressors.

Hardware River: The first public meeting for the Hardware River Bacteria TMDL was held on November 30, 2006 at the Scottsville Municipal Offices. There were over 20 people in attendance. Information pertaining to the impairment and the TMDL process was presented by Robert Brent from VADEQ. The next public meeting will be held sometime in February-March 2007. Currently, we are looking for input from watershed stakeholders about animal populations and landuse changes Calibration of the model is nearing completion and allocations model runs will begin shortly.

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The Center's mission is to conduct interdisciplinary research, teaching, and outreach to improve the integrity of the Nation's waters and watersheds by advancing the science, tools, and expertise available for developing, evaluating, and implementing watershed planning and management processes.