A FRAMEWORK FOR POLLUTANT TRADING DURING THE TMDL ALLOCATION PHASE

A. Z. Zaidi[1], S. M. deMonsabert[2], R. El-Farhan[3], and S. Choudhury[4]

ABSTRACT

The Environmental Protection Agency (EPA) encourages pollutant trading programs that help achieve Total Maximum Daily Load (TMDL) implementation goals. Such trades need to be consistent with water quality standards. For an approved TMDL, EPA recommends that the point and/or nonpoint source waste load allocations be used as the baseline for trading credits. The complexity inherent in modeling the effects of pollutants on receiving bodies makes it difficult to understand the implications associated with trading pollutant loads from different sources. The reduction of one credit from one source does not equal the reduction of one credit at another location in the watershed. Similarly, unit costs for load reductions vary considerably depending on the control strategy and the level of reduction. Though trading ratios may account for some uncertainties associated with estimates of nonpoint source loads and long-term performance of the control measures, the selection of an effective trading ratio is not very straightforward and does not fully address the environmental impacts. Although higher trading ratios may be used, this alone cannot guarantee that the water quality standard will be met and may unnecessarily increase mitigation costs. This paper proposes an alternative strategy for the TMDL trading framework. Instead of explicitly determining trading ratios, a trading scenario selection method is utilized. Water quality is simulated for the alternate trading scenarios based on various pollutant loads obtained from accepted models such as HSPF. The costs associated with the nonpoint reductions are compared for various load allocation strategies. This comparison enables an efficient screening of watersheds to identify those well-suited for a pollutant trading strategy. Watersheds with high cost variations and flexibility among allocation strategies are ideal candidates for trading. The methodology is demonstrated using the results of the TMDL allocation for the Muddy Creek WAR1 subwatershed in Rockingham County, Virginia.

KEYWORDS. TMDL Trading, Fecal Coliform TMDL, Economic Analysis, Optimization, Mathematical Modeling

---

[1] Graduate Research Assistant, George Mason University, Fairfax, VA. 22030-4444, azaidi@gmu.edu

[2] Associate Professor of Civil, Environmental and Infrastructure Engineering, George Mason University, Fairfax, VA. 22030-4444, sdemonsa@gmu.edu

[3] Senior Water Resources Engineer, The Louis Berger Group, Washington, D.C., 20037, relfarhan@louisberger.com

[4] Postdoctoral Fellow, George Mason University, George Mason University, Fairfax, VA, 22030-4444, shc758@yahoo.com

INTRODUCTION

According to the United States Environmental Protection Agency (EPA) the market-based approaches such as water quality trading provide greater flexibility and have potential to achieve greater environmental benefits than would otherwise be achieved under more traditional regulatory approaches (EPA, 2003). Given the inherent scientific uncertainty in the nature of nonpoint pollutants there is a high risk involved in complying with environmental regulation while trading nonpoint pollutants. The objective of this paper is to utilize a previous model developed by Zaidi et al (2003) as a decision tool to evaluate and determine the cost-effectiveness of various trading options during the TMDL allocation phase. The approach uses a mathematical model to minimize the costs for the subwatershed load allocation to achieve the desired water quality goal while minimizing the uncertainties associated with the nonpoint pollutant trading. The costs associated with the subwatershed load allocations establish the basis for pollutant trading.

TMDL TRADING FRAMEWORK DURING THE ALLOCATION PHASE

Use of the proposed cost optimization approach can help to determine at the allocation stage whether a specific TMDL lends itself to a watershed-based pollutant trading approach. Furthermore, the approach will provide an estimate of the potential savings that may be realized by incorporating a pollutant trading approach in the TMDL load allocation phase. Water quality based trading accomplishes time and economic efficiencies. Not only are the reductions more cost-effective but also the process of achieving the reductions necessary to meet the water quality standard is accelerated.

For an approved TMDL, EPA recommends the consideration of applicable point source waste load allocations or non-point source load allocations to establish a baseline for trading credits. A baseline is defined as the level below which a reduction is made to create a pollutant reduction credit (EPA, 2003). Pollutant trading takes advantage of the control cost differentials and economies of scale between various sources of pollutants. Under EPA guidelines, watershed based trading may be considered if it results in an overall reduction of pollutant loads without violation of the water quality standard. Commonly, “trading ratios” are used to account for the expected differences in impact on water quality, for two different loadings in a watershed. These factors, may also account for the uncertainties associated with estimates of nonpoint source loads and reductions achieved through treatment options or other control measures. The relative impact of one unit of pollutant discharged from different sources from varied locations is never the same.

MUDDY CREEK WATERSHED

In this paper, nonpoint trading options are evaluated under the framework of an approved TMDL for fecal coliform bacteria in a subwatershed (WAR1) of the Muddy Creek watershed. For TMDL modeling purposes, the Muddy Creek watershed was delineated into eight interconnected subwatersheds as shown in Figure 1. The Muddy Creek watershed is located in Rockingham County, Virginia. Muddy Creek is on the Commonwealth of Virginia's 1998 303(d) list of impaired waterbodies because of fecal coliform bacteria violations. The Virginia Department of Environmental Quality (VADEQ) ambient water quality monitoring stations recorded the exceedance of the standard to indicate that the stream does not support primary contact recreation (swimming). The Muddy Creek fecal coliform target was a geometric mean of 200 counts/100ml with 0% violation. The Muddy Creek loads are comprised of direct loads (in-stream discharges due to animals, failed septic systems and uncontrolled releases) and indirect loads (surface depositions resulting from land use).

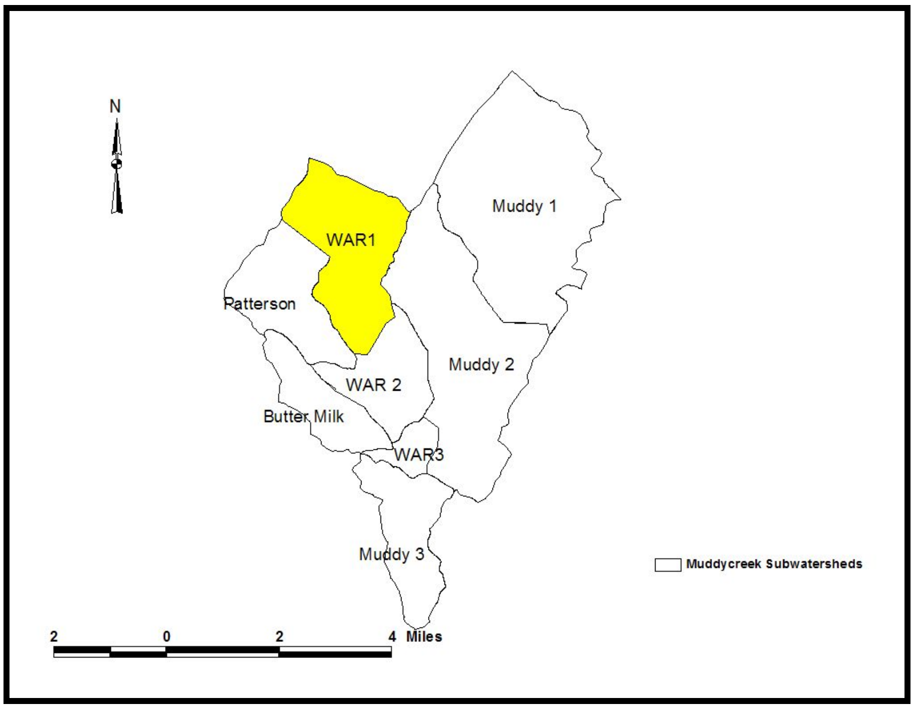

Figure 1. Muddy Creek Subwatersheds

POTENTIAL TRADING SCENARIOS

The proposed methodology identifies viable load allocation tradeoffs such that implementation costs are minimized while achieving an acceptable level of water quality in the stream. The optimization model identifies the minimum cost mitigation approach for a given allocation scenario. A comparison of the costs associated with the mitigation strategies for various allocation scenarios, provides a starting point for discussion and evaluation of trading options. For several reasons, including site characteristics (soil type, slope, etc.), fecal load deposition (direct vs. indirect), diversity in control strategies, etc. the remediation costs may differ among sources. Only scenarios that produce modeled results consistent with the TMDL standards are considered. In the case of the Muddy Creek WAR1 subwatershed, the trading scenarios were modeled using a calibrated HSPF model provided by The Virginia Department of Conservation and Recreation (DCR). The fecal coliform bacteria sources for the Muddy Creek WAR1 subwatershed are: land-based loads, wildlife loads, failed septic systems, and direct deposit as listed in Tables 1 and 2. In the final TMDL allocation report for Muddy Creek (VADEQ, 2000), the allocated TMDLs are based on variable monthly reductions for each source. For the purposes of this work, the maximum monthly reduction from each source was used in the analysis.

Table 1: Baseline Scenario

Nonpoint Source	Total Existing Load (counts/yr)	Load Reduction (counts/yr)	PV Cost[1] ($)
Land-based Loads	3.51E+11	1.68E+11	3,085
Wildlife Loads	2.67E+10	0.00E+00	30,056[2]
Failed Septic System	1.04E+11	1.04E+11	17,286
Direct Deposit	1.95E+13	1.95E+13	164,682
Total	2.00E+13	1.98E+13	215,109

1. Total Present Value (PV) costs are calculated for a 7% interest rate and 15-year planning horizon.
2. This management option reflects the cost of maintaining the existing wildlife population (assuming a 10% growth rate). As such, it does not constitute a load reduction.

Tables1 and 2 present the baseline scenario based on the TMDL allocation report (VADEQ, 2000), and a potential trading scenario respectively. In these tables the annual load reduction from each source and the cost of achieving that reduction are given. These costs depend not only upon the level of load reduction but also upon the choices and selection of control measures. In this study the vegetative buffer strip for land-based load, wildlife management for wildlife load, system repair and installation for failed septic systems, and streamside fencing for direct cattle deposit are considered as control strategies.

Table 2: Potential Trading Scenario

Nonpoint Source	Load Reduction (counts/yr)	PV Cost ($)
Land-based Loads	8.59E+10	1,094
Wildlife Loads	1.47E+10	31,751
Failed Septic System	0.0	0
Direct Deposit	1.95E+13	164,682
Total	1.96E+13	197,527

As shown in Table 1 the total load reduction cost for the baseline scenario is $215,109, whereas for the alternate trading scenario (Table 2) the cost is $197,527. The alternate trading scenario presents a cost savings of 8% from the baseline scenario. The baseline scenario represents a slightly higher annual load reduction with higher cost as compared to the alternate trading scenario. Despite a lower annual load reduction, the alternate scenario is also a viable scenario since it complies with the state standard as modeled in Figure 2. Also the geometric means of the fecal coliform concentrations for the trading scenario are generally less than for the baseline scenario. In both cases, the direct deposit load reduction dominates the load allocation. The direct deposit is several orders of magnitude greater; for this reason, reductions in the land-based, wildlife and failed septic system loads are insignificant relative to the direct deposit reduction.

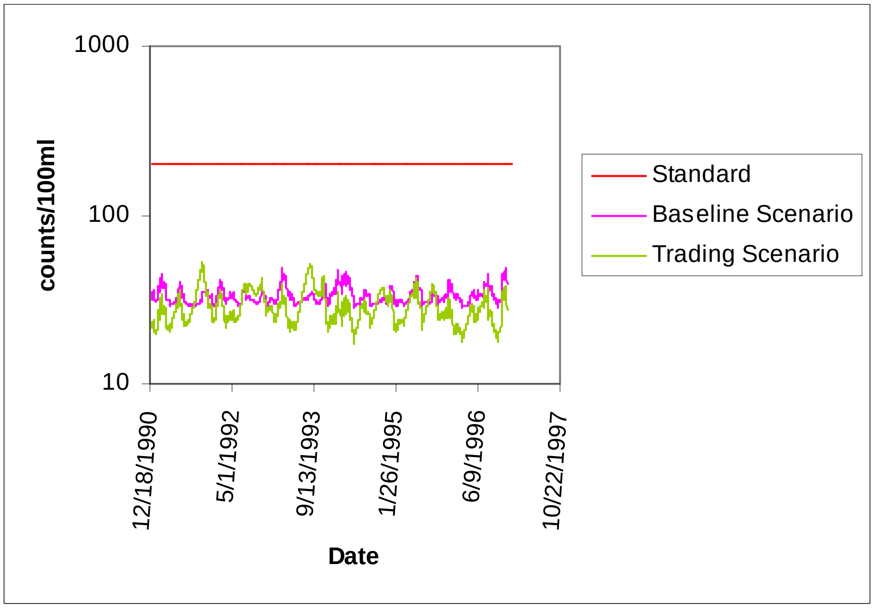

Figure 2. 30-Day Geometric Mean Fecal Coliform Loadings under Baseline and Trading Scenarios

A matrix of viable trading scenarios may be produced using the calibrated HSPF model. The calibrated HSPF model for Muddy Creek watershed obtained from DCR is used for this analysis. This matrix of options will help to identify potential tradeoffs in the reduction of pollutant loads from different categories of nonpoint sources to levels below the standard and their associated costs.

The existing load distribution in the watershed does not offer much flexibility to the Muddy Creek subwatershed WAR1 for pollutant trading because of the dominance of the direct loads. For the illustration purpose, a synthetic load distribution was used in the following section to better illustrate the strengths of the model.

TRADING SCENARIO ANALYSIS

The existing loads for the WAR 1 subwatershed were multiplied with randomly selected coefficients to provide a synthetic load distribution that would better illustrate the proposed methodology. Table 4 shows the synthetic loads used in the analysis. Table 5 presents three alternative trading scenarios. Each of these scenarios represents an option that will meet the water quality standard. Individual and total load reduction costs for each source are shown in Table 5.

Table 4: Synthetic Loads

Nonpoint Source	Loads (counts/year)
Land-based Loads	2.66E+12
Wildlife Loads	2.02E+11
Failed Septic System	2.60E+10
Direct Deposit	9.31E+11
Total Synthetic Load	3.82E+12

Table 5: Trading Scenario PV Costs

	Scenario I		Scenario II		Scenario III	
Nonpoint Source	Reduction[1] (%)	PV Cost[2] ($)	Reduction[1] (%)	PV Cost[2] ($)	Reduction[1] (%)	PV Cost[2] ($)
Land-based Loads	57 (75)	7,409	0	0	73.7 (74.2)	4,899
Wildlife Loads	67.8	249,113	87.13	253,618	49.4	244,854
Failed Septic System	100	4,322	0	0	0	0
Direct Deposit	80 (89.7)	94,706	79 (89.7)	94,706	92 (93.3)	127,942
Total	63.6 (77)	355,550	24 (26.5)	348,324	76.4 (77)	377,695

1. Values in parentheses are the actual reductions achieved after applying the control measures.
2. Total Present Value (PV) costs are calculated for a 7% interest rate and 15-year planning horizon.

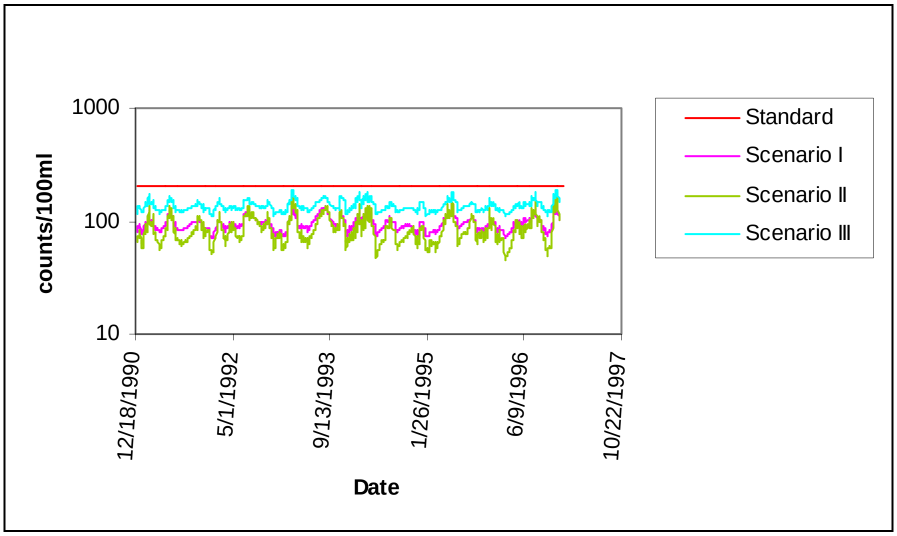

Figure 3. 30-Day Geometric Mean Fecal Coliform Loadings under Scenarios I, II and III

Discussion

Scenario II provides the best results from both an economic and environmental perspective. The modeled geometric means of the fecal coliform concentrations are generally less than those for Scenarios I and III (see Figure 3). It is interesting to note that the least cost option (Scenario II, minimum annual load reduction) provides the "best" environmental solution. This result supports the need for economic assessment during the load allocation phase of the TMDL development. In a trading environment, Scenario II would be preferred over Scenarios I and III.

Also a comparison of Scenarios I and III supports a trading solution. Scenario III yields a solution that is environmentally inferior to Scenario I, yet the total cost is greater. The total cost is 5.86% greater for Scenario III than Scenario I despite a reduced environmental load. This result suggests that trading could result in an improved solution (both environmentally and economically). Under Scenario I, the land based, wildlife and failing septic systems loads would sell the 'polluting rights' to the direct deposit loads for reduced total costs and improved water quality. To better understand the concept, consider scenario III as the baseline scenario. A mutually advantageous trade may be conducted between scenarios I and III. Greater reductions in the pollutants from land-based, wildlife, and failed septic systems are needed in scenario I than in the scenario III. Similarly the costs associated with these added reductions are greater. The benefits associated with reducing the direct deposit load reductions ($33,236) far exceed the net dollar loss ($11,090) from the other three sources. Therefore, an opportunity for trading between direct deposit sources and the other sources exists. Direct deposit sources can purchase 'pollutant rights' from other sources. If the 'pollutant rights' cost more than what is required by the three sources to achieve the level of pollutant reduction in scenario I (more that $11,090), then the direct load sources will save money by purchasing these rights at a cost less than $33,236 (their cost to reduce a comparable load).

CONCLUSIONS

The trading scenario selection method provides improved assurance of meeting the water quality goal. Economic modeling during the allocation phase of TMDL development is vitally important to the environmental and economic success. Cost data, coupled with modeled geometric means of fecal coliform concentrations will enable improved allocations that accomplish both environmental and economic goals. Without economic information for the various proposed allocation scenarios, it is difficult to determine what solution would be preferred. For example, in the case study presented above, the solution with a higher load reduction produces an environmentally and economically inferior solution. This solution presents an opportunity for improved water quality at a reduced cost through the use of trading scenarios.

REFERENCES

1. USEPA. 2003. Final Water Quality Trading Policy. United States Environmental Protection Agency, Office of Water, January 13, 2003. http://www.epa.gov/owow/watershed/trading/finalpolicy2003.html
2. VADEQ. 2000. Revised Final Report: Fecal coliform *TMDL Development For Muddy Creek, Virginia*. The Muddy Creek TMDL Establishment Workgroup. http://www.deq.state.va.us/pdf/rivers/mdycrk.pdf
3. Zaidi, Arjumand Z., deMonsabert, S. M., El-Farhan, R. 2003. A Cost-Based Strategy for TMDL Allocation. Proceedings of the Second Conference on Watershed Management to Meet Emerging TMDL Environmental Regulations, ASAE, Albuquerque, New Mexico, November 8-12, 2003.