Water Quality Analysis of Sediment in Middle Patuxent River, Howard County, Maryland

FINAL

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List of Abbreviations

BIBI	Benthic Index of Biotic Integrity
BMP	Best Management Practice
BSID	Biological Stressor Identification Methodology
CBP P4.3	Chesapeake Bay Program Phase 4.3
CBP P5.2	Chesapeake Bay Program Phase 5.2
CWA	Clean Water Act
EOF	Edge-of-Field
EOS	Edge-of-Stream
EPA	Environmental Protection Agency
ETM	Enhanced Thematic Mapper
FIBI	Fish Index of Biologic Integrity
GIS	Geographic Information System
MAL	Minimum Allowable IBI Limit
MD 8-Digit	Maryland 8-Digit Watershed
MDE	Maryland Department of the Environment
MBSS	Maryland Biological Stream Survey
NRCS	Natural Resource Conservation Service
NRI	Natural Resources Inventory
RESAC	Regional Earth Science Applications Center
SCS	Soil Conservation Service
TMDL	Total Maximum Daily Load
TM	Thematic Mapper
Ton/Yr	Tons per year
UMCFA	University of Maryland Central Farm Area
USDA	United States Department of Agriculture
USGS	United Stated Geological Survey
WQA	Water Quality Analysis
WQLS	Water Quality Limited Segment

EXECUTIVE SUMMARY

This document, upon approval by the U.S. Environmental Protection Agency (EPA), presents a Water Quality Analysis (WQA) of sediment in the Middle Patuxent River watershed (basin number 02131106) (2008 *Integrated Report of Surface Water Quality in Maryland* Assessment Unit ID: MD-02131106). Section 303(d) of the federal Clean Water Act (CWA) and the EPA's implementing regulations direct each state to identify and list waters, known as water quality limited segments (WQLSs), in which current required controls of a specified substance are inadequate to achieve water quality standards. For each WQLS, the State is to either establish a Total Maximum Daily Load (TMDL) of the specified substance that the waterbody can receive without violating water quality standards, or demonstrate that water quality standards are being met (CFR 2009).

The Maryland Department of the Environment (MDE) has identified the waters of the Middle Patuxent River watershed on the State's 2008 Integrated Report as impaired by metals - zinc (1996), sediments (1996), and nutrients – nitrogen and phosphorus (1996) (MDE 2008). The designated use of the Middle Patuxent River mainstem and its tributaries is Use I-P (Water Contact Recreation, Protection of Aquatic Life, and Public Water Supply) (COMAR 2009a,b).

The WQA presented herein by MDE will address the 1996 sediments listing, for which a data solicitation was conducted, and all readily available data from the past five years have been considered. A WQA for eutrophication to address the nutrients listing was approved by the EPA in 2007, and a WQA for zinc was approved by the EPA in 2009.

Currently in Maryland, there are no specific numeric criteria that quantify the impact of sediment on the aquatic life of nontidal stream systems. Therefore, in order to quantify the impact of sediment on the aquatic life of the watershed stream system, a reference watershed approach was used and resulted in the establishment of a *sediment loading threshold* (Currey et al. 2006). This threshold is based on a detailed analysis of sediment loads from watersheds that are identified as supporting aquatic life (i.e., reference watersheds) based on Maryland's biocriteria (Roth et al. 1998, 2000; Stribling et al. 1998; MDE 2008). As per the 2008 Integrated Report's biological assessment of Maryland's 8-digit (MD 8-digit) watersheds, the Middle Patuxent River watershed was identified as supporting aquatic life and was therefore included as a reference watershed in the development of the *sediment loading threshold* (see Appendix A) (MDE 2008).

Analysis of the reference watershed sediment loads required that the watersheds be similar in physical and hydrological characteristics. To satisfy this requirement, Currey et al. (2006) selected reference watersheds only from the Highland and Piedmont physiographic regions. Furthermore, to reduce the effect of the variability within the Highland and Piedmont physiographic regions, the watershed sediment loads were then normalized by a constant background condition, the all forested watershed condition. This new normalized term, defined as the *forest normalized sediment load*, represents how many times greater the current watershed sediment load is than the *all forested sediment load*. Based on this analysis, the *sediment loading threshold* was determined to be approximately 3.3 times greater than the sediment load of the all forest watershed condition (Currey et al. 2006).

This WQA evaluates whether or not the Middle Patuxent River watershed's *forest normalized sediment load* is at a level to support aquatic life. The computational framework chosen for the analysis was the Chesapeake Bay Program Phase 5.2 (CBP P5.2) watershed model target *edge-of-field* (EOF) land use sediment loading rate calculations combined with a *sediment delivery ratio*. The spatial domain of the CBP P5.2 watershed model segmentation aggregates to the MD 8-digit watersheds, which is consistent with the sediment impairment listing; however, the Middle Patuxent River watershed consists of only one CBP P5.2 model segment. The current watershed sediment load is approximately 2.9 times the all forested watershed condition. This indicates that current watershed sediment loads do not exceed the sediment loading threshold and confirms that the Middle Patuxent River watershed is not impaired by elevated sediment loads to the watershed stream system. Therefore, the current watershed sediment loads are at a level to support the Use I-P designation for the watershed stream system, and more specifically, at a level to support aquatic life.

This analysis supports the conclusion that a TMDL for sediments is not necessary to achieve water quality standards in the Middle Patuxent River watershed. Although the waters of the Middle Patuxent River watershed do not display signs of a sediment impairment, the State reserves the right to require future controls in the watershed if evidence suggests that sediments from the basin are contributing to downstream water quality problems. For instance, reductions may be required by the forthcoming Chesapeake Bay TMDL, which is currently under development.

Barring the receipt of contradictory data, this report will be used to support a revision of the 2008 Integrated Report sediment listing for the Middle Patuxent River watershed from Category 5 ("waterbody is impaired, does not attain the water quality standard, and a TMDL is required") to Category 2 ("waterbody is meeting some [in this case sediments-related] water quality standards, but with insufficient data to assess all impairments"), when MDE proposes the revision of the Integrated Report.

FINAL

1.0 INTRODUCTION

This document, upon approval by the U.S. Environmental Protection Agency (EPA), presents a Water Quality Analysis (WQA) of sediment in the Middle Patuxent River watershed (basin number 02131106) (2008 *Integrated Report of Surface Water Quality in Maryland* Assessment Unit ID: MD-02131106). Section 303(d) of the federal Clean Water Act (CWA) and the EPA's implementing regulations direct each state to identify and list waters, known as water quality limited segments (WQLSs), in which current required controls of a specified substance are inadequate to achieve water quality standards. For each WQLS, the State is to either establish a Total Maximum Daily Load (TMDL) of the specified substance that the waterbody can receive without violating water quality standards, or demonstrate that water quality standards are being met (CFR 2009).

A segment identified as a WQLS may not require the development and implementation of a TMDL if more recent information invalidates previous findings. The most likely scenarios obviating the need for a TMDL are: 1) analysis of more recent data indicating that the impairment no longer exists (i.e., water quality standards are being met); 2) results of more recent and updated water quality modeling which demonstrates that the segment is attaining standards; 3) refinements to water quality standards or to the interpretation of those standards accompanied by analysis demonstrating that the standards are being met; or 4) identification and correction of errors made in the initial listing.

The Maryland Department of the Environment (MDE) has identified the waters of the Middle Patuxent River watershed on the State's 2008 Integrated Report as impaired by metals - zinc (1996), sediments (1996), and nutrients – nitrogen and phosphorus (1996) (MDE 2008). The designated use of the Middle Patuxent River mainstem and its tributaries is Use I-P (Water Contact Recreation, Protection of Aquatic Life, and Public Water Supply) (COMAR 2009a,b)

The WQA presented herein will address the 1996 sediments listing, for which a data solicitation was conducted, and all readily available data from the past five years have been considered. A WQA for eutrophication to address the nutrients listing was approved by the EPA in 2007, and a WQA for zinc was approved by the EPA in 2009.

The remainder of this report lays out the general setting of the Middle Patuxent River watershed and presents a discussion of the water quality characteristics in the basin in terms of the existing water quality standards relating to sediments. Currently in Maryland, however, there are no specific numeric criteria that quantify the impact of sediment on the aquatic life of nontidal stream systems. Therefore, in order to quantify the impact of sediment on the aquatic life of the watershed stream system, a reference watershed approach was used and resulted in the establishment of a *sediment loading threshold* (Currey et al. 2006). This threshold is based on a detailed analysis of sediment loads from watersheds that are identified as supporting aquatic life (i.e., reference watersheds) based on Maryland's biocriteria (Roth et al. 1998, 2000; Stribling et al. 1998; MDE 2008). As per the 2008 Integrated Report's biological assessment of Maryland's 8-digit (MD 8-digit) watersheds, the Middle Patuxent River watershed was identified as supporting aquatic life and was therefore included as a reference watershed in the development of the *sediment loading threshold* (see Appendix A). This analysis supports the conclusion that

current watershed sediment loads do not exceed the sediment loading threshold and are therefore at a level to support the Use I-P designation for the watershed stream system, and more specifically, at a level to support aquatic life. Thus, a TMDL is not required

2.0 GENERAL SETTING

Location

The Middle Patuxent is a free flowing river that originates just south of Route 144 in the town of Cooksville in Howard County, Maryland and flows 24 miles in a southeasterly direction until it empties into the nontidal Little Patuxent River, just south of Interstate 95 near the town of Savage. On the way from its headwaters to its confluence with the Little Patuxent River, the river flows under Route 32, directly through the University of Maryland Central Farm Area (UMCFA), under Route 108, through the Middle Patuxent Environmental Area, and under Cedar Lane and Route 32. The Middle Patuxent River watershed is located in the Patuxent River sub-basin of the Chesapeake Bay watershed within Howard County, Maryland and covers approximately 58 square miles (see Figure 1). The downstream portion of Carroll's Branch is the only "high quality", or Tier II, stream segment (Benthic Index of Biotic Integrity (BIBI) and Fish Index of Biotic Integrity (FIBI) aquatic life assessment scores > 4 (on a scale of 1 to 5)) located within the watershed (southwestern portion) requiring the implementation of Maryland's antidegradation policy (COMAR 2009c; MDE 2009a). Also, approximately 0.09% of the watershed area is covered by water (i.e., streams, ponds, etc.). The total population in the Middle Patuxent River watershed is approximately 82,120 (US Census Bureau 2000).

Geology/Soils

The Middle Patuxent River lies entirely within the Northern Piedmont geologic province of Maryland. This province is characterized by gentle to steep rolling topography, low hills and ridges. The surficial geology is characterized by crystalline igneous and metamorphic rocks of volcanic origin consisting primarily of schist and gneiss (DNR 2009; MGS 2009; MDE 2000).

The Middle Patuxent River watershed is comprised of several different soil series, which include the Chester, Baile, Lehigh, and Beltsville series. The Chester series consists of very deep, well-drained soils located on upland divides and upper slopes in the Northern Piedmont geologic province that were formed in materials weathered from micaceous schist. Saturated hydraulic conductivity is moderately high to high in this soil series. The Baile series consists of very deep, poorly drained soils that have a moderately low to moderately high saturated hydraulic conductivity and are located on upland depressions and foot slopes. These soils were formed in mica schist and granitized schist and gneiss. The Lehigh series consists of deep, moderately well and somewhat poorly drained soils that were formed in residuum from metamorphosed sandstone and shale and are located on hills and low ridges. The Beltsville soil series consists of very deep, moderately well drained soils that are located in the upland and coastal plain landscapes. Saturated hydraulic conductivity for Beltsville soils is high above the fragipan and moderately low to low in the fragipan.

Soil type for the Middle Patuxent River watershed is also categorized by the United States Department of Agriculture (USDA) Soil Conservation Service (SCS) into four hydrologic soil groups: Group A soils have high infiltration rates and are typically deep well-drained to excessively drained sands or gravels; Group B soils have moderate infiltration rates and consist of moderately deep to deep and moderately well to well drained soils, with moderately fine to moderately coarse textures; Group C soils have slow infiltration rates and a layer that impedes

downward water movement and consist of moderately fine to fine textured soils; Group D soils have very slow infiltration rates and consist of clay soils with a permanently high water table that are shallow and often over nearly impervious material. The Middle Patuxent River watershed is comprised of primarily B type soils (74%) with smaller amounts of and C (16%) and D soils (10%) (USDA 2006).

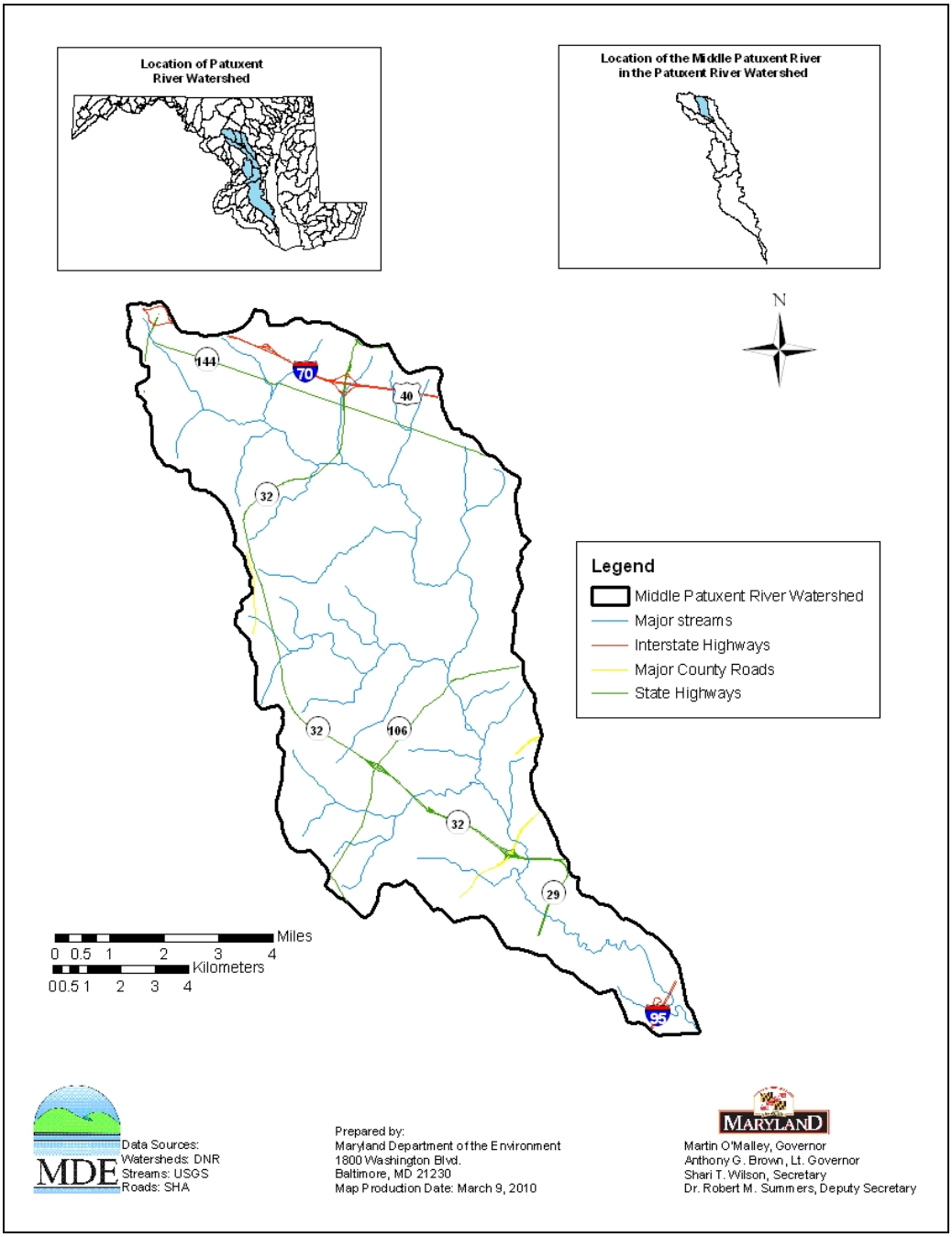

Figure 1: Location Map of the Middle Patuxent River Watershed in Howard County, Maryland

Land Use

The Middle Patuxent River watershed consists primarily of urban land use (42.6%) and forest land use (36.6%). There are also smaller amounts of crop (15.9%) and pasture (4.9%), as per the Chesapeake Bay Program Phase 5.2 (CBP P5.2) watershed model (US EPA 2009). A detailed summary of the watershed land use areas is presented in Table 1, and a land use map is provided in Figure 2 (see Appendix B for a detailed description of CBP P5.2 land use development).

Table 1: Land Use Percentage Distribution for the Middle Patuxent River Watershed

General Land Use	Detailed Land Use	Area (Acres)	Percent	Grouped Percent of Total
Crop	Animal Feeding Operations	14.0	0.0	15.9
	Hay	1,598.1	4.3	
	High Till	675.4	1.8	
	Low Till	3,580.8	9.7	
	Nursery	8.5	0.0	
Extractive	Extractive	5.9	0.0	0.0
Forest	Forest	13,433.9	36.3	36.6
	Harvested Forest	135.7	0.4	
Pasture	Pasture	1,812.7	4.9	4.9
	Trampled Pasture	0.0	0.0	
Urban	Urban: Barren	92.0	0.2	42.6
	Urban: Impervious	1,440.0	3.9	
	Urban: Pervious	14,243.8	38.5	
Total		37,040.8	100.0	100.0

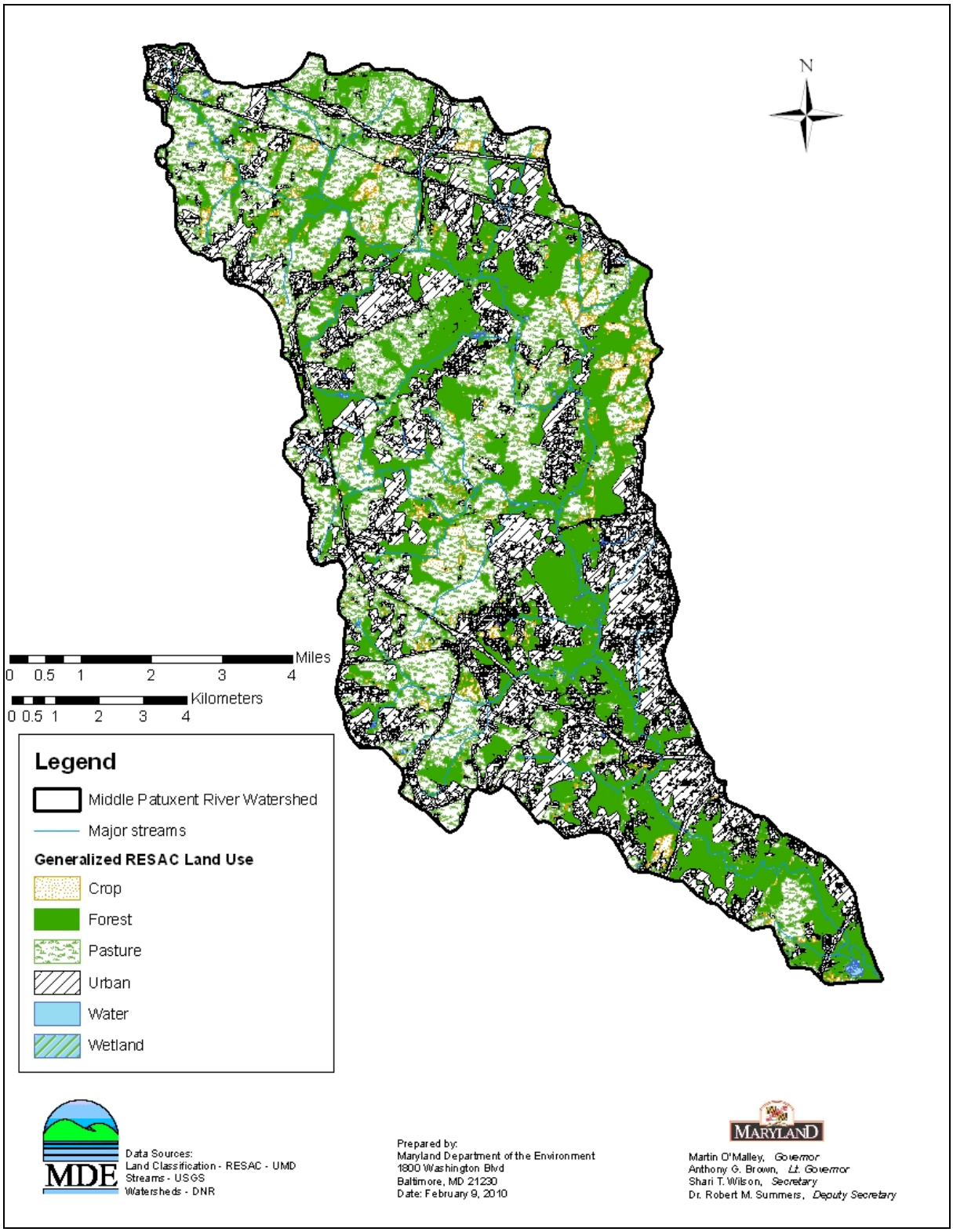

Figure 2: Land Use of the Middle Patuxent River Watershed

3.0 WATER QUALITY CHARACTERIZATION

The Maryland water quality standards surface water use designation for the Middle Patuxent River mainstem and its tributaries is Use I-P (Water Contact Recreation, Protection of Aquatic Life, and Public Water supply) (COMAR 2009a,b). A water quality standard is the combination of a designated use for a particular body of water and the water quality criteria designed to protect that use. Designated uses include activities such as fishing, swimming, drinking water supply, protection of aquatic life, and shellfish propagation and harvest. Water quality criteria consist of narrative statements and numeric values designed to protect the designated uses. Criteria may differ among waters with different designated uses.

The Middle Patuxent River watershed was originally listed on Maryland's 1996 303(d) List as impaired by elevated sediments from nonpoint sources, with supporting evidence cited in Maryland's 1996 305(b) report. The 1996 305(b) report did not directly state that elevated sediments were a concern, and it has been determined that the sediment listing was based on best professional judgment (MDE 2004; DNR 1996).

Currently in Maryland, there are no specific numeric criteria for suspended sediments. Therefore, to determine whether aquatic life is impacted by elevated sediment loads, MDE's Biological Stressor Identification (BSID) methodology is applied for watersheds that are identified on Maryland's 2008 Integrated Report as impaired for impacts to biological communities. The primary goal of the BSID analysis is to identify the most probable cause(s) for observed biological impairments throughout MD's 8-digit watersheds (MDE 2009b).

3.1 Biological Stressor Identification Analysis

The Middle Patuxent River watershed is identified in Maryland's 2008 Integrated Report as supporting aquatic life and is therefore not listed as impaired for impacts to biological communities. The biological assessment is based on the combined results of Maryland Biological Stream Survey (MBSS) round one (1995-1997) and round two (2000-2004) data, which includes 14 stations. Only three of the 14 stations, or 20% of the stream miles in the watershed, are assessed as having BIBI and/or FIBI scores significantly lower than 3.0 (on a scale of 1 to 5), which is not significantly different from the MBSS reference sites (MDE 2008). Thus, since the watershed was identified as supporting aquatic life, a BSID analysis was not required, and it can be determined that aquatic life can not be impacted by elevated sediment loads. See Figure 3 and Table 2 for station locations and information.

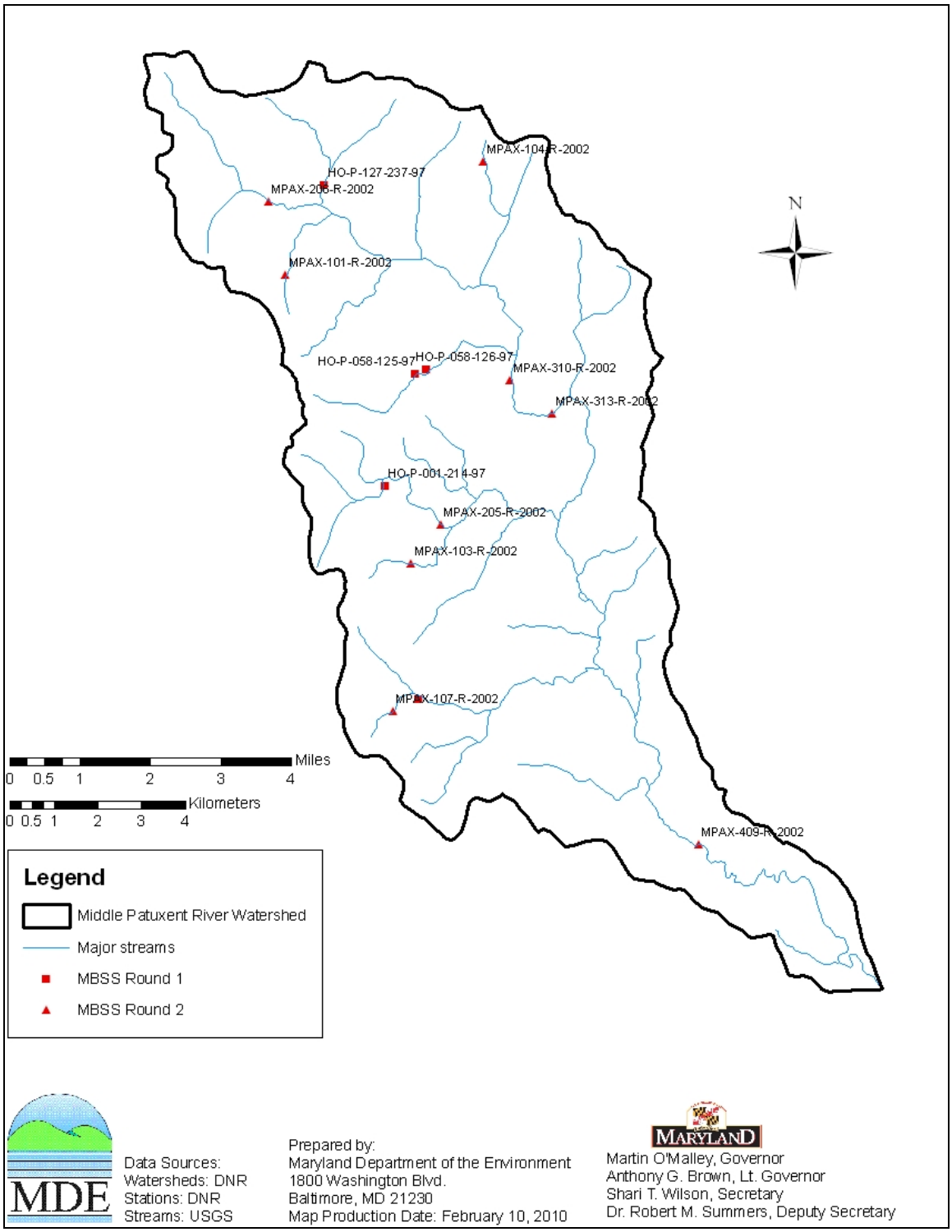

Figure 3: Monitoring Stations in the Middle Patuxent River Watershed

Table 2: Monitoring Stations in the Middle Patuxent River Watershed

Site Number	Sponsor	Site Type	Site Name	Latitude (dec degrees)	Longitude (dec degrees)
HO-P-001-214-97	MD DNR	MBSS, Round 1	Middle Patuxent River, Unnamed Tributary 1 to Unnamed Tributary 2	39.2410	-76.9630
HO-P-058-125-97	MD DNR	MBSS, Round 1	Benson Bridge	39.2640	-76.9550
HO-P-058-126-97	MD DNR	MBSS, Round 1	Benson Bridge	39.2650	-76.9520
HO-P-069-229-97	MD DNR	MBSS, Round 1	Middle Patuxent River	39.1970	-76.9540
HO-P-127-237-97	MD DNR	MBSS, Round 1	Middle Patuxent River, Unnamed Tributary 3	39.3030	-76.9790
MPAX-101-R-2002	MD DNR	MBSS, Round 2	Middle Patuxent River, Unnamed Tributary 5	39.2844	-76.9893
MPAX-103-R-2002	MD DNR	MBSS, Round 2	Middle Patuxent River, Unnamed Tributary 2	39.2249	-76.9560
MPAX-104-R-2002	MD DNR	MBSS, Round 2	Middle Patuxent River, Unnamed Tributary 6	39.3077	-76.9368
MPAX-107-R-2002	MD DNR	MBSS, Round 2	Middle Patuxent River, Unnamed Tributary 4	39.1945	-76.9610
MPAX-205-R-2002	MD DNR	MBSS, Round 2	Middle Patuxent River, Unnamed Tributary 2	39.2329	-76.9483
MPAX-206-R-2002	MD DNR	MBSS, Round 2	Middle Patuxent River	39.2996	-76.9939
MPAX-310-R-2002	MD DNR	MBSS, Round 2	Middle Patuxent River	39.2628	-76.9298
MPAX-313-R-2002	MD DNR	MBSS, Round 2	Middle Patuxent River	39.2557	-76.9187
MPAX-409-R-2002	MD DNR	MBSS, Round 2	Middle Patuxent River	39.1670	-76.8801

3.2 Current Watershed Sediment Load Analysis

In the absence of specific numeric criteria that quantify the impact of sediment on the aquatic life of non-tidal stream systems, the average annual sediment load is an indicator that is currently available and can be used to account for potential sediment related impacts to the aquatic community. Thus, it is applied in this analysis as an indicator, in addition to the biological assessment of the watershed, to determine whether aquatic life is impacted by elevated sediment loads. The average annual sediment load is estimated using the CBP P5.2 watershed model and then assessed for impairment using a reference watershed approach, as described below.

Sediment Load Estimation

The watershed model framework chosen for this WQA and average annual watershed sediment load estimation was the CBP P5.2 long-term average annual watershed model *Edge-of-stream* (EOS) loading rates. The estimation of the average annual watershed sediment load provides a quantitative estimate of the sediment load delivered to the highest order (largest) stream in the watershed. The spatial domain of the CBP P5.2 watershed model segmentation aggregates to the MD 8-digit watersheds, which is consistent with the sediment impairment listing. The EOS

loading rates were used because actual time variable CBP P5.2 calibration and scenario runs were not available upon development of the nontidal watershed sediment TMDL methodology (Currey et al. 2006). These target-loading rates have been used to calibrate the land use EOS loads within the CBP P5.2 model and thus should be consistent with future CBP modeling efforts.

The current average annual sediment load generated within the Middle Patuxent River watershed is calculated as the sum of corresponding land use EOS loads within the watershed and represent a long-term average loading rate. Individual land use EOS loads are calculated as a product of the land use area, land use target loading rate, and loss from the *Edge-of-field* (EOF) to the main channel. The loss from the EOF to the main channel is the *sediment delivery ratio* and is defined as the ratio of the sediment load reaching a basin outlet to the total erosion within the basin. A *sediment delivery ratio* is estimated for each land use type based on the proximity of the land use to the main channel. Thus, as the distance to the main channel increases, more sediment is stored within the watershed (i.e., *sediment delivery ratio* decreases). Details of the data sources for the unit loading rates and a more detailed description of the methods used to estimate the current watershed sediment load can be found in Appendix C of this report. The Middle Patuxent River watershed consists of only one CBP P5.2 model segment (see Figure 4).

For further details and results of the model analysis, see Appendix C.

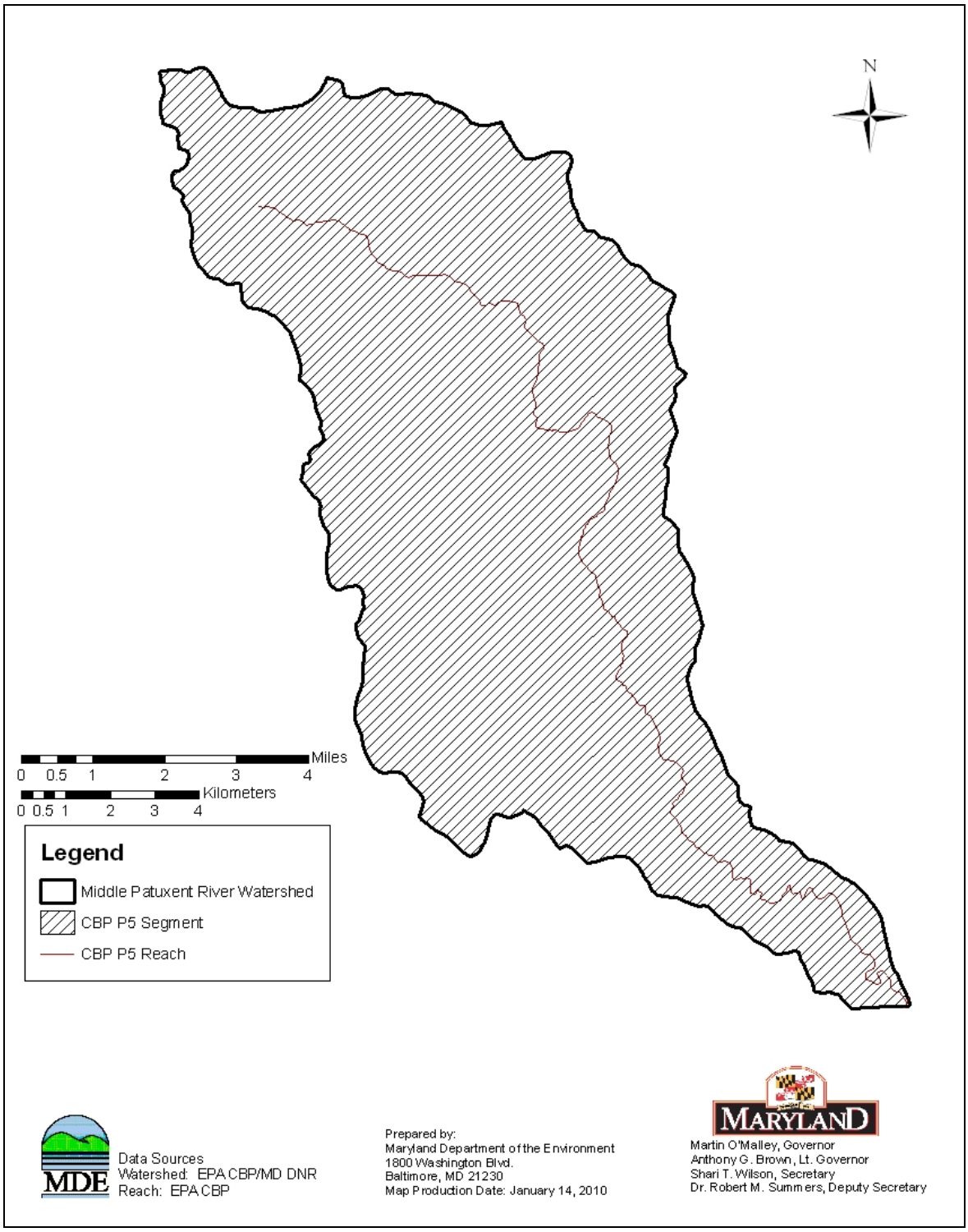

Figure 4: Middle Patuxent River Watershed Characterization Segmentation

Reference Watershed Approach

This WQA for the Middle Patuxent River watershed determines whether aquatic life is impacted by elevated sediment loads. Currently in Maryland, there are no specific numeric criteria that quantify the impact of sediment on the aquatic life of non-tidal stream systems. Therefore, in order to quantify the impact of sediment on the aquatic life of non-tidal stream systems, a reference watershed approach was used and resulted in the establishment of a *sediment loading threshold* for watersheds within the Highland and Piedmont physiographic regions (Currey et al. 2006). Reference watersheds were determined based on Maryland's biocriteria methodology. The biocriteria methodology assesses biological impairment at the 8-digit watershed scale based on the percentage of MBSS monitoring stations, translated into watershed stream miles, that have BIBI and/or FIBI scores lower than the Minimum Allowable IBI Limit (MAL). The MAL is calculated based on the average annual allowable IBI value of 3.0 (on a scale of 1 to 5). It accounts for annual variability and helps to avoid classification errors (i.e., false positives) when assessing for biological impairments (Roth et al. 1998, 2000; Stribling et al. 1998; MDE 2008).

Comparison of watershed sediment loads to loads from reference watersheds requires that the watersheds be similar in physical and hydrological characteristics. To satisfy this requirement, Currey et al. (2006) selected reference watersheds only from the Highland and Piedmont physiographic regions (see appendix A for the list of reference watersheds). This region is consistent with the non-coastal region that was identified in the 1998 development of FIBI and subsequently used in the development of BIBI (Roth et al. 1998; Stribling et al. 1998).

To reduce the effect of the variability within the Highland and Piedmont physiographic regions, the watershed sediment loads were then normalized by a constant background condition, the all forested watershed condition. This new normalized term, defined as the *forest normalized sediment load* (Y_n), represents how many times greater the current watershed sediment load is than the *all forested sediment load*. A similar approach was used by EPA Region IX for sediment TMDLs in California (e.g., Navarro River or Trinity River TMDLs), where the loading capacity was based on an analysis of the amount of human-caused sediment delivery that can occur in addition to natural sediment delivery, without causing adverse impacts to aquatic life. The *forest normalized sediment load* for this WQA is calculated as the current watershed sediment load divided by the *all forested sediment load*. The equation for the *forest normalized sediment load* is as follows:

$$Y_n = \frac{y_{ws}}{y_{for}} \qquad \text{(Equation 4.1)}$$

where:

Y_n = forest normalized sediment load
y_{ws} = current watershed sediment load (ton/yr)
y_{for} = all forested sediment load (ton/yr)

Nine reference watersheds were selected from the Highland/Piedmont region. Reference watershed *forest normalized sediment loads* were calculated using CBP P5.2 2000 land use in order to maintain consistency with MBSS sampling years. The median and 75th percentile of the

reference watershed *forest normalized sediment loads* were calculated and found to be 3.3 and 4.2 respectively. These values are in close agreement with more complex methods used to determine the *sediment loading threshold* applied in nontidal sediment TMDLs developed prior to 2009. Therefore, the median value of 3.3 was established as the *sediment loading threshold* as an environmentally conservative approach to evaluating current Middle Patuxent River watershed sediment loadings (see Appendix A for more details).

The *forest normalized sediment load* for the Middle Patuxent River watershed (estimated as 2.9) was calculated using CBP P5.2 2005 land use, to best represent current conditions. A comparison of the Middle Patuxent River watershed *forest normalized sediment load* to the *forest normalized reference sediment load* (also referred to as the *sediment loading threshold*) (3.3) demonstrates that the watershed does not exceed the *sediment loading threshold*, indicating that it is receiving loads below the maximum allowable load that it can sustain and still meet water quality standards. Thus, current watershed sediment loads are at a level to support aquatic life.

4.0 CONCLUSION

Based on the analyses presented in the preceding section of this report indicating that the watershed is identified in Maryland's 2008 Integrated Report as supporting aquatic life (i.e., not listed as impaired for impacts to biological communities) and that the current watershed sediment load does not exceed the *sediment loading threshold*, which is based on the median value of the reference watershed (i.e., watersheds identified in the 2008 Integrated Report as supporting aquatic life) forest normalized sediment loads, MDE concludes that the Middle Patuxent River watershed is not impaired for sediment. Thus, this analysis supports the conclusion that current watershed sediment loads are at a level to support the Use I-P designation for the Middle Patuxent River watershed, and more specifically, at a level to support aquatic life.

Barring the receipt of contradictory data, this report will be used to support a revision of the 2008 Integrated Report sediment listing for the Middle Patuxent River watershed from Category 5 ("waterbody is impaired, does not attain the water quality standard, and a TMDL is required") to Category 2 ("waterbody is meeting some [in this case sediments-related] water quality standards, but with insufficient data to assess all impairments"), when MDE proposes the revision of the Integrated Report. Although the waters of the Middle Patuxent River watershed do not display signs of a sediment impairment, the State reserves the right to require future controls in the watershed if evidence suggests that sediments from the basin are contributing to downstream water quality problems. For instance, reductions may be required by the forthcoming Chesapeake Bay TMDL, which is currently under development.

REFERENCES

CFR (Code of Federal Regulations). 2009. *40 CFR 130.7*. http://a257.g.akamaitech.net/7/257/2422/22jul20061500/edocket.access.gpo.gov/cfr_2006/julqtr/40cfr130.7.htm (accessed December, 2009).

COMAR (Code of Maryland Regulations). 2009a. *26.08.02.02 B(2)*. http://www.dsd.state.md.us/comar/ (accessed December, 2009).

_____. 2009b. *26.08.02.08 M(1)(a)*. http://www.dsd.state.md.us/comar/ (accessed December, 2009).

_____. 2009c. *26.08.02.04*. http://www.dsd.state.md.us/comar/ (Accessed December, 2009).

Currey, D. L, A. A. Kasko, R. Mandel, and M. J. Brush. 2006. A Methodology for Addressing Sediment Impairments in Maryland's Non-tidal Watersheds. Baltimore, MD: Maryland Department of the Environment. Also Available at http://www.mde.state.md.us/assets/document/Sediment%20TMDL%20Method%20Report_20070728.pdf.

DNR (Department of Natural Resources). 1996. *Maryland Water Quality Inventory, 1993-1995: A report on The Status of Natural Waters in Maryland Required by Section 305(b) of the Federal Water Pollution Control Act and Reported to the US Environmental Protection Agency and Citizens of the State of Maryland*. Annapolis, MD: Department of Natural Resources.

_____. 2009. *Physiography of Maryland*. http://www.dnr.state.md.us/forests/healthreport/mdmap.html (Accessed December, 2009).

Goetz, S. J., C. A. Jantz, S. D. Prince, A. J. Smith, R. Wright, and D. Varlyguin. 2004. Integrated Analysis of Ecosystem Interactions with Land Use Change: the Chesapeake Bay Watershed. In *Ecosystems and Land Use Change*, edited by R. S. DeFries, G. P. Asner, and R. A. Houghton. Washington, DC: American Geophysical Union.

MDE (Maryland Department of the Environment). 2000. *An Overview of Wetlands and Water Resources of Maryland*. Baltimore, MD: Maryland Department of the Environment.

_____. 2004. *2004 List of Impaired Surface Waters [303(d) List] and Integrated Assessment of Water Quality in Maryland Submitted in Accordance with Sections 303(d) and 305(b) of the Clean Water Act*. Baltimore, MD: Maryland Department of the Environment. Also Available at http://www.mde.state.md.us/Programs/WaterPrograms/TMDL/Maryland%20303%20dlist/final_2004_303dlist.asp.

_____. 2008. *The 2008 Integrated Report of Surface Water Quality in Maryland*. Baltimore, MD: Maryland Department of the Environment. Also Available at http://www.mde.state.md.us/Programs/WaterPrograms/TMDL/Maryland%20303%20dlist/2008_Final_303d_list.asp.

_____. 2009a. *Maryland Tier II Dataset.* Baltimore, MD: Maryland Department of the Environment.

_____. 2009b. *Maryland Biological Stressor Identification Process*. Baltimore, MD: Maryland Department of the Environment.

MGS (Maryland Geological Survey). 2009. *A Brief Description of the Geology of Maryland*. http://www.mgs.md.gov/esic/brochures/mdgeology.html (Accessed December, 2009).

Nusser, S. M., and J. J. Goebel. 1997. The National Resources Inventory: A Long-Term Multi-Resource Monitoring Program. *Environmental and Ecological Statistics* 4: 181-204.

Roth, N., M. T. Southerland, J. C. Chaillou, R. Klauda, P. F. Kazyak, S. A. Stranko, S. Weisberg, L. Hall Jr., and R. Morgan II. 1998. Maryland Biological Stream Survey: Development of a Fish Index of Biotic Integrity. *Environmental Management and Assessment* 51: 89-106.

Roth, N. E., M. T. Southerland, J. C. Chaillou, P. F. Kazyak, and S.A. Stranko. 2000. *Refinement and Validation of a Fish Index of Biotic Integrity for Maryland Streams*. Columbia, MD: Versar, Inc. with Maryland Department of Natural Resources, Monitoring and Non-Tidal Assessment Division.

Stribling, J. B., B. K. Jessup, J. S. White, D. Boward, and M. Hurd. 1998. *Development of a Benthic Index of Biotic Integrity for Maryland Streams*. Owings Mills, MD: Tetra Tech, Inc. with Maryland Department of Natural Resources, Monitoring and Non-Tidal Assessment Program.

US Census Bureau. 2000. *2000 Census*. Washington, DC: US Census Bureau.

USDA (United States Department of Agriculture). 1982. *1982 Census of Agriculture*. Washington, DC: United States Department of Agriculture.

_____. 1983. Sediment Sources, Yields, and Delivery Ratios. In *National Engineering Handbook, Section 3, Sedimentation*. Washington, D.C: United States Department of Agriculture, Natural Resources Conservation Service.

_____. 1987. *1987 Census of Agriculture*. Washington, DC: United States Department of Agriculture.

_____. 1992. *1992 Census of Agriculture*. Washington, DC: United States Department of Agriculture.

_____. 1997. *1997 Census of Agriculture*. Washington, DC: United States Department of Agriculture.

_____. 2002. *2002 Census of Agriculture*. Washington, DC: United States Department of Agriculture.

_____. 2006. *State Soil Geographic (STATSGO) Database for Maryland*. Washington, DC: United States Department of Agriculture, Natural Resources Conservation Service. Also Available at http://www.soils.usda.gov/survey/geography/statsgo/.

US EPA (U.S. Environmental Protection Agency). 2009. In Preparation. *Chesapeake Bay Phase V Community Watershed Model*. Annapolis, MD: U.S. Environmental Protection Agency with Chesapeake Bay Program.

APPENDIX A – Watershed Characterization Data

Table A-1: Reference Watersheds

MD 8-digit Name	MD 8-digit	Percent stream mile BIBI/FIBI < 3.0 (%)[1,2]	Forest Normalized Sediment Load[3,4]
Deer Creek	02120202	11	3.9
Broad Creek	02120205	12	4.5
Little Gunpowder Falls	02130804	15	3.3
Prettyboy Reservoir	02130806	16	3.7
Middle Patuxent River	02131106	20	3.2
Brighton Dam	02131108	11	4.2
Sideling Creek	02140510	20	1.9
Fifteen Mile Creek	02140511	4	1.6
Savage River	02141006	7	2.5
Median			**3.3**
75th			**4.2**

Notes: [1]Based on the percentage of MBSS stations with BIBI and/or FIBI scores significantly lower than 3.0 within the MD 8-digit watershed (MDE 2008).

[2]The percent stream miles with BIBI and/or FIBI scores significantly lower than the 3.0 threshold to determine if an 8-digit watershed is impaired for impacts to biological communities is based on a comparison to reference conditions (MDE 2008).

[3]Forest normalized sediment loads based on Maryland watershed area only (consistent with MBSS random monitoring data).

[4]The reference watershed forest normalized sediment loads presented in this appendix are based on CBP P5.2 2000 land use, and the Middle Patuxent River watershed forest normalized sediment load presented in Section 3.0 and Appendix D is based on CBP P5.2 2005 land use (See Section 4.0 for a more detailed description of the reason for this difference).

APPENDIX B – Land Use Methodology

The framework used to characterize the watershed land use in this WQA was originally developed for the CBP P5.2 watershed model.[1] The CBP P5.2 land use Geographic Information System (GIS) framework was based on two distinct layers of development. The first GIS layer was developed by the Regional Earth Science Applications Center (RESAC) at the University of Maryland and was based on satellite imagery (Landsat 7-Enhanced Thematic Mapper (ETM) and 5-Thematic Mapper (TM)) (Goetz et al. 2004). This layer did not provide the required level of accuracy that is especially important when developing agricultural land uses. In order to develop accurate agricultural land use calculations, the CBP P5.2 used county level U.S. Agricultural Census data as a second layer (USDA 1982, 1987, 1992, 1997, 2002).

Given that land cover classifications based on satellite imagery are likely to be least accurate at edges (i.e., boundaries between covers), the RESAC land uses bordering agricultural areas were analyzed separately. If the agricultural census data accounted for more agricultural use than the RESAC's data, appropriate acres were added to agricultural land uses from non-agricultural land uses. Similarly, if census agricultural land estimates were smaller than RESAC's, appropriate acres were added to non-agricultural land uses.

Adjustments were also made to the RESAC land cover to determine developed land uses. RESAC land cover was originally based on the United States Geological Survey (USGS) protocols used to develop the 2000 National Land Cover Database. The only difference between the RESAC and USGS approaches was RESAC's use of town boundaries and road densities to determine urban land covered by trees or grasses. This approach greatly improved the accuracy of the identified urban land uses, but led to the misclassification of some land adjacent to roads and highways as developed land. This was corrected by subsequent analysis. To ensure that the CBP P5.2 watershed model accurately represented development over the simulation period, post-processing techniques that reflected changes in urban land use have been applied.

The result of this approach is that CBP P5.2 land use does not exist in a single GIS coverage; instead it is only available in a tabular format. The CBP P5.2 watershed model is comprised of 25 land uses. Most of these land uses are differentiated only by their nitrogen and phosphorus loading rates. The land uses are divided into 13 classes with distinct sediment erosion rates. Table 1 in Section 2.0 of the main report lists the CBP P5.2 generalized land uses, detailed land uses, which are classified by their erosion rates, and the acres of each land use in the Middle Patuxent River watershed. Details of the land use development methodology have been summarized in the report entitled *Chesapeake Bay Phase 5 Community Watershed Model* (US EPA 2009).

[1] The EPA Chesapeake Bay Program developed the first watershed model in 1982. There have been many upgrades since the first phase of this model. The CBP P5.2 was developed to estimate flow, nutrient, and sediment loads to the Bay.

APPENDIX C – Watershed Sediment Loads Calculation Methodology

General Load Estimation Methodology

Sediment loads generated within the Middle Patuxent River watershed are estimated based on the *EOS calibration target loading rates* from the CBP P5.2 model. This approach is based on the fact that not all of the EOF sediment load is delivered to the stream or river (some of it is stored on fields down slope, at the foot of hillsides, or in smaller rivers or streams that are not represented in the model). To calculate the actual EOS loads, a *sediment delivery ratio* (the ratio of sediment reaching a basin outlet compared to the total erosion within the basin) is used. Details of the methods used to calculate sediment load have been summarized in the report entitled *Chesapeake Bay Phase 5 Community Watershed Model* (US EPA 2009).

Edge-of-Field Target Erosion Rate Methodology

EOF target erosion rates for agricultural land uses and forested land use were based on erosion rates determined by the Natural Resource Inventory (NRI). NRI is a statistical survey of land use and natural resource conditions conducted by the Natural Resource Conservation Service (NRCS) (USDA 2006). Sampling methodology is explained by Nusser and Goebel (1997).

Estimates of average annual erosion rates for pasture and cropland are available on a county basis at five-year intervals, starting in 1982. Erosion rates for forested land uses are not available on a county basis from NRI; however, for the purpose of the Chesapeake Bay Program Phase 4.3 (CBP P4.3) watershed model, NRI calculated average annual erosion rates for forested land use on a watershed basis. These rates are still being used as targets in the CBP P5.2 model.

The average value of the 1982 and 1987 surveys was used as the basis for EOF target loads. The erosion rates from this period do not reflect best management practices (BMPs) or other soil conservation policies introduced in the wake of the effort to restore the Chesapeake Bay. To compensate for this, a BMP factor was included in the loading estimates using best available "draft" information from the CBP P5.2. Rates for urban pervious, urban impervious, and barren land were based on a combination of best professional judgment, literature analysis, and regression analysis. Table C-1 lists erosion rates specific to the Middle Patuxent River watershed.

Table C-1: Summary of EOF Erosion Rate Calculations

Land Use	Data Source	Howard County (tons/acre/year)
Forest	Phase 2 NRI	0.5
Harvested Forest[1]	Average Phase 2 NRI (x 10)	3
Nursery	Pasture NRI (x 9.5)	30.4
Pasture	Pasture NRI (1982-1987)	3.2
Trampled pasture[2]	Pasture NRI (x 9.5)	30.4
Animal Feeding Operations[2]	Pasture NRI (x 9.5)	30.4
Hay[2]	Crop NRI (1982-1987) (x 0.32)	2.02
High Till[2]	Crop NRI (1982-1987) (x 1.25)	7.89
Low Till[2]	Crop NRI (1982-1987) (x 0.75)	4.73
Pervious Urban	Intercept Regression Analysis	0.74
Extractive	Best professional judgment	10
Barren	Literature survey	12.5
Impervious	100% Impervious Regression Analysis	5.18

Notes: [1]Based on an average of NRI values for the Chesapeake Bay Phase 5 segments.
[2]NRI score data adjusted based on land use.

Sediment Delivery Ratio: The base formula for calculating *sediment delivery ratio*s in the CBP P5.2 model is the same as the formula used by the NRCS (USDA 1983).

$$DF = 0.417762 * A^{-0.134958} - 0.127097 \qquad \text{(Equation C1)}$$

Where:
DF (delivery factor) = the sediment delivery ratio
A = drainage area in square miles

In order to account for the changes in sediment loads due to distance traveled to the stream, the CBP P5.2 model uses the *sediment delivery ratio*. Land use specific *sediment delivery ratios* were calculated for each river segment using the following procedure:

(1) mean distance of each land use from the river reach was calculated;

(2) *sediment delivery ratio*s for each land use were calculated (drainage area in Equation C1 was assumed to be equal to the area of a circle with radius equal to the mean distance between the land use and the river reach).

Edge-of-Stream Loads

EOS loads are the loads that actually enter the river reaches (i.e., the mainstem of a watershed). Such loads represent not only the erosion from the land but all of the intervening processes of deposition on hillsides and sediment transport through smaller rivers and streams.

APPENDIX D – Middle Patuxent River Watershed Sediment Loads

Sediment loads were estimated for the current condition and the all forested watershed condition. The forest normalized sediment load (representing how many times greater the current watershed sediment load is than the all forested sediment load) is calculated as the current watershed sediment load divided by the all forested sediment load. A summary of the current sediment budget and the forest normalized sediment loads for the Middle Patuxent River watershed are presented in table D-1 and D-2.

Table D-1: Detailed Baseline Sediment Budget Loads Within the Middle Patuxent River Watershed

General Land Use	Description	Load (Ton/Yr)	Percent	Grouped Percent of Total
Crop	Animal Feeding Operations	88.3	0.7	43.2
	Hay	643.4	5.4	
	High Till	980.7	8.2	
	Low Till	3375.0	28.4	
	Nursery	53.7	0.5	
Extractive	Extractive	12.9	0.1	0.1
Forest	Forest	1645.7	13.8	14.7
	Harvested Forest	100.1	0.8	
Pasture	Pasture	1018.9	8.6	8.6
	Trampled Pasture	0.0	0.0	
Urban	Urban: Barren	253.0	2.1	33.5
	Urban: Impervious	1541.9	13.0	
	Urban: Pervious	2185.4	18.4	
	Total	**11,899.1**	**100.0**	**100.0**

Table D-2: Sediment Loads for the Middle Patuxent River Watershed

Area (Acres)	Current Watershed Sediment Load (Ton/Yr)[1]	All Forested Load (Ton/Yr)	Forest Normalized Sediment Load
37,040.8	11,899.1	4,150.2	2.9

Note: [1]ton/yr = tons per year