FALL 2010

WATERSHED SCIENCE BULLETIN

AWSPs
Association of Watershed & Stormwater Professionals

Journal of the Association of Watershed & Stormwater Professionals

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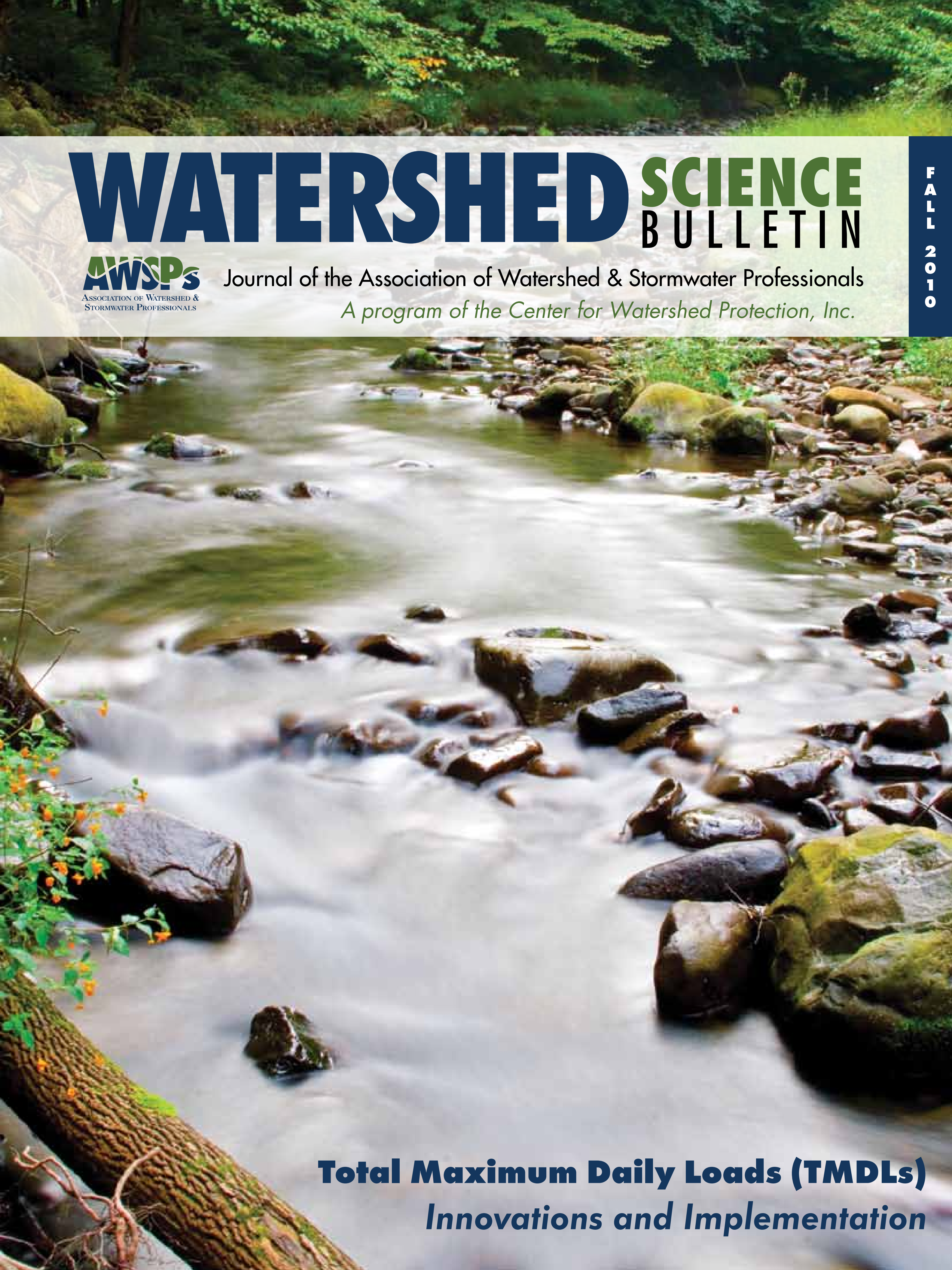

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Innovations and Implementation

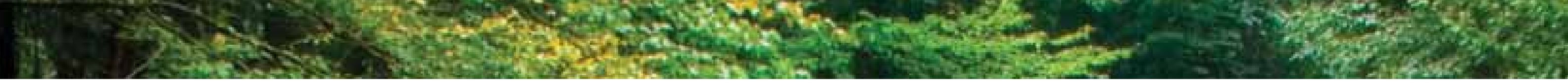

TABLE OF CONTENTS

FEATUREDCONTENT

Exploring Alternatives to Pollutant-Based TMDLs

Responding to the First Impervious Cover–based TMDL in the Nation /**11**
Chester L. Arnold, Christopher Bellucci, Kelly Collins, and Rich Claytor

TMDLs: Improving Stakeholder Acceptance with Science-based Allocations /**19**
Jason A. Hubbart, John Holmes, and Georganne Bowman

Integrating TMDLs and MS4 Permits

Collaboration, Clean Water Act Residual Designation Authority, and Collective Permitting: A Case Study of Long Creek /**25**
Dave Owen, Curtis Bohlen, Peter Glaser, Zach Henderson, and Christopher Kilian

Tracking Watershed Restoration in Montgomery County, Maryland /**35**
Nick L. Lindow, Steven P. Shofar, and Meosotis C. Curtis

Adaptive Implementation of TMDLs

Adaptive Management and Effective Implementation of Sediment TMDLs in the Lake Tahoe Basin, USA /**42**
Mark E. Grismer, Kevin M. Drake, and Michael P. Hogan

Center for Watershed Protection Feature

Monroe County, New York, Field Tests the Watershed Treatment Model 2010 Beta Edition /**49**
Paula Smith, Andy Sansone, and Deb Caraco

Vignettes

Reducing DDT and Sediment Loads in the Yakima River: A Success Story /**55**
Thermal Load Trading in the Tualatin River Basin: A Watershed-based NPDES Permit /**56**
Optimizing Resources To Achieve Pollutant Reductions in Wisconsin /**57**
Lake Clarity Crediting Program for Lake Tahoe: An Adaptive Management Approach for Water Quality Credits /**59**

BULLETINDEPARTMENTS

Bulletin Board
From the Editor's Desk /**5**
Overview: The ABCs of TMDLs /**7**

Ask the Experts
Xavier Swamikannu, retired, chief of the Stormwater Permitting Program for the Los Angeles Regional Water Board /**61**
Rick Parrish, senior attorney, Southern Environmental Law Center /**63**
Michael Bateman, deputy bureau chief, Resource Regulation, Northwest Florida Water Management District /**65**

Watershed Spotlight
AWSPs Photolog Contest Winner /**34**
Nominate a "Watershed Superstar" /**66**

Latest News from AWSPs
Membership Information /**67**
Next Issue /**67**
Upcoming Events /**67**
Sponsorship /**67**

Book Review
Up River: A Novel of Attempted Restoration by George Ivey /**33**

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8390 Main St. 2nd Floor • Ellicott City, MD 21043 • 410-461-8323 (phone)
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Watershed Science Bulletin (ISSN: 2156-8545) is the journal of the Association of Watershed and Stormwater Professionals (AWSPs), and is published semi-annually by the Center for Watershed Protection, Inc. (CWP).

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MISSION: The mission of the *Watershed Science Bulletin* (the *Bulletin*) is to synthesize research and experience from the numerous disciplines that inform watershed management and transmit this valuable information to researchers, regulators, practitioners, managers, and others working to protect and restore watersheds everywhere.

POSTMASTER: Please send address changes to the Watershed Science Bulletin address listed above.

SUBSCRIPTIONS AND BACK ISSUES: Subscription is included for AWSPs members as part of member dues. The subscription rate for non-members is $89/year. Single copies and back issues can be purchased for $49 each. For a complete listing of back issues or to purchase a subscription, please visit www.awsps.org.

SUBMISSION: To submit an article, please visit www.awsps.org.

Graphic Design by Down to Earth Design, LLC (d2edesign.com)

Copyediting by Elizabeth Stallman Brown

Printed by the YGS Group, York, PA.

Cover photo courtesy of Bryan Seipp (www.btseippphotography.com), Watershed Manager, Center for Watershed Protection

This photo was taken along Pocono Creek in Monroe County, PA, near Camelback Mountain. Like many streams in Pennsylvania, it is dominated by a forested watershed and provides critical habitat for trout populations. Some tributaries in the Pocono Creek watershed qualify for the highest level of water quality protection under Pennsylvania regulations. Population growth and the resulting urbanization and hydrologic changes are a threat to the health of the watershed.

Tracking Watershed Restoration in Montgomery County, Maryland

Nick L. Lindow,[a] Steven P. Shofar,[b] and Meosotis C. Curtis[c]*

Abstract

To track its ongoing effort to treat impervious cover and reduce pollutants in its surface waterways, the Montgomery County (Maryland) Department of Environmental Protection (MCDEP) applied the Watershed Treatment Model (WTM) to inventory the baseline status and forecast the results of watershed restoration practice implementation. The countywide watershed restoration modeling effort required consistency across the complicated regulatory environment in Montgomery County and a flexible countywide pollutant load estimation and progress tracking tool. The model used event mean concentration and discretized urban land use from geographic information system data to track total maximum daily loads (TMDLs), which included those for nutrients, sediment, bacteria, and trash, depending on the watershed. The modeling assumptions for Montgomery County's watershed restoration implementation plan were consistent with the Chesapeake Bay Program and with state and federal regulations for pollutant loading and removal estimates. The WTM proved to be an accurate modeling framework that estimated the baseline bacterial loading to Rock Creek within 10% of the measured load for the TMDL. Meeting bacterial loading limits set forth in the Rock Creek TMDL proved to be a challenging task, despite the focus in the restoration plan on implementing state-of-the-art structural stormwater management practices to all suitable public and private areas in the watershed. Results of the initial analysis illustrated that a pet waste education program could provide cost-effective pollutant removal and better targeting than structural stormwater management and land conversion practices.

Introduction

Montgomery County, Maryland, covers approximately 1,295 km^2 (500 mi^2) in central Maryland and has a population of 940,000 people; in terms of the average number of people per square kilometer, Montgomery County is second only to Baltimore City within Maryland. Overall, the county has 12% impervious cover and drains to the Potomac and Patuxent Rivers, which drain to the Chesapeake Bay.

The county's location in Maryland and in the Chesapeake Bay watershed places it in a unique situation vis-à-vis a number of recent policy and programmatic changes in Maryland: the state permitting authority (Maryland Department of the Environment [MDE]) has issued new 2010 stormwater regulations requiring environmental site design (ESD), the governor has established a Bay restoration program with two-year and 2020 milestones, and the federal government has issued an executive order to improve the Bay's water quality under the authority of the US Environmental Protection Agency (USEPA). In addition, as of June 2010, USEPA had approved ten total maximum daily load (TMDL) limits in the county, in seven different water bodies, regulating sediment, nutrients, and bacteria. TMDLs for additional water bodies and pollutants are planned for approval in the future, including a Chesapeake Bay TMDL, which will include a wasteload allocation (WLA) for nutrients and sediment in the Potomac and Patuxent Rivers and will cover the entire county. MDE is also currently in the final public commenting phase of a trash TMDL for the Anacostia River.

MDE issued the county's current National Pollutant Discharge Elimination System (NPDES) municipal separate storm sewer system (MS4) stormwater permit on February 16, 2010—the first of its kind in Maryland to require the use of ESD and low-impact development (LID) to capture stormwater. These changes were made in conjunction with the improvement of the county's stormwater management regulations and modification of the county's planning and zoning codes. The permit includes the following major new components:

- Watershed restoration
- TMDLs
- Trash and litter
- Pollutant reduction estimating and tracking

In this article, we describe efforts by the MCDEP to accomplish these four permit goals by developing a countywide watershed restoration implementation plan. We also present some challenges and lessons learned from this process.

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Working within the Regulatory Framework

The countywide watershed restoration modeling effort required consistency across the complicated regulatory environment in Montgomery County as well as a flexible countywide pollutant load estimation and progress tracking tool. The permit requires MCDEP to provide an estimating and accounting framework, which (a) should include information on the types of stormwater management practices implemented, pollutant reduction tracking conducted, and total area treated to the maximum extent practicable (MEP) and (b) can be used to estimate pollutant reductions from varying scenarios of watershed restoration implementation. A system that provides for geographically referenced calculation and accounting was necessary for proper accounting and estimating since field verification was not possible. MCDEP used the Watershed Treatment Model (WTM; Caraco 2001) to develop an innovative tracking and accounting tool, incorporating pollutant load, structural stormwater management, and municipal programmatic practice modeling within a single framework. The WTM is a spreadsheet modeling approach using output from a geographic information system (GIS) for land use and stormwater BMPs. In addition, the WTM is able to explicitly model the volume reduction benefits of ESD practices.

The countywide watershed restoration modeling effort required consistency across the complicated regulatory environment in Montgomery County as well as a flexible countywide pollutant load estimation and progress tracking tool

The current stormwater permit requires the implementation, over the next five years, of restoration on 20% of the impervious surfaces not currently controlled to the MEP, in addition to the 10% restoration requirement from the previous permit cycle. This goal requires runoff control for an additional 16.6 km^2 (6.4 mi^2) of impervious surface countywide. The MEP definition includes structural best management practices (BMPs), nonstructural BMPs, programmatic practices, and stream restoration projects. The structural restoration program includes BMPs for ESD and LID—a decentralized, distributed stormwater management approach. The county's stormwater permit also requires the implementation of projects to make progress toward achieving the WLAs of the TMDL.

The last major piece of the stormwater permit includes a requirement to complete a trash and litter reduction strategy as set forth in the Trash Free Potomac Watershed Initiative 2006 Action Agreement. The agreement, signed by 105 elected officials, pledges their commitment to a trash-free Potomac by 2013 and their agreement to (a) work with regional leaders, businesses, government agencies, nonprofits, and communities to implement strategies aimed at reducing trash and increasing recycling; (b) increase education and awareness of the trash issue; and (c) reconvene annually to discuss and evaluate measures and actions addressing trash reduction. In addition, regulatory limits on trash are being developed by MDE for the Anacostia River. For the Anacostia watershed, MCDEP is working to establish a trash pollution baseline, implement a trash abatement program, expand education to citizens, and monitor trash loading to the Potomac.

We present two case studies below describing MCDEP's effort to develop a coordinated implementation plan and track progress using the WTM. These include a summary, issues, and lessons learned from tracking implementation and from targeting practices to meet bacterial loading limits.

Tracking Implementation Case Study

MCDEP staff applied the WTM (v3.1) to inventory the baseline status and forecast the pollutant load reductions associated with implementing the watershed restoration plan. MCDEP staff initially tested the WTM in the Rock Creek watershed, using event mean concentration (EMC) and discretized urban land use from GIS data to track the baseline stormwater pollutant load. An EMC is a method for characterizing pollutant concentrations in receiving water from a runoff event. The value is determined by compositing (in proportion to flow rate) a set of samples, taken at various points in time during a runoff event, into a single sample for analysis (Natural Resources Defense Council 1999). The project team estimated the existing level of stormwater management within the model by categorizing BMPs from the county's current inventory of urban BMPs according to their historic performance criteria, a national comparative review of pollutant removal and runoff reduction performance criteria (Center for Watershed Protection [CWP] 2007; CWP and Chesapeake Stormwater Network 2008), and performance studies on individual practices (Schueler, 1998a; and Schueler, 1998b). MCDEP staff then used the WTM to test a suite of future ESD practices on suitable public and private properties within the county and predicted the resulting reduction in nutrient, sediment, bacterial, and trash loads.

Our modeling approach used land use categories as the primary source to estimate pollutant loads of total nitrogen (TN), total phosphorus (TP), total suspended sediment (TSS), fecal coliforms (FC), and trash in stormwater runoff. The land use–based EMCs are well documented for TN and TP. However, the method is more difficult for FC, because of the lack of data, and for TSS, because of the differences in land-based sediment load, instream loads, and delivery factors. For bacteria, the baseline load and WLA in the TMDLs are from direct instream measurements, and are not based on land use distribution. Bacterial loads are typically from dispersed, mobile sources such as sanitary sewer overflows (SSOs), failed septic systems, wildlife, domestic pet waste, and livestock. However, the model produced acceptable results for Rock Creek, within 10% of the MDE baseline load. The EMCs used in the WTM were based on the National Stormwater Quality Database (Pitt 2008). And importantly, for the purposes of the TMDL, human and livestock sources were allocated to the nonpoint source load, which is not included in the county MS4 WLA.

We used the WTM to calculate reductions in pollutant loading from planned BMPs. Any BMPs approved prior to the data collection period for the TMDL were applied to the watershed to calculate a baseline load and were compared to the TMDL baseline load. BMPs approved after the TMDL data collection period, as well as any planned stormwater ponds and LID retrofits from the Capital Improvement Project (CIP) inventory, were applied to the model to track pollutant load reductions toward meeting the WLA. MDE has tentatively approved this method as an acceptable procedure. In addition, we used the model to test scenarios of pollutant load reductions beyond the planned CIP inventory, including reductions from retrofits of other public sites, nonstructural BMPs, and programmatic practices. We compared the results to the required reductions needed to meet the WLA of the TMDL.

The strategy required very detailed GIS data, including BMP types and locations with individual drainage areas delineated and impervious cover captured. Many drainage areas included multiple BMPs, requiring the project team to attach unique identifiers—called *sequence numbers*—to individual BMPs to appropriately assign pollutant removal and effectively automate the procedure to create reproducible results. We grouped the BMPs into five categories:

ESD practices: BMPs that maximize runoff reduction and pollutant mass reduction, such as bioretention, dry swales, working infiltration, and vegetated swales.

Effective practices: BMPs with limited runoff reduction capabilities but moderate to high pollutant removal, and which tend to have large drainage areas. Examples include wet ponds, extended detention, wetlands, sand filters, and infiltration practices.

Underperforming practices: BMPs with moderate to large drainage areas, no runoff reduction, and low to moderate pollutant removal capability. These BMPs have high retrofit potential and include infiltration basins and dry ponds with quality control.

Nonperforming BMPs: Practices that provide detention and peak discharge control but marginal pollutant or runoff volume reduction. These practices, which include dry detention ponds and underground detention, are ideal candidates for retrofits.

Pretreatment practices: This class of BMPs includes flow splitters, oil-grit separators, and plunge pools, which were never intended to provide significant pollutant removal or volume reduction and were, instead, designed to protect the function of a downstream practice. However, in certain situations, MCDEP staff installed these BMPs as standalone practices and provides intensive maintenance for them; thus, they provide limited pollutant removal and volume reduction.

These categories were developed to calculate treatment efficiencies across the watershed and to track retrofit opportunities (Table 1). Tracking retrofits also required using sequence numbers so that when a BMP was targeted for retrofit, the drainage area treated and pollutant removal efficiency could be incrementally increased and not double-counted.

Table 1. Pollutant removal efficiencies used in developing the implementation plan.

Performance Category	RR (%)	Discount Factor	TSS (%)	TN (%)	TP (%)	FC (%)
Pretreatment BMPs	5	0.15	20	5	5	10
Nonperforming BMPs	0	0.05	5	0	0	0
Underperforming BMPs	5	0.15	20	5	5	10
Effective BMPs	10	0.75	80	40	50	65
ESD Practices	60	1.0	90	65	65	75

Notes: Discount factor, fraction of contributing impervious acres effectively treated to the water quality volume, used to rate BMP treatability; FC, fecal coliform removal rate; RR, percentage annual reduction in post-development runoff volume for storms; TN, total nitrogen removal rate; TP, total phosphorus removal rate; TSS, sediment removal rate. Source: Schueler 2010, Appendix B.

We used the WTM to track pollutant load reductions due to BMP implementation from urban land. This assumption follows the protocol proposed by the typical TMDL, which uses urban land (residential and commercial areas) to allocate loading to the county MS4. To properly allocate loading between jurisdictions, the team excluded loading from other MS4 permitting entities, state and federal properties, Maryland–National Capital Park and Planning Commission property, and rural areas. However, the Maryland Department of Planning 2002 GIS data used in the model included some rural and forested areas within the county's MS4 area. These nonurban areas have an associated pollutant loading from wildlife sources, but the WTM only applies load reductions from stormwater BMPs to urban land use categories. For Rock Creek, the WTM predicted a bacterial load associated with forest and rural areas (wildlife sources) that was actually slightly higher than the WLA. Because it includes some of the wildlife sources, the WLA could not be met even if the entire urban area were treated to the MEP. This result was consistent with MDE's analysis of the MEP for the TMDL. Since the bacterial load attributed to wildlife in Rock Creek was a significant component, the reductions may be beyond practical limits (MDE 2007).

Each TMDL, whether the targeted pollutant is nutrients, sediment, bacteria, or trash, requires unique considerations. To target the pollutant of concern and properly track progress, the WTM allows the incorporation of programmatic restoration techniques such as pet waste education, SSO repair, septic system education, and cooperative riparian reforestation. The modeling assumptions are highly reliant on various subjective factors, including an *awareness of message* factor and a *participation* factor, but the model provides default values based on extensive survey data. For the purposes of tracking the pollutant load reductions associated with pet waste education, we assumed 80% awareness and 90% participation to calculate the source load eliminated by an applicable program. These are high percentages based on the default WTM values for education campaigns, but MCDEP is assuming an aggressive homeowner targeting strategy and enforcement policy.

Targeting Strategy: Bacteria Case Study

The strategy employed by the individual watershed implementation plans was intended to match the practices with the combination of watershed restoration and TMDL goals. Because of competition for county resources, the project team had to prioritize restoration efforts to allow for the allocation of staff and resources. The county budget had to be balanced across watersheds to properly meet competing TMDL, watershed restoration, and trash goals. For the Rock Creek bacteria TMDL, targeting programmatic practices such as pet waste education were far more cost-effective in reducing bacteria than new ESD retrofits or riparian reforestation.

Stormwater management in general only targets overland flow sources of bacteria, such as domestic pets and wildlife. MDE determined that the bacterial loading to Rock Creek was derived from a distribution of sources, including domestic animals, human waste, livestock, and wildlife, based on bacterial source tracking. The distribution of bacterial sources depended on location and flow, with the highest contribution of bacterial loading generally coming from wildlife, followed by livestock, domestic animals, and human sources. MDE allocated human, livestock, and a portion of the wildlife loads to the load allocation (LA), or nonpoint source loads within the watershed; therefore, this portion is not attributed to the county MS4 load. Results from WTM modeling showed only a moderate reduction in bacterial loading using structural stormwater BMPs, including ESD and LID practices and retrofits. In general, the maximum percentage of bacterial removal attributable to ESD practices is 75%, which will not achieve the 96% reduction required by the TMDL. Even riparian reforestation—which helps buffer streams from overland flow, removes potential source areas, and reduces runoff volume—only marginally reduces bacterial loading. A much more suitable approach was to target programmatic practices, including pet waste education.

Issues and Lessons Learned

Comparing the county GIS data with the TMDL results involved balancing the differences in baseline year for land cover and BMPs. MDE used land use data from different years to develop the various county TMDLs. The data sources differed in land use categories, and it was difficult to calibrate the model to a baseline LA and determine when to set the cut-off year for BMP approval. In addition, all of the individual watershed plans had to fit into the larger countywide implementation plan, which is why we aimed for a single land use data set.

To be compatible with the larger Chesapeake Bay TMDL in development, the BMP types and percentage removal efficiencies had to be compatible with the MDE assumptions for tracking purposes. We used the best science and literature values for setting BMP efficiency according to practice type. However, the Chesapeake Bay Program has developed a Chesapeake Bay Watershed Model, which is used to estimate the delivery of nutrients and sediments to the Bay and set tributary allocation caps. The Bay model uses BMP installation date to set the efficiency, with no pollutant removal credit for BMPs constructed prior to 1986 (before full implementation of the Maryland Stormwater law of 1984), an increased removal credit for BMPs constructed between 1986 and 2002, and the highest pollutant removal credit for BMPs constructed after 2002 (after the more stringent 2000 *Maryland Stormwater Design Manual* went into effect; see Table 2). The Bay model currently does not give credit for bacterial removal, give recommendations for treatability factors, or provide removal credit for ESD practices. It was for these reasons and the greater definition of removal efficiencies by BMP type that the categorization strategy in Table 1 was adopted for the county implementation plan. However, it was important that our strategy remain consistent within the larger Chesapeake Bay context.

Table 2. The Chesapeake Bay Program's Chesapeake Bay Watershed Model stormwater management efficiency, by era.

Development Era	Description	TSS (%)	TN (%)	TP (%)
Prior to 1986	No stormwater regulations	0	0	0
1986–2002	1984 Maryland Stormwater Management Act	50	20	30
2002–2010	2000 Maryland Stormwater Design Manual	80	30	40
Post-2010	ESD to the MEP required	TBD	TBD	TBD
Retrofits	Retrofits of pre-2002 BMPs	65	25	35

Notes: TBD, to be determined; TN, total nitrogen removal rate; TP, total phosphorus removal rate; TSS, sediment removal rate.

Before pollutant reduction estimates can be made, an accurate baseline condition for the watersheds must be set using a method compatible with federal guidelines. The *simple method* provides a simple way to calculate runoff and pollutant loads based on impervious cover, rainfall, and EMC data for various water quality parameters. The assumptions for EMCs used in the WTM's land use–based loading model tracked well with the Anacostia River model of the US Army Corps of Engineers (ACOE) and the county's NPDES sampling results model for TN and TP. The EMCs by land use are well documented by Pitt (2008). Table 3 shows the comparison among EMCs. We have found some difficulty justifying suitable EMCs for TSS because of the differences in upland-based sediment load, instream loads, and delivery factors. Current research-based EMCs yielded a baseline sediment load of roughly 50% of the total sediment load modeled by the TMDLs. We attributed this to the additional instream sources of sediment from stream bank erosion, which are not picked up by a primary source, land use–based model. The difference in a watershed's *wash load*, which is primarily from the upland areas, is significantly different from suspended loads and bed loads, which are hydraulically controlled and difficult to model in a land use–based approach. Literature values of land use–based sediment EMCs are roughly 50% of those in the ACOE Anacostia model and NPDES samples.

Table 3. EMCs used in the WTM compared to ICPRB 2007 Anacostia model (Montgomery County and Prince George's County data) and Montgomery County NPDES stormwater sampling.

Land Use Designation	TN (mg/L)	TP (mg/L)	TSS (mg/L)	Source
Residential	2.3	0.35	139	ICPRB, 2007
	1.9	0.24	116.94	MCDEP, 2006
	2	0.3	59	WTM; Pitt 2008
Commercial	3.5	0.2	132	ICPRB, 2007
	3.64	0.17	55.35	MCDEP, 2006
	2.2	0.22	55	WTM; Pitt 2008
Industrial	2.1	0.24	218	ICPRB, 2007
	2.21	0.21	256.63	MCDEP, 2006
	2.1	0.26	73	WTM; Pitt 2008
Municipal	1.3	0.11	125	MC in-stream Anacostia
	—	—	—	MCDEP, 2006
	1.8	0.22	18	WTM; Pitt 2008

Notes: Highlighted rows were used in the WTM modeling effort; MC: Montgomery County, MD.

An important lesson learned came from the overall targeting strategy, the need to balance budgets across watersheds, and the ability of CIP projects versus programmatic practices to reduce specific pollutants for the TMDL. From a cost perspective, structural stormwater practices are not the most cost-effective strategies for meeting a bacteria TMDL requirement. The average ESD practice has approximately 75% bacterial removal efficiency. Thus, even extensive ESD implementation would not provide adequate treatment to meet the strict 96% removal requirement of the Rock Creek TMDL. Rather, the programmatic practices are more cost-effective and result in greater bacterial removal. For instance, Table 4 illustrates results from Rock Creek bacterial modeling on how programmatic practices, such as pet waste education, were more cost-effective in reducing bacteria than new ESD retrofits. We assumed various costs for structural BMPs based on specific county data on previously installed practices. These may become cheaper in the future, given designer and contractor familiarity with the newer ESD practices. We assumed that riparian reforestation would cost $20,000 per acre planted. We estimated the pet waste education program at $15 per household and assumed that the program would target every household in the county. A similar trend is expected for trash TMDLs: the implementation of ESD retrofits will not yield the necessary reduction in trash to meet TMDL goals. The current county budget includes about $5.7 million for a countywide recycling program, household hazardous waste program, illegal dumping prevention and enforcement, right-of-way clean up, and the volunteer programs for Adopt-A-Road and storm drain marking.

Table 4. Comparison of the cost-efficiency of structural stormwater BMPs, riparian reforestation, and pet waste education in bacteria removal.

Restoration Strategy	Restoration Target	Bacteria Removal (billion MPN/yr)	Cost (million $)	Efficiency (billion MPN /million $)
Structural BMPs	3,265 Acres IC	131,262	$211	622
Riparian Reforestation	358 Acres	5,700	$7.2	796
Pet Waste Education	78,909	53,603	$1.2	45,286

Notes: Bacteria removal from WTM analysis. IC: impervious cover; MPN: Most Probable Number

The final lesson learned was the importance of flexibility. The base version of the WTM does not have an extension for calculated trash pollutant loading and reduction strategies. However, the model is an open source spreadsheet, and we adjusted it to accommodate trash. A similar land use–based load calculation was performed using trash loading rates from the draft Anacostia River trash TMDL in development, which is expected to be released in 2010. The TMDL includes a detailed approach to calculate trash sources and loading rates from different land uses, so the methodology fit well within the framework of the WTM. A spreadsheet-based modeling approach, rather than more complicated proprietary or closed-source programs, was an important component to adjust to the changing fields of TMDLs being developed.

Conclusion

The county's location in Maryland and in the Chesapeake Bay watershed places it in a unique situation in that the state, the federal government, and various regional government entities all have different, and sometimes conflicting, goals and guidance. Any restoration strategy must remain balanced within the regulatory framework and larger watershed goals. The modeling assumptions for Montgomery County's watershed restoration implementation plan were consistent with the Chesapeake Bay Program, MDE, and USEPA for pollutant loading and removal estimates. The next steps are to create a strategy and timeline for implementation that meets the goals of both the MS4 permit and the Chesapeake Bay TMDL. Developing a countywide pollutant load accounting and tracking model is a data-intensive endeavor. However, the WTM has a robust modeling framework that provided accurate results (with 10% of the measured bacterial load for Rock Creek) and a simple data entry interface for rapid testing of complex restoration scenarios. The open-source spreadsheet format also permitted flexibility in the model, allowing us to add a trash loading component to the base version of the model.

Bacteria are a difficult pollutant to track and effectively remove to meet water quality standards, and domestic pet and wildlife sources are dispersed and mobile within the watershed. We explored how to target bacteria in the watershed and the bacterial removal efficiencies of the practices tested. For bacteria TMDLs, programmatic practices such as pet waste education and enforcement may be the most cost-effective treatment methods. Since the bacterial load attributed to wildlife is often a significant component, the required reductions to achieve water quality standards may be beyond practical limits.

Acknowledgments

The authors are grateful for the hard work of the Montgomery County Department of Environmental Protection, Biohabitats, Chesapeake Stormwater Network, Horsley-Witten, and Versar staff in developing the technical guidance for the work described herein.

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