Appendix C – Application of the Reference Watershed Approach in the Anacostia River Watershed

Introduction

Maryland has no numeric criteria for suspended sediment in free-flowing non-tidal waters. When the tidal and non-tidal portions of the eight-digit Anacostia River watershed were placed on Maryland's 1996 303(d) List as impaired by sediments, the listing was made on the basis of best professional judgment.

The Maryland Department of the Environment (MDE) is currently developing a methodology to determine for rural, non-tidal eight-digit watersheds (1) if the watershed is impaired by sediment and, if so, (2) what sediment loads are compatible with watersheds meeting water quality standards (Currey *et al*., 2006). The methodology is based on an analysis of the results of the MBSS surveys, which are used to identify unimpaired watersheds. The Chesapeake Bay Program's (CBP) Phase 5 Watershed Model is then used to determine sediment loads for both impaired and unimpaired watersheds. Sediment TMDLs for impaired watersheds can then be calculated on the basis of a reference sediment yield (in tons/acre/year) expressed as a ratio of the sediment yield for unimpaired watersheds to a regional all-forested sediment yield.

Currently, MDE does not envision applying the methodology to either urban or tidal watersheds. In urban watersheds, there are multiple stressors of the aquatic biological community, confounding the relation between sediment loads and the biological health of streams. Indeed, specific twelve-digit subwatersheds in the Anacostia watershed have been listed on the basis of biological impairment in Maryland's draft 20006 303(d) List. In tidal watersheds, the estuarine receiving waterbody is likely to be more sensitive to sediment loads than the non-tidal watershed; the residence time of sediment loads in tidal waters is longer than in free-flowing streams, and overall sediment loading rates can be expected to be more indicative of water quality. Based on the recommendations of the CBP, MDE has recently proposed numeric water quality standards for clarity in tidal waters that potentially could be used to set the TMDL endpoints for eight-digit watersheds draining to tidal waters.

The Anacostia River is an urban watershed draining to tidal waters. The water quality standards for the tidal river, not only in Maryland but the District of Columbia as well, are the most appropriate determinant of the sediment TMDL endpoint for the eight-digit watershed as a whole. Specific biological impairments in subwatersheds will be addressed at a later date.

Nevertheless, there is some value in demonstrating heuristically that the level of reductions in sediment loads mandated to protect water quality in the tidal river will also protect water quality in the non-tidal free-flowing streams of the watershed. For that reason, the sediment loads compatible with protecting in-stream water quality in the non-tidal Anacostia River were determined using the "reference watershed" approach.

The reference watershed approach is a standard method for determining TMDL endpoints in the absence of numerical criteria for a pollutant. In the reference watershed approach, current loads from the impaired watershed are compared to the loads from an unimpaired watershed, similar in size, land use, soils, and geology. The underlying assumption is that the sediment loads from the unimpaired watershed are at least as large as the maximum loads compatible with water quality standards--in other words, the TMDL.

Sediment TMDLs have been developed in Pennsylvania (Evans *et al*., 2002) and Virginia (BSE, 2005) using the reference watershed approach. The Generalized Watershed Loading Functions model (GWLF), with the streambank erosion equation, has been used in both states to develop the TMDLs. The Hydrological Simulation Program—Fortran (HSPF) computer simulation model of the non-tidal Anacostia River (Mandel and Schultz, 2006) was adapted to the reference watershed approach by closely following the methods used in previous sediment TMDLs in EPA Region III. In particular, the approach used in the sediment TMDL for Lower Opequon Creek in Virginia (BSE, 2003), guided the development of reference loads for the Anacostia River. In that TMDL, a subwatershed, the upper portion of Opequon Creek, was selected as the reference watershed for the impaired segment of Opequon Creek downstream. Similarly, reference loads for Anacostia watersheds will be developed based on subwatersheds in the Anacostia River Basin. The use of subwatersheds as reference watersheds necessitates adjusting the reference watershed loads to the size of the impaired watersheds. The procedures used in the Lower Opequon Creek TMDL were used to adapt the loads from the reference watersheds to the other watersheds in the Anacostia River Basin.

Selection of Reference Watersheds

Ideally, a reference watershed should have the following characteristics:

1. It should be assessed as unimpaired for the TMDL pollutant;
2. It should be the same size as the impaired watershed;
3. It should have the same soils and geology as the impaired watershed; and
4. It should have the same land use as the impaired watershed.

Perhaps the ideal reference watershed would be one identical to the impaired watershed, except that sufficient BMPs and other water quality control measures have been implemented to protect water quality. In actuality, it is often difficult to find any unimpaired watershed that resembles the impaired watershed, and in practice there is considerable latitude in the selection of the reference watershed, and, in respect to the size requirement, methods have been developed to adjust the size of the reference watershed loads to the size of the impaired watershed. For urban watersheds, the problem of the selection of a reference watershed is compounded by the fact that Maryland has not yet developed a method for determining whether an urban watershed is impaired by sediment. As was mentioned above, the listing of the Anacostia River at the eight-digit scale in 1996 was based on best professional judgment.

Two subwatersheds of the Anacostia, Upper Beaverdam Creek and Upper Paint Branch, were chosen to serve as references for the Coastal Plain and Piedmont portions of the Anacostia River watershed, respectively. As subwatersheds of the Anacostia, they are representative of the coastal plain and Piedmont sections of the watershed as a whole with respect to soils and underlying geology, although they are less urbanized than many portions of the Anacostia watershed.

Upper Beaverdam Creek was chosen as a reference for the Coastal Plain portion of the watershed on the basis of a detailed stream channel assessment the Metropolitan Washington Council of Governments (MWCOG) performed under the auspices of MDE (Trieu *et al*., 2004). Using MWCOG's Rapid Stream Assessment Technique (RSAT), Trieu *et al.* evaluated the mainstem and tributaries in Upper Beaverdam Creek according to six categories:

1. Bank Stability
2. Channel Scouring/Sediment Deposition
3. Physical Instream Habitat
4. Water Quality
5. Riparian Habitat Condition
6. Biological Indicators

Trieu *et al.* found that the mean bank stability of the mainstem Upper Beaverdam Creek, as measured by the RSAT, was excellent. They observed only 0.01 linear feet/mile of servere erosion, 0.18 linear feet/mile of moderate-to-severe erosion, and 0.72 feet/mile of moderate streambank erosion along the mainstem. Streambank heights along the mainstem were also within reference condition ranges. Riparian habitat conditions were rated excellent, fair, and good for the Upper, Middle, and Lower mainstem, respectively. Streambank conditions in the tributaries to Upper Beaverdam Creek were more variable. Mean bank stability in the tributaries was in the good to excellent range and riparian habitat conditions were also rated good to excellent, although channel widths and bank heights in the tributaries tended to be slightly higher than expected for reference conditions. Trieu *et al*. recommended that mainstem Upper Beaverdam Creek could serve as a reference for evaluating stream channels in the rest of the Anacostia watershed.

Although Trieu *et al*.'s stream channel assessment provides the most direct and detailed evidence that Upper Beaverdam Creek is not impaired by sediment, some additional support is provided by biological assessments. The only site in the Anacostia watershed which the Maryland Biological Stream Survey (MBSS) rated good with respect to the benthic index of biological integrity (B-IBI) is on the lower mainstem of Upper Beaverdam Creek. Figure C.1 shows the location and ratings of MBSS assessment sites in the Anacostia watershed. A second site on the lower mainstem was one of two sites in the Anacostia watershed rated fair. As shown in Figure C.2, MBSS also rated the same two sites good with respect to the fish index of biological integrity (F-IBI). In contrast, however, biological monitoring performed by Tetra Tech (Leppo *et al.*, 2003) on behalf of Prince George's County tended to rate sites in Upper Beaverdam Creek and fair or poor with respect to their B-IBI. Both the MBSS and Tetra Tech assessments are essentially snapshots taken on a single day and may be overly influenced by conditions prevailing at that time. In particular, Tetra Tech's assessment occurred in early March, 2000, after an unusually dry winter, which could have influenced their results.

Unlike Upper Beaverdam Creek, there has been no explicit sediment survey of the Upper Paint Branch. Upper Paint Branch, however, has a naturally-reproducing brown trout population. The Maryland-National Park and Planning Commission (1995) even asserts that the Upper Paint Branch is "the only stream system in Montgomery County with a *proven, consistent, long-term self-sustaining* trout population." Upper Paint Branch has been designated a Special Protection Area by the Montgomery County Department of Environmental Protection (DEP) and an "aquatic resource of national importance" by the U. S. Department of the Interior (Eyes of the Paint Branch, 1997). MBSS has not monitored inthe Upper Paint Branch but the Montgomery County DEP, which has performed extensive biological monitoring in the watershed as part of their Countywide Stream Protection Strategy, confirms that the Upper Paint Branch supports good stream conditions (MCDEP, 1998 and 2003). Figure C.3 shows the DEP's assessment of the Paint Branch's subwatersheds.

The HSPF Model of the Non-tidal Anacostia River Watershed

Both baseline sediment loads and reference loads were calculated using the HSPF Model of the Non-tidal Anacostia River watershed developed for Maryland's sediment TMDLs for the Anacostia River. The model represents the major subwatersheds in the Northwest and Northeast Branches, including Upper Paint Branch and Upper Beaverdam Creek, as well as Lower Beaverdam Creek and Watts Branch. The Anacostia Model's simulation of the fate and transport of sediment was calibrated using the following edge-of-stream (EOS) and streambank erosion sediment load targets:

- EOS load targets for forest, pasture, and cropland were based on the CBP Phase 5 edge-of-field (EOF) erosion targets for these land uses and a sediment delivery ratio;
- EOS load targets for developed land were based on monitoring data collected by Montgomery and Prince George's County for their MS4 permits;
- Overall sediment load targets for the NE and NW Branches were based on ESTIMATOR loads (see Appendix A);
- Streambank erosion targets are equal to the difference between total sediment load targets and EOS targets; and
- Streambank erosion targets for Lower Beaverdam Creek, Watts Branch, and the subwatersheds of the NE and NW Branches were set proportional to the streambank erosion calculated with *Evans et al.*'s (2003) streambank erosion algorithm.

Mandel and Schultz (2006) discuss in more detail the development of the HSPF Anacostia Model.

Determination of Reference Watershed Loads

Reference watershed loads were determined for (1) the Northwest Branch, (2) the Northeast Branch, (3) Lower Beaverdam Creek, and (4) Watts Branch. The methodology used for the Lower Opequon Creek TMDL (BSE, 2003) was adapted to the HSPF model. Specifically, in the Lower Opequon Creek TMDL, reference sediment loads were calculated using GWLF as follows:

1. The reference watershed was resized to match the impaired watershed by multiplying reference watershed land use acreages by the ratio of the overall size of the impaired watershed to the reference watershed.
2. Loads from specific land uses were calculated in GWLF using the resized land uses.
3. Monthly flows were recalculated using the resized reference watershed.
4. Streambank erosion was determined using (i) the monthly flows from (3), (ii) the reference watershed “a” factor, and (iii) the stream length of the impaired watershed.
5. Total reference load is the sum of land use-specific loads and streambank erosion.

In the HSPF model of the non-tidal Anacostia River watershed, land use-specific loads correspond to the EOS loads. EOS loads are calculated as the product of the edge-of-field (EOF) loads (which do not vary by subwatershed) for specific land uses and a sediment delivery ratio based on watershed area. This is analogous to the GWLF model, in which the EOF load is determined by the Universal Soil Loss Equation and a watershed sediment delivery ratio is applied to determine the delivered load. In the HSPF model, streambank erosion was determined by calibration with monthly ESTIMATOR loads, but distributed to subwatersheds based on the AVGWLF streambank erosion algorithm. This enables a reference load to be calculated from the results of the HSPF model as follows:

1. Upper Paint Branch land use was resized to serve as the reference watershed for the Northwest Branch. Upper Beaverdam Creek was resized to serve as the reference watershed for Lower Beaverdam Creek and Watts Branch. The reference watershed for the Northeast Branch was determined by assigning the land uses from Upper Paint Branch to Piedmont subwatersheds and the land uses from Upper Beaverdam Creek to Coastal Plain subwatersheds.
2. EOS loads were calculated for the resized reference watersheds based on the land use acreage, yields, and the sediment delivery ratio for each subwatershed.
3. Average annual monthly flow was determined by simulating the resized reference watersheds using HSPF.
4. Streambank erosion was determined using (i) the monthly flows from (3), (ii) the reference watershed “a” factor, and (iii) the stream length of the impaired watershed.
5. Total reference load is the sum of land use-specific loads and streambank erosion.

Results

Table C.1 presents the results. All flows and sediment loads are based on a ten-year simulation, 1995-2004. Based on the reference watershed methodology, sediment loads in the Northwest Branch, Northeast Branch, and Lower Beaverdam Creek would need to be reduced about 40% to protect in-stream water quality from impairment by sediment. The reductions for Watts Branch are only about 13%. As discussed above, there is some uncertainty in the sediment loads in Watts Branch under high flow conditions, because no stormwater monitoring has been performed there, and it is possible that lower reductions postulated for the Watts Branch stem from underestimating streambank erosion.

As anticipated, the load reductions required to protect non-tidal water quality, as calculated using the reference watershed approach, are considerably lower than those required to meet water quality standards, specifically for water clarity, in DC's tidal waters.

Table C.1. Reference Watershed Loads and Estimated Load Reductions Necessary For Protection of Instream Water Quality

	Northwest Branch	Northeast Branch	Lower Beaverdam Creek	Watts Branch
annual average monthly flow $^{0.6}$ (cfs) –reference conditions	120	164	60	24
a-factor—reference conditions	0.000980	0.000508	0.000354	0.000354
Streamlength (m)	182,173	293,607	62,429	13,732
Reference Streambank erosion (tons/year)	10,105	10,440	567	50
Reference Yield (tons/acre/year)	0.075	0.150	0.175	0.175
Reference EOS Load (tons/year)	2,362	6,996	1,686	371
Reference Watershed Load (tons/year)	12,466	17,436	2,253	421
Baseline Load (tons/year)	19,802	30,301	3,548	485
Reduction	37%	42%	37%	13%

References

Biological Systems Engineering Department, Virginia Polytechnic Institute and State University. 2003. Opequon Watershed TMDLs for Benthic Impairments: Abrams Creek and Lower Opequon Creek, Frederick and Clarke Counties, Virginia. Blacksburg, VA. http://www.deq.virginia.gov/tmdl/apptmdls/shenrvr/abropebc.pdf

Biological Systems Engineering Department, Virginia Polytechnic Institute and State University. 2005. Using GWLF for TMDL Development. American Society for Agricultural Engineers. Third Conference on Watershed Management to Meet Water Quality Standards and Emerging TMDL. Atlanta, GA. March 6, 2005.

Currey, D. L., A. A. Kasko, and R. Mandel. 2006. A Methodology for Addressing Sediment Impairments in Maryland's Non-tidal Rural Watersheds. Maryland Department of the Environment. Baltimore, MD.

Evans, B.M., D.W. Lehning, K.J. Corradini, G.W. Petersen, E. Nizeyimana, J.M.Hamlett, P.D. Robillard, and R.L. Day, 2002. A Comprehensive GIS-Based Modeling Approach for Predicting Nutrient Loads in Watersheds. J. Spatial Hydrology, Vol. 2, No. 2.

Evans, B. M., S. A. Sheeder, and D. W. Lehning. 2003. A Spatial Technique For Estimating Streambank Rosion Based On Watershed Characteristics. Journal of Spatial Hydrology, Vol. 3, No. 1.

Eyes of Paint Branch. 1999. Restoring Paint Branch. Silver Spring, MD. http://www.eopb.org/publications/restoring_pb.php. Revision of Interstate Commission on the Potomac River Basin. 1992. Restoring Paint Branch. Rockville, MD.

Leppo, E. W., J. B. Stribling, C. Marino, and P. McCreesh. 2003. Biological Assessment of the Streams and Watersheds of Prince George's County, Maryland. Spring Index Period 2000. PGDER Report 03-1. Tetra Tech. Owings Mills, MD.

Mandel, R. A. Nagel and C.L. Schultz. In preparation. *Anacostia sediment models: Phase 3 Anacostia HSPF watershed model and Version 3 TAM/WASP water clarity model.* Interstate Commission on the Potomac River Basin, Rockville, MD.

Maryland-National Capital Parks and Planning Commission. Montgomery County Planning Department. 1995. Upper Paint Branch Watershed Planning Study. Silver Spring, MD.

Montgomery County Department of Environmental Protection. Countywide Stream Protection Strategy. 1998. Rockville, MD. http://www.montgomerycountymd.gov/deptmpl.asp?url=/content/dep/CSPS/home.asp

Montgomery County Department of Environmental Protection. Countywide Stream Protection Strategy. 2003 Update. 2003. Rockville, MD. http://www.montgomerycountymd.gov/content/dep/Publications/pdf/CSPS2003.pdf

Trieu, P., J. Galli, K. Levendosky, and C. Vatovec. 2004. Technical Memorandum: Anacostia Tributary Streambank Erosion Pilot Study. Phase I. Upper Beaverdam Creek Subwatershed. Metropolitan Washington Council of Governments. Washington, DC.

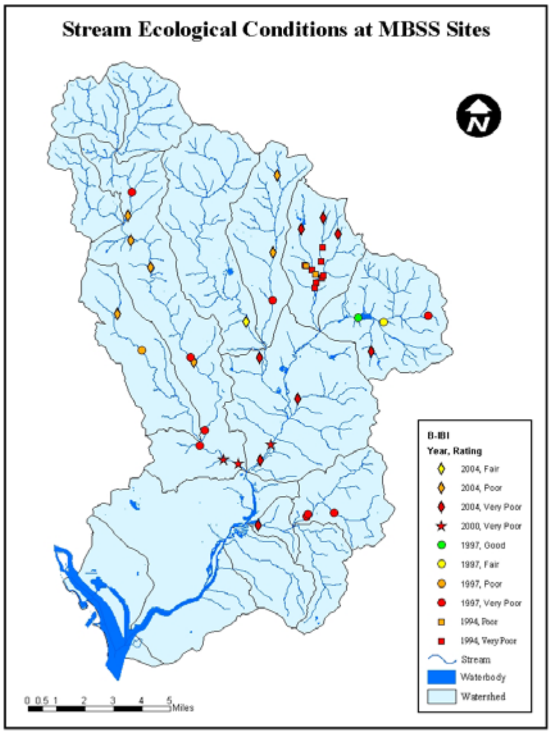

Figure C.1. MBSS B-IBI Scores in the Anacostia Watershed

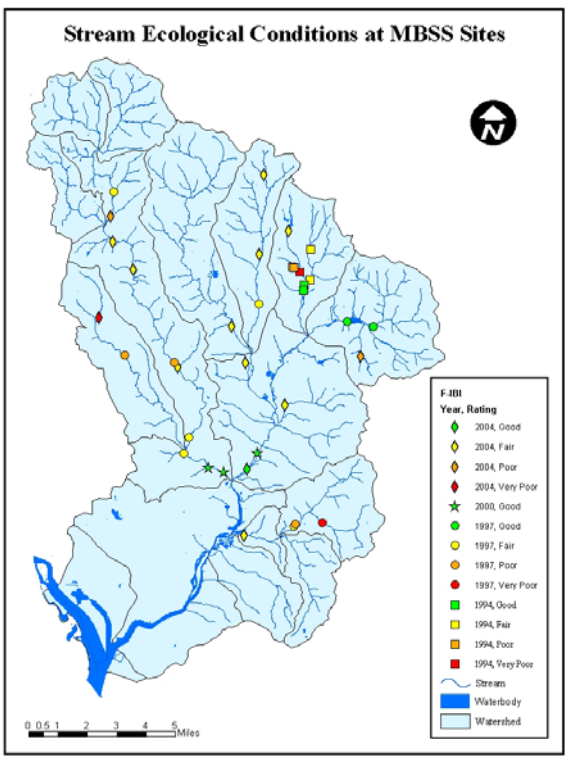

Figure C.2. MBSS F-IBI Scores in the Anacostia Watershed

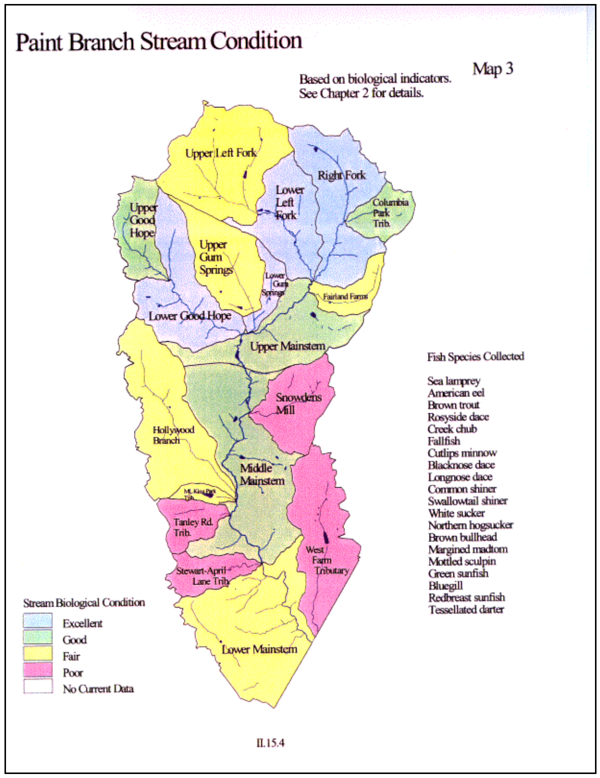

Figure C.3. Montgomery County DEP Water Quality Evaluations of Paint Branch Subwatersheds (MCDEP, 2003)