Total Maximum Daily Load of Sediment in the Patapsco River Lower North Branch Watershed, Baltimore City and Baltimore, Howard, Carroll and Anne Arundel Counties, Maryland

FINAL

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Submitted to:

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1650 Arch Street
Philadelphia, PA 19103-2029

September 2011

EPA Submittal Date: September 3, 2009
EPA Approval Date: September 30, 2011

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List of Abbreviations

BIBI	Benthic Index of Biotic Integrity
BIP	Buffer Incentive Program
BMP	Best Management Practices
BSID	Biological Stressor Identification
CBP P5	Chesapeake Bay Program Phase 5
CV	Coefficient of Variation
CWA	Clean Water Act
DNR	Maryland Department of Natural Resources
EOF	Edge-of-Field
EOS	Edge-of-Stream
EPA	Environmental Protection Agency
EPT	Ephemeroptera, Plecoptera, and Trichoptera
EPSC	Environmental Permit Service Center
ESD	Environmental Site Design
ETM	Enhanced Thematic Mapper
FDC	Flow Duration Curve
FIBI	Fish Index of Biologic Integrity
GIS	Geographic Information System
HSPF	Hydrological Simulation Program – FORTRAN
IBI	Index of Biotic Integrity
LA	Load Allocation
MAL	Minimum Allowable IBI Limit
MBSS	Maryland Biological Stream Survey
MD 8-Digit	Maryland 8-digit Watershed
MDE	Maryland Department of the Environment
MDL	Maximum Daily Load
MGD	Millions of Gallons per Day
mg/l	Milligrams per liter
MOS	Margin of Safety
MS4	Municipal Separate Storm Sewer System

NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resource Conservation Service
NRI	Natural Resources Inventory
PCBs	Polychlorinated Biphenyls
PSU	Primary Sampling Unit
RESAC	Regional Earth Science Applications Center
TMDL	Total Maximum Daily Load
Ton/yr	Tons per Year
TSD	Technical Support Document
TSS	Total Suspended Solids
TM	Thematic Mapper
USGS	United Stated Geological Survey
WLA	Waste Load Allocation
WTP	Water Treatment Plant
WQA	Water Quality Analysis
WQIA	Water Quality Improvement Act
WQLS	Water Quality Limited Segment
WWTP	Wastewater Treatment Plant

EXECUTIVE SUMMARY

This document, upon approval by the U.S. Environmental Protection Agency (EPA), establishes a Total Maximum Daily Load (TMDL) for sediment in the Patapsco River Lower North Branch watershed (basin number 02130906) (2010 *Integrated Report of Surface Water Quality in Maryland* Assessment Unit ID: MD-02130906). 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 required to either establish a 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 2008b).

The Maryland Department of the Environment (MDE) has identified the waters of the Patapsco River Lower North Branch on the State's 2010 Integrated Report as impaired by metals – Chromium, Arsenic, Cadmium, Copper, Mercury, Nickel, Lead, Selenium, and Zinc (1996), metals – Lead and Copper (2006 – Herbert Run), sediments (1996), nutrients - Phosphorus (1996), bacteria (2002 and 2008), Polychlorinated Biphenyls (PCBs) in fish tissue (2008), chlorides (2010), sulfates (2010), and impacts to biological communities (2006) (MDE 2010). The designated use of the Patapsco River Lower North Branch and its tributaries is Use I (Water Contact Recreation, and Protection of Nontidal Warmwater Aquatic Life), except for Brice Run, which is designated as Use III (Nontidal Coldwater) (COMAR 2008a,b,c).

The TMDL established 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. The Patapsco River Lower North Branch was delisted for metals – Chromium, Arsenic, Cadmium, Copper, Mercury, Nickel, Lead, Selenium, and Zinc in 2005, metals – Lead and Copper in Herbert Run in 2008, and bacteria in 2004 (relisted for bacteria in 2008). A nutrient Water Quality Analysis (WQA) and a bacteria TMDL were approved by the EPA in 2009. The general listing for impacts to biological communities was removed due to a stressor identification analysis completed in 2009, and as a result, the 2010 Integrated Report now identifies chlorides, sulfates, and sediments as specific stressors impairing aquatic life (MDE 2010).

The Patapsco River Lower North Branch watershed aquatic health scores, consisting of the Benthic Index of Biotic Integrity (BIBI) and Fish Index of Biotic Integrity (FIBI), indicate that the biological metrics for the watershed exhibit a significant negative deviation from reference conditions based on Maryland's biocriteria listing methodology. The biocriteria listing methodology assesses the overall condition of Maryland's 8-digit (MD 8-digit) watersheds that have multiple sites with failing biological metrics by measuring the percentage of stream miles that are degraded, based on the BIBI and FIBI scores at these sites, and then calculating whether the percentage of degraded stream miles differs significantly from reference conditions (i.e., unimpaired watershed <10% stream miles degraded) (Roth et al. 2005; MDE 2010). The objective of the TMDL established herein is to ensure that there will be no sediment impacts affecting aquatic health, thereby establishing a sediment load that supports the Use I/III designations for the Patapsco River Lower North Branch watershed.

Currently in Maryland, there are no specific numeric criteria that quantify the impact of sediment on the aquatic health of nontidal stream systems. Therefore, to determine whether aquatic health is impacted by elevated sediment loads, MDE's recently developed *Biological Stressor Identification* (BSID) methodology was applied. The BSID identifies the most probable cause(s) for observed biological impairments throughout MD's 8-digit watersheds by ranking the likely stressors affecting a watershed using a suite of available physical, chemical, and land use data. The ranking of stressors was conducted via a risk-based, systematic, weight-of-evidence approach. The risk-based approach estimates the strength of association between various stressors and a degraded biological community. The BSID analysis then identifies individual stressors (pollutants) as probable or unlikely causes of the poor biological conditions within a given MD 8-digit watershed and subsequently concludes whether or not these individual stressors or groups of stressors are contributing to the impairment (MDE 2009a).

The BSID analysis for the Patapsco River Lower North Branch watershed concludes that biological communities are likely impaired due to flow/sediment related stressors. Three individual stressors (channel alteration, channelization, and bar formation) that are associated with sediment related impacts and an altered hydrologic regime were identified as being probable causes of the biological impairment. Furthermore, the degradation of biological communities in the watershed is strongly associated with urban land use and its concomitant effects: altered hydrology, sediment related impacts, and elevated levels of sulfate, chlorides, and conductivity (a measure of the presence of dissolved substances) (MDE 2009b).

In order to quantify the impact of sediment on the aquatic health of non-tidal stream systems, a reference watershed TMDL 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 2010). This threshold is then used to determine a watershed specific sediment TMDL.

The computational framework chosen for the Patapsco River Lower North Branch watershed TMDL was the Chesapeake Bay Program Phase 5 (CBP P5) watershed model target *edge-of-field* (EOF) land use sediment loading rate calculations combined with a *sediment delivery ratio*. The *edge-of-stream* (EOS) sediment load is calculated per land use as a product of the land use area, land use target loading rate, and loss from the EOF to the main channel. The spatial domain of the CBP P5 watershed model segmentation aggregates to the MD 8-digit watersheds, which is consistent with the impairment listing.

EPA's regulations require TMDLs to take into account seasonality and critical conditions for stream flow, loading, and water quality parameters (CFR 2008b). The intent of this requirement is to ensure that the water quality of the waterbody is protected during times when it is most vulnerable. The biological monitoring data used to determine the reference watersheds reflect the impacts of stressors (i.e., sediment impacts to stream biota) over the course of time (i.e., captures the impacts of all high and low flow events). Thus, critical conditions are inherently addressed. Seasonality is captured in two components. First, it is implicitly included in biological sampling as biological communities reflect the impacts of stressors over time, as described above. Second, the Maryland Biological Stream Survey (MBSS) dataset included benthic sampling in the spring and fish sampling in the summer.

All TMDLs need to be presented as a sum of waste load allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources generated within the assessment unit, natural background, tributary, and adjacent segment loads. Furthermore, all TMDLs must include a margin of safety (MOS) to account for any lack of knowledge and uncertainty concerning the relationship between loads and water quality (CFR 2008a,b). It is proposed that the estimated variability around the reference watershed group used in this analysis already accounts for such uncertainty, and therefore the MOS is implicitly included.

The Patapsco River Lower North Branch Total Baseline Sediment Load is 37,728.1 tons per year (ton/yr). This baseline load consists of upstream loads generated outside the assessment unit (i.e., MD 8-digit watershed): a South Branch Patapsco River Upstream Baseline Load (BL_{SB}) of 15,019.4 ton/yr, and loads generated within the assessment unit: a Patapsco River Lower North Branch Watershed Baseline Load Contribution of 22,708.8 ton/yr. The Patapsco River Lower North Branch Watershed Baseline Load Contribution is further subdivided into a nonpoint source baseline load (Nonpoint Source BL_{PR}) and two types of point source baseline loads: National Pollutant Discharge Elimination System (NPDES) regulated stormwater (NPDES Stormwater BL_{PR}) and regulated process water (Process Water BL_{PR}) (see Table ES-1).

Table ES-1: Patapsco River Lower North Branch Baseline Sediment Loads (ton/yr)

		Upstream Baseline Load[1]		**Patapsco River Lower North Branch Watershed Baseline Load Contribution**				
Total Baseline Load (ton/yr)	=	$\mathbf{BL_{SB}}$	+	**Nonpoint Source $\mathbf{BL_{PR}}$**	+	**NPDES Stormwater $\mathbf{BL_{PR}}$**	+	**Process Water $\mathbf{BL_{PR}}$**
37,728.1	=	15,019.4	+	7,160.4	+	15,536.8	+	11.5

Note: [1] Although the Upstream Baseline Load is reported here as a single value, it could include point and nonpoint sources.

The Patapsco River Lower North Branch Average Annual TMDL of Sediment/Total Suspended Solids (TSS) is 35,244.2 tons per year. Biological results from the Maryland Department of Natural Resources (DNR) Core/Trend stations along the mainstem of the Patapsco River Lower North Branch indicate that mainstem water quality can be classified as good. Based on this information, MDE concluded that the sediment impairment in the Patapsco River Lower North Branch watershed is restricted to the lower order streams within the watershed. Consequently, no sediment reductions have been applied to the loads transported to the main channel of the Patapsco River Lower North Branch via the South Branch Patapsco River. The TMDL consists of allocations attributed to loads generated outside the assessment unit referred to as Upstream Load Allocations: a South Branch Patapsco Upstream Load Allocation (LA_{SB}) of 15,019.4 ton/yr, and allocations attributed to loads generated within the assessment unit: a Patapsco River Lower North Branch Watershed TMDL Contribution of 20,224.8 ton/yr. The Patapsco River Lower North Branch Watershed TMDL Contribution is further subdivided into point and nonpoint source allocations and is comprised of a Load Allocation (LA_{PR}) of 7,160.4 tons per year, an NPDES Stormwater Waste Load Allocation (NPDES Stormwater WLA_{PR}) of 13,052.9 tons per year, and a Process Water Waste Load Allocation (Process Water WLA_{PR}) of 11.5 tons per year (see Table ES-2). This TMDL will ensure that the sediment loads and resulting effects are at a level to support the Use I/III designations for the Patapsco River Lower North Branch watershed, and more specifically, at a level the watershed can sustain without causing any sediment related impacts to aquatic health. The TMDL, however, will not completely resolve the impairment to biological communities within the watershed. Since the BSID watershed analysis identifies other stressors (i.e., chlorides, sulfate, conductivity) as impacting the biological conditions, this impairment remains to be fully addressed through the Integrated Report listing process and the TMDL development process, such that all impairing substances identified as impacting biological communities in the watershed are reduced to levels that will meet water quality standards, as established in future TMDLs for those substances (MDE 2009a).

Table ES-2: Patapsco River Lower North Branch Average Annual TMDL of Sediment/Total Suspended Solids (ton/yr)

		LA				**WLA**				
TMDL (ton/yr)	=	**LA_{SB}**	+	**LA_{PR}**	+	**NPDES Stormwater WLA_{PR}**	+	**Process Water WLA_{PR}**	+	**MOS**
35,244.2	=	15,019.4		7,160.4	+	13,052.9	+	11.5	+	Implicit
		Upstream Load Allocations[1,2]		Patapsco River Lower North Branch Watershed TMDL Contribution						

Notes:[1] Although for the purpose of this analysis the upstream load is referred to as an LA, it could include loads from point and nonpoint sources.
[2] A delivery factor of 1 was used for the Upstream Load Allocation.

Table ES-3: Patapsco River Lower North Branch Baseline Load, TMDL, and Total Reduction Percentage

Baseline Load (ton/yr)	**TMDL** (ton/yr)	**Total Reduction** (%)
37,728.1	35,244.2	6.6

In addition to the TMDL value, a Maximum Daily Load (MDL) is also presented in this document. The calculation of the MDL, which is derived from the TMDL average annual loads, is explained in Appendix C and presented in Table C-1.

Once the EPA has approved this TMDL, and it is known what measures must be taken to reduce pollution levels, implementation of best management practices (BMPs) is expected to take place primarily via the municipal separate storm sewer system (MS4) permitting process for medium and large municipalities. MDE intends for the required reduction to be implemented in an iterative process that first addresses those sources with the largest impact to water quality, with consideration given to ease and cost of implementation.

Maryland has several well-established programs to draw upon, including the Water Quality Improvement Act of 1998 (WQIA) and the Federal Nonpoint Source Management Program (§ 319 of the Clean Water Act). Several potential funding sources available for local governments for implementation are available, such as the Buffer Incentive Program (BIP), the State Water Quality Revolving Loan Fund, and the Stormwater Pollution Cost Share Program.

1.0 INTRODUCTION

This document, upon approval by the U.S. Environmental Protection Agency (EPA), establishes a Total Maximum Daily Load (TMDL) for sediment in the Patapsco River Lower North Branch watershed (basin number 02130906) (2010 *Integrated Report of Surface Water Quality in Maryland* Assessment Unit ID: MD-02130906). Section 303(d)(1)(C) of the federal Clean Water Act (CWA) and the EPA's implementing regulations direct each state to develop a TMDL for each impaired water quality limited segment (WQLS) on the state's Integrated Report, taking into account seasonal variations, critical conditions, and a protective margin of safety (MOS) to account for uncertainty (CFR 2008b). A TMDL reflects the total pollutant loading of the impairing substance a waterbody can receive and still meet water quality standards.

TMDLs are established to determine the pollutant load reductions needed to achieve and maintain water quality standards. 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 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 Maryland Department of the Environment (MDE) has identified the waters of the Patapsco River Lower North Branch on the State's 2010 Integrated Report as impaired by metals – Chromium, Arsenic, Cadmium, Copper, Mercury, Nickel, Lead, Selenium, and Zinc (1996), metals – Lead and Copper (2006 – Herbert Run), sediments (1996), nutrients – Phosphorus (1996), bacteria (2002 and 2008), Polychlorinated Biphenyls (PCBs) in fish tissue (2008), chlorides (2010), sulfates (2010), and impacts to biological communities (2006) (MDE 2010). The designated use of the Patapsco River Lower North Branch and its tributaries is Use I (Water Contact Recreation, and Protection of Nontidal Warmwater Aquatic Life), except for Brice Run, which is designated as Use III (Nontidal Coldwater) (COMAR 2008a,b,c).

The TMDL established 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. The Patapsco River Lower North Branch was delisted for metals – Chromium, Arsenic, Copper, Mercury, Nickel, Lead, Selenium, and Zinc in 2005, metals – Lead and Copper in Herbert Run in 2008, and bacteria in 2004 (relisted in 2008). A nutrient Water Quality Analysis (WQA) and a bacteria TMDL were approved by the EPA in 2009. The general listing for impacts to biological communities was removed due to a stressor identification analysis completed in 2009, and as a result, the 2010 Integrated Report now identifies chlorides, sulfates, and sediments as specific stressors impairing aquatic life (MDE 2010).

The objective of the TMDL established herein is to ensure that there will be no sediment impacts affecting aquatic health, thereby establishing a sediment load that supports the Use I/III designations for the Patapsco River Lower North Branch watershed. Currently in Maryland, there are no specific numeric criteria that quantify the impact of sediment on the aquatic health of nontidal stream systems. Therefore, to determine whether aquatic health is impacted by elevated sediment loads, MDE's recently developed *Biological Stressor Identification* (BSID) methodology was applied.

The BSID identifies the most probable cause(s) for observed biological impairments throughout Maryland's 8-digit (MD 8-digit) watersheds by ranking the likely stressors affecting a watershed using a suite of available physical, chemical, and land use data. The ranking of stressors was conducted via a risk-based, systematic, weight-of-evidence approach. The risk-based approach estimates the strength of association between various stressors and a degraded biological community. The BSID analysis then identifies individual stressors (pollutants) as probable or unlikely causes of the poor biological conditions within a given MD 8-digit watershed and subsequently concludes whether or not these individual stressors or groups of stressors are contributing to the impairment (MDE 2009a).

In order to quantify the impact of sediment on the aquatic health of non-tidal stream systems, a reference watershed TMDL 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 2010). This threshold is then used to determine a watershed specific sediment TMDL.

2.0 SETTING AND WATER QUALITY DESCRIPTION

2.1 General Setting

Location

The nontidal Patapsco River originates in Carroll County, Maryland and flows 58 miles until it empties into the tidal Patapsco River. The watershed is located in the Patapsco River sub-basin of the Chesapeake Bay watershed and covers approximately 368 square miles. The watershed can be subdivided into three distinct MD 8-digit watersheds: the Patapsco River Lower North Branch, the South Branch Patapsco River, and the Liberty Reservoir.

The assessment unit identified on the Maryland 2008 Integrated Report and consequently addressed by this TMDL consists only of the Patapsco River Lower North Branch Watershed. Sediment loads transported to the main channel of the Patapsco River Lower North Branch via the South Branch Patapsco River are included in the analysis, but will be referred to as upstream loads. Sediment loads from the Liberty Reservoir were determined to be *de minimis* based on the infrequent discharge of the reservoir, and have not been included in this analysis (MDE 2007b).

The Patapsco River Lower North Branch watershed comprises the downstream portions of the nontidal Patapsco River located in the Patapsco River sub-basin of the Chesapeake Bay watershed (see Figure 1). The watershed covers 118 square miles and is located within portions of Baltimore, Howard, Carroll, and Anne Arundel Counties and Baltimore City. There are no "high quality," or "Tier II", stream segments (Benthic Index of Biotic Integrity (BIBI)/Fish Index of Biotic Integrity (FIBI) aquatic health scores > 4 (scale 1-5)) within the watershed requiring the implementation of Maryland's anti-degradation policy. Also, approximately 0.1% of the total watershed area is covered by water (i.e., streams, ponds, etc.). The total population in the Patapsco River Lower North Branch watershed is approximately 289,886 (US Census Bureau 2000).

Geology/Soils

The Patapsco River Lower North Branch watershed drains from northwest to southeast, following the dip of the underlying crystalline bedrock in the Piedmont geologic province of Central Maryland, which is characterized by a gentle to steep rolling topography, consisting of a series of small hills and ridges. Downstream portions of the watershed are also located in the Coastal Plain province of Central Maryland, which is characterized by broad upland areas with low slopes and slow drainage (DNR 2008; MGS 2008; MDE 2000). The surface elevations within the watershed range from approximately 620 feet above sea level to sea level itself at the shoreline of the Chesapeake Bay. Stream channels of the sub-watersheds are well incised in the Eastern Piedmont and exhibit relatively straight reaches and sharp bends, reflecting their tendency to follow zones of fractured or weathered rock. The stream channels broaden abruptly as they flow down across the fall line into the soft, flat Coastal Plain sediments (CES 1995).

Crystalline rocks of volcanic origin consisting primarily of schist and gneiss characterize the surficial geology. These formations are resistant to short-term erosion and often determine the limits of the stream bank and streambed. These crystalline formations decrease in elevation from northwest to southeast and eventually extend beneath the younger sediments of the Coastal Plain. The fall line represents the transition between the Atlantic Coastal Plain and the Piedmont province. Thick, unconsolidated marine sediments deposited over the crystalline rock of the Piedmont province characterize the surficial geology of the Atlantic Coastal Plain province. The deposits include clays, silts, sands and gravels (CES 1995).

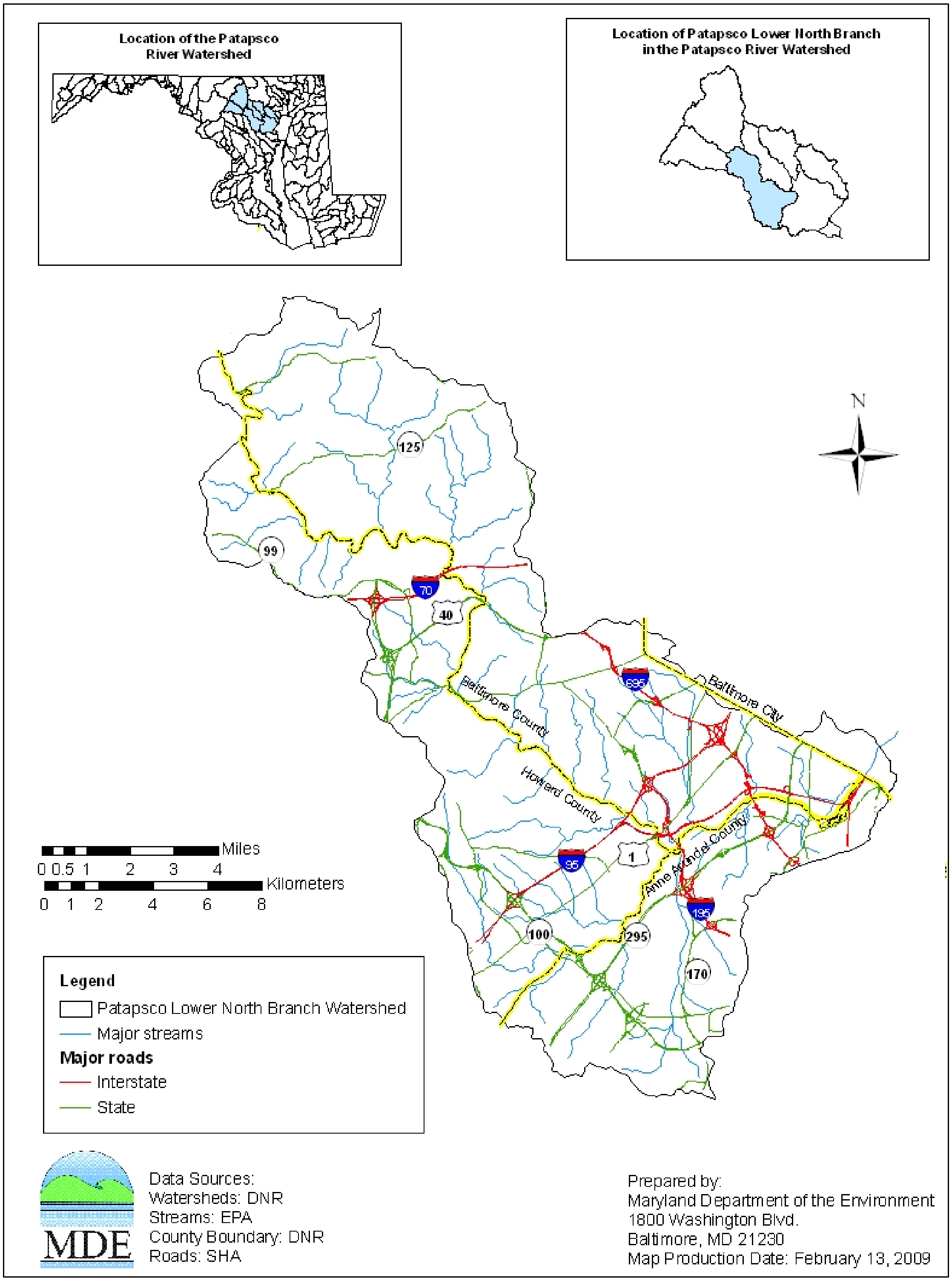

Figure 1: Location Map of the Patapsco River Lower North Branch Watershed in Baltimore City and Baltimore, Howard, Carroll, and Anne Arundel Counties, Maryland

2.1.1. Land Use

Land Use Methodology

The land use framework used to develop this TMDL was originally developed for the Chesapeake Bay Program Phase 5 (CBP P5) watershed model.[1] The CBP P5 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 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 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 land use does not exist in a single GIS coverage; instead it is only available in a tabular format. The CBP P5 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 lists the CBP P5 generalized land uses, detailed land uses, which are classified by their erosion rates, and the acres of each land use in the Patapsco River Lower North Branch watershed. Details of the land use development methodology have been summarized in the report entitled *Chesapeake Bay Phase 5 Community Watershed Model* (US EPA 2008).

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[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 was developed to estimate flow, nutrient, and sediment loads to the Bay.

Patapsco River Lower North Branch Watershed Land Use Distribution

The Patapsco River Lower North Branch watershed consists mostly of urban and forest land use. The land use distribution in the watershed is approximately 35% forest, 59% urban, 5% crop, and 2% pasture. A detailed summary of the watershed land use areas is presented in Table 1, and a land use map is provided in Figure 2.

Table 1: Land Use Percentage Distribution for the Patapsco River Lower North Branch Watershed

General Land Use	Detailed Land Use	Area (Acres)	Percent	Grouped Percent of Total
Crop	Animal Feeding Operations	78.6	0.1	
	Hay	1,056.1	1.4	
	High Till	555.4	0.7	
	Low Till	1,774.3	2.3	
	Nursery	4.2	0.0	4.6
Extractive	Extractive	103.0	0.1	0.1
Forest	Forest	25,908.3	34.2	
	Harvested Forest	261.7	0.3	34.5
Pasture	Pasture	1,202.5	1.6	
	Trampled Pasture	3.4	0.0	1.6
Urban	Urban: Barren (Construction)	89.7	0.1	
	Urban: Impervious	11,941.3	15.8	
	Urban: Pervious	32,796.5	43.3	59.2
Total		75,775.1	100.0	100.0

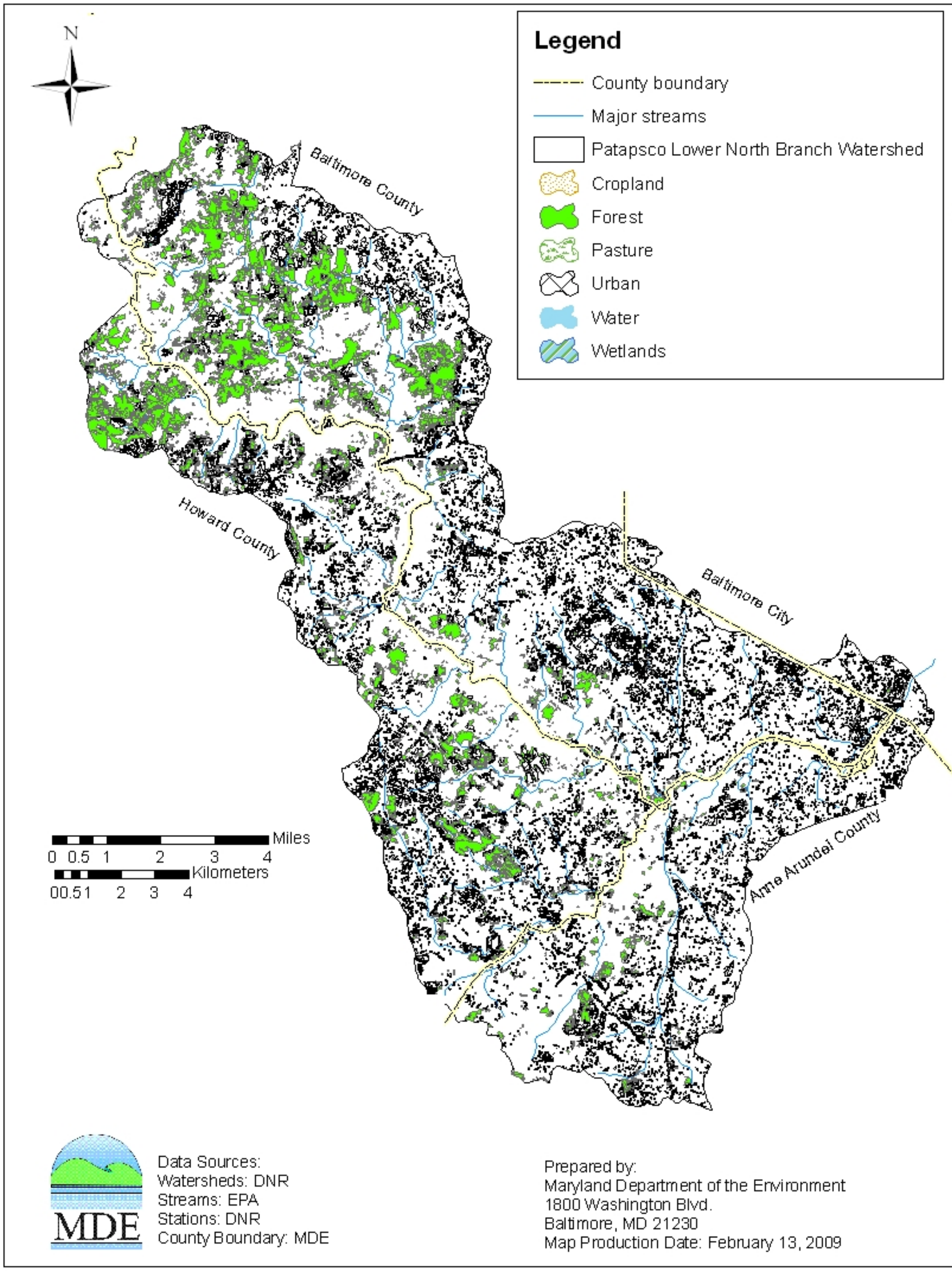

Figure 2: Land Use of the Patapsco River Lower North Branch Watershed

2.2 Source Assessment

The Patapsco River Lower North Branch Total Baseline Sediment Load consists of loads generated outside the 8-digit assessment unit, referred to as the Upstream Baseline Load, and loads generated within the assessment unit, referred to as the Patapsco River Lower North Branch Watershed Baseline Load Contribution. The Patapsco River Lower North Branch Watershed Baseline Load Contribution can be further subdivided into nonpoint and point source loads. This section summarizes the methods used to derive each of these distinct source categories.

2.2.1 Nonpoint Source Assessment

In this document, the nonpoint source loads account for sediment loads from unregulated stormwater runoff within the Patapsco River Lower North Branch watershed. This section provides the background and methods for determining the nonpoint source baseline loads generated within the Patapsco River Lower North Branch watershed (Nonpoint Source BL_{PR}). This approach was also used to estimate the South Branch Patapsco Upstream Baseline Load.

General load estimation methodology

Nonpoint source sediment loads generated within the Patapsco River Lower North Branch watershed are estimated based on the *edge-of-stream (EOS) calibration target loading rates* from the CBP P5 model. This approach is based on the fact that not all of the *edge-of-field* (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 2008).

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 Resources 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 CBP Phase 2 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 model.

The average value of the 1982 and 1987 surveys was used as the basis for EOF target rates for pasture and cropland. 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. For further details regarding EOF Erosion rates, please see Section 9.2.1 of the community watershed model documentation (US EPA 2008).

Rates for urban pervious, urban impervious, extractive, and barren land were based on a combination of best professional judgment, literature analysis, and regression analysis. Table 2 lists erosion rates specific to the Patapsco River Lower North Branch watershed.

Table 2: Summary of EOF Erosion Rate Calculations

Land Use	Data Source	Anne Arundel County (tons/acre/year)	Baltimore County (tons/acre/year)	Baltimore City (tons/acre/year)	Howard County (tons/acre/year)	Carroll County (tons/acre/year)
Forest	Phase 2 NRI	0.29	0.46	0.46	0.5	0.34
Harvested Forest[1]	Average Phase 2 NRI (x 10)	3	3	3	3	3
Pasture	Pasture NRI (1982-1987)	0.47	1.29	1.29	3.2	0.85
Trampled pasture[2]	Pasture NRI (x 9.5)	4.47	12.26	12.26	30.4	8.08
Animal Feeding Operations[2]	Pasture NRI (x 9.5)	4.47	12.26	12.26	30.4	8.08
Hay[2]	Crop NRI (1982-1987) (x 0.32)	2.58	3.18	3.18	2.02	1.05
High Till	Crop NRI (1982-1987) (x 1.25)	10.06	12.42	12.42	7.89	4.09
Low till With Manure[2]	Crop NRI (1982-1987) (x 0.75)	6.04	7.45	7.45	4.73	2.45
Nursery	Pasture NRI (x 9.5)	4.47	12.26	12.26	8.08	30.4
Pervious Urban	Intercept Regression Analysis	0.74	0.74	0.74	0.74	0.74
Extractive	Best professional judgment	10	10	10	10	10
Barren	Literature survey	12.5	12.5	12.5	12.5	12.5
Impervious	100% Impervious Regression Analysis	5.18	5.18	5.18	5.18	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 model is the same as the formula used by the NRCS (USDA 1983).

$$DF = 0.417762 * A^{-0.134958} - 0.127097 \qquad \text{(Equation 2.1)}$$

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 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 2.1 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

Edge-of-stream 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. The formula for the EOS loads calculation is as follows:

$$\sum_{i}^{n} EOS = Acres_i * EOF_i * SDR_i * BMP_i \qquad \text{(Equation 2.2)}$$

where:
n = number of land use classifications
i = land use classification
EOS = Edge of stream load, tons/yr
Acres = acreage for land use i
EOF = Edge-of-field erosion rate for land use i, tons/ac/yr
SDR = sediment delivery ratio for land use i, per Equation 2.1
BMP = BMP factor for land use i, as applicable

Streambank Erosion

Many studies have documented the relationship between high amounts of connected impervious surfaces, increases in storm flows, and stream degradation in the form of streambank erosion (Schueler 1994; Arnold and Gibbons 1996). In many urbanized watersheds, small stream channels have been replaced by sewer pipes. As a result, impervious surfaces such as rooftops, parking lots, and road surfaces are now directly connected to the main stream channel via the storm sewer system. During a storm event, this causes a greater amount of precipitation to flow more rapidly into a given stream channel once it reaches the surface. Furthermore, less water infiltrates into the ground both during and after a storm event, thereby limiting the amount of groundwater recharge to a stream. This altered urban hydrology typically causes abnormally high flows in streams during storms and abnormally low flows during dry periods. The high flows occurring during storm events increase sheer stress and cause excessive erosion of streambanks and streambeds, which leads to degraded stream channel conditions for biological communities (MDE 2007a).

Two methods of estimating streambank erosion were presented in the *Total Maximum Daily Loads of Sediment/Total Suspended Solids for the Anacostia River Basin, Montgomery and Prince George's Counties, Maryland and The District of Columbia*. The first estimate uses the Anacostia Hydrological Simulation Program – FORTRAN (HSPF) watershed model in conjunction with the Penn State University streambank erosion equation (Evans et al. 2003). The analysis estimated that approximately 73% of the total annual sediment load within the Anacostia River watershed could be attributed to streambank erosion (MDE 2007a).

The second method analyzes the long term relationship between flow and total suspended solids (TSS) concentrations to quantify the effects of an altered urban hydrology on watershed sediment loads. Changes in hydrology in the Anacostia River watershed were characterized using daily flow data from the USGS gage stations. The long-term changes over time in the flow duration curves (FDCs) for each of these stations were quantified using a type of statistical analysis known as "quantile regression." The portion of the FDC representing the highest flows was determined to have increased significantly over time, consistent with hydrologic alteration from increased impervious surfaces. Also, a "sediment rating curve" (i.e., the relationship between suspended sediment concentration and flow) was computed and combined with the FDCs to estimate annual sediment loads before and after increased development (i.e., altered hydrology). The results of the analysis indicate that approximately 75% of the total annual sediment load in the Anacostia River watershed is due to alterations in hydrology (MDE 2007a).

Using CBP P5 urban sediment EOF target values, MDE developed a formula for estimating the percent of erosional sediment resultant from streambank erosion (i.e., that portion of the total urban sediment load attributed to stream bank erosion) based on the amount of impervious land within a watershed. The equation uses the urban sediment loading factors to estimate the proportion of the urban sediment load from stream bank erosion. The assumption is that as impervious surfaces increase, the upland sources decrease, flow increases, and the change in sediment load results from increased streambank erosion. While this formula only represents an empirical approximation, it is consistent with results from the Anacostia River Sediment TMDL and recognizes that stream bank erosion can be a significant portion of the total sediment load. The formula is as follows:

$$\%E = \frac{I * L_I}{I * L_I + (1 - I)L_P} \qquad \text{(Equation 2.3)}$$

where:
% E = percent erosional sediment resultant from streambank erosion
I = percent impervious
L_I = Impervious urban land use EOF load
L_P = Pervious urban land use EOF load

The relationship demonstrated in equation 2.3 is expressed graphically in Figure 3. Using the equation, the Anacostia River watershed (23% impervious) would equate to approximately a 68% erosional sediment load resultant from streambank erosion. Per Table 1, approximately 16% of the Patapsco River Lower North Branch watershed is covered by impervious surfaces. This would equate to approximately a 57% erosional sediment load resultant from streambank erosion.

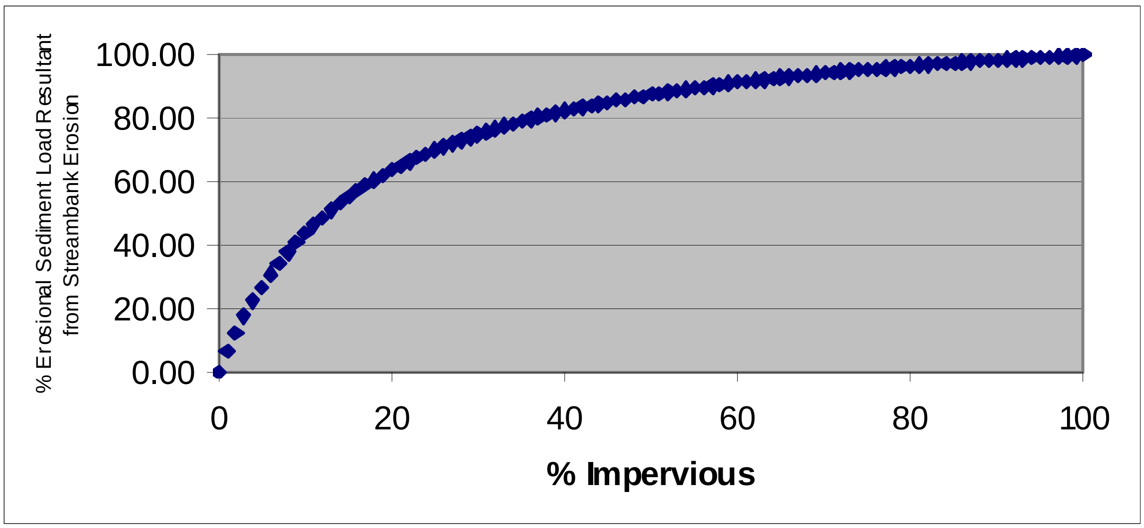

Figure 3: Percent Impervious vs. Percent Erosional Sediment Load Resultant from Streambank Erosion (Based on Equation 2.3)

For this TMDL, erosional sediment resultant from streambank erosion represents an aggregate load within the total urban impervious EOF loads as described in the report *Chesapeake Bay Phase V Community Watershed Model* (US EPA 2008) and is not explicitly reported.

2.2.2 Point Source Assessment

A list of 70 active permitted point sources that contribute to the sediment load in the Patapsco River Lower North Branch watershed was compiled using MDE's Environmental Permit Service Center (EPSC) database. The types of permits identified include individual industrial, individual municipal, individual municipal separate storm sewer systems (MS4s), general mineral mining, general industrial stormwater, and general MS4s. The permits can be grouped into two categories, process water and stormwater. The stormwater category includes all National Pollutant Discharge Elimination System (NPDES) regulated stormwater discharges. The process water category includes those loads generated by continuous discharge sources whose permits have TSS limits. Other permits that do not meet these conditions are considered *de minimis* in terms of the total sediment load.

The sediment loads for the 12 process water permits (Process Water BL_{PR}) are calculated based on their TSS limits (average monthly or weekly concentration values) and corresponding flow information. The 58 NPDES Phase I or Phase II stormwater permits identified throughout the Patapsco River Lower North Branch watershed are regulated based on BMPs and do not include TSS limits. In the absence of TSS limits, the NPDES regulated stormwater baseline load (NPDES Stormwater BL_{PR}) is calculated using Equation 2.2 and watershed specific urban land use factors. A detailed list of the permits appears in Appendix B.

2.2.3 Upstream Loads Assessment

For the purposes of this analysis, two upstream watersheds have been identified: 1) the South Branch Patapsco River watershed (basin number 02130908) and 2) the Liberty Reservoir watershed (basin number 02130907). Subsequently, sediment baseline loads from the South Branch Patapsco River watershed will be presented as an Upstream Baseline Load (BL_{SB}) within the analysis. The BL_{SB} is estimated based on land use specific sediment delivery ratios (this method is described in Section 2.2.1). Sediment loads from the Liberty Reservoir were determined to be *de minimis* based on the infrequent discharge of the reservoir, and have not been included in this analysis (MDE 2007b).

2.2.4 Summary of Baseline Loads

Table 3 summarizes the Patapsco River Lower North Branch Baseline Sediment Load, reported in tons per year (ton/yr) and presented in terms of an Upstream Baseline Load and Patapsco River Lower North Branch Watershed TMDL Contribution nonpoint and point source loadings.

Table 3: Patapsco River Lower North Branch Baseline Sediment Loads (ton/yr)

		Upstream Baseline Load[1]		**Patapsco River Lower North Branch Watershed Baseline Load Contribution**				
Total Baseline Load (ton/yr)	=	BL_{SB}	+	**Nonpoint Source** BL_{PR}	+	**NPDES Stormwater** BL_{PR}	+	**Process Water** BL_{PR}
37,728.1	=	15,019.4	+	7,160.4	+	15,536.8	+	11.5

Note: [1] Although the Upstream Baseline Load is reported here as a single value, it could include point and nonpoint sources.

Table 4 presents a breakdown of the baseline loads generated within the Patapsco River Lower North Branch watershed, detailing loads per land use. The largest portion of the sediment load is from urban land (68%). The remainder of the sediment load is from crop land (17%), forest (12%), and pasture (2%).

Table 4: Detailed Baseline Sediment Budget Loads Within the Patapsco River Lower North Branch Watershed

General Land Use	Detailed Land Use	Load (Ton/Yr)	Percent	Grouped Percent of Total
Crop	Animal Feeding Operations	282.2	1.2	
	Hay	527.4	2.3	
	High Till	977.0	4.3	
	Low Till	2,032.3	9.0	
	Nursery	16.5	0.1	16.9
Extractive	Extractive	191.0	0.8	0.8
Forest	Forest	2,525.1	11.1	
	Harvested Forest	171.9	0.8	11.9
Pasture	Pasture	423.6	1.9	
	Trampled Pasture	13.3	0.1	1.9
Urban[1]	Urban: Barren (Construction)	877.6	3.9	
	Urban: Impervious	10,532.0	46.4	
	Urban: Pervious	4,127.2	18.2	68.4
	Process Water	11.5	0.1	0.1
	Total[2]	22,708.8	100.0	100.0

Notes: [1] The urban land use load represents the permitted stormwater load.
[2] The South Branch Patapsco River drains to the Patapsco River Lower North Branch. The South Branch Patapsco Upstream Baseline Load is 15,019.4 and is estimated based on the methods described in Section 2.2.1.

2.3 Water Quality Characterization

The Patapsco River Lower North Branch 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 health is impacted by elevated sediment loads, MDE's recently developed biological stressor identification methodology was applied. 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 2009a).

The BSID analysis applies a case-control, risk-based, weight-of-evidence approach to identify potential causes of biological impairment. The risk-based approach estimates the strength of association between various stressors and a degraded biological community. The BSID analysis then identifies individual stressors as probable or unlikely causes of the poor biological conditions within a given MD 8-digit watershed and subsequently reviews ecological plausibility/concludes whether or not these individual stressors or groups of stressors are contributing to the impairment (MDE 2009a).

The primary dataset for BSID analysis is round two Maryland Department of Natural Resources (DNR) Maryland Biological Stream Survey (MBSS) data (collected between 2000-2004) because it provides a broad spectrum of paired data variables, which allow for a more comprehensive stressor analysis. The MBSS is a robust statewide probability-based sampling survey for assessing the biological conditions of wadeable, non-tidal streams (Klauda et al. 1998; Roth et al. 2005). It uses a fixed length (75 m) randomly selected stream segment for collecting site level information within a primary sampling unit (PSU), also defined as a watershed. The randomly selected stream segments, from which field data are collected, are selected using either stratified random sampling with proportional allocation, or simple random sampling (Cochran 1977). The random sample design allows for unbiased estimates of overall watershed conditions. Thus, the dataset facilitated case-control analyses because 1) in-stream biological data are paired with chemical, physical, and land use data variables that could be identified as possible stressors and 2) it uses a probabilistic statewide monitoring design.

The BSID analysis groups the individual stressors (physical and chemical variables) into three generalized parameters in order to assess how the resulting impacts of these stressors can alter the biological community and structure. The three generalized parameters include: sediment, habitat, and water chemistry. Identification of a sediment/flow stressor as contributing to the biological impairment is based on the results of the individual stressor associations within both the sediment and habitat parameters that reveal the effects of sediment related impacts or an altered hydrologic regime (MDE 2009a).

In addition to the MBSS round two data applied within the BSID analysis, data was also obtained from the Maryland DNR Core/Trend Program. The program collected benthic macroinvertebrate data between 1976 and 2006. This data was used to calculate four benthic community measures: total number of taxa, the Shannon Weiner diversity index, the modified Hilsenhoff biotic integrity index, and percent Ephemeroptera, Plecoptera, and Trichoptera (EPT). DNR has extensive monitoring data for two stations on the mainstem of the Patapsco River Lower North Branch through the Core/Trend program. Both stations are located within the Patapsco Valley State Park (See Figure 4 and table 5) (DNR 2007).

Patapsco River Lower North Branch Watershed Monitoring Stations

A total of 35 water quality monitoring stations were used to characterize the Patapsco River Lower North Branch Watershed. Thirty-three biological/physical habitat monitoring stations from the MBSS program round one and two data collection were used to characterize the Patapsco River Lower North Branch Watershed in Maryland's 2010 Integrated Report. The BSID analysis used the 16 biological/physical habitat monitoring stations from the MBSS program round two data collection. Additionally, two biological monitoring stations from the Maryland Core/Trend monitoring network were applied within the TMDL analysis as well. All stations are presented in Figure 4 and listed in Table 5.

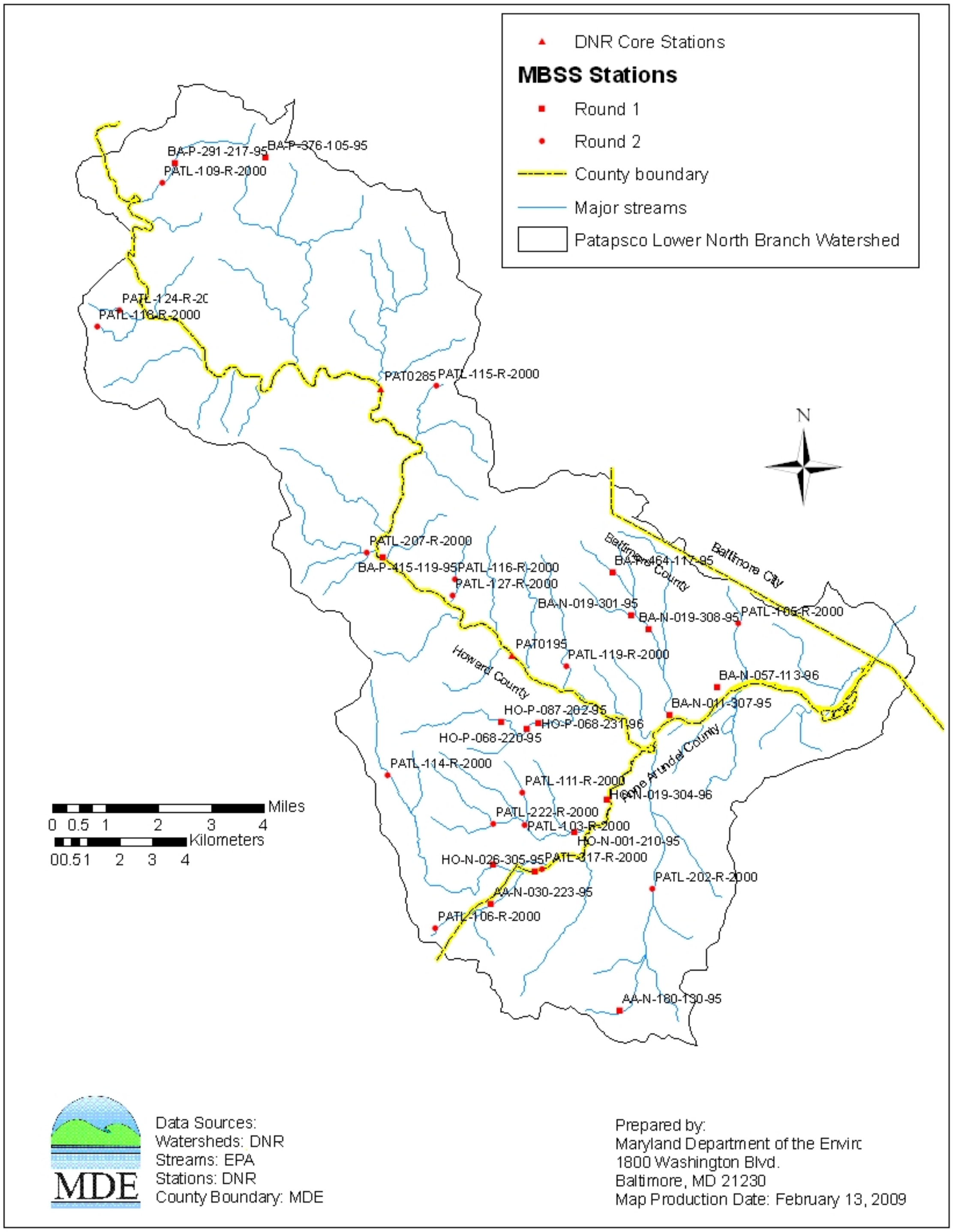

Figure 4: Monitoring Stations in the Patapsco River Lower North Branch Watershed

Table 5: Monitoring Stations in the Patapsco River Lower North Branch Watershed

Site Number	Sponsor	Site Type	Latitude (dec degrees)	Longitude (dec degrees)
AA-N-030-223-95	MD DNR	MBSS R1	39.1703	76.7542
AA-N-180-130-95	MD DNR	MBSS R1	39.1408	76.7087
BA-N-011-307-95	MD DNR	MBSS R1	39.2223	76.6909
BA-N-019-301-95	MD DNR	MBSS R1	39.2498	76.7041
BA-N-019-308-95	MD DNR	MBSS R1	39.2460	76.6982
BA-N-057-113-96	MD DNR	MBSS R1	39.2300	76.6740
BA-P-291-217-95	MD DNR	MBSS R1	39.3746	76.8652
BA-P-376-105-95	MD DNR	MBSS R1	39.3761	76.8333
BA-P-415-119-95	MD DNR	MBSS R1	39.2658	76.7921
BA-P-464-117-95	MD DNR	MBSS R1	39.2615	76.7109
HO-N-001-210-95	MD DNR	MBSS R1	39.1902	76.7245
HO-N-018-213-95	MD DNR	MBSS R1	39.1813	76.7531
HO-N-019-304-96	MD DNR	MBSS R1	39.1990	76.7130
HO-N-026-305-95	MD DNR	MBSS R1	39.1793	76.7383
HO-P-068-220-95	MD DNR	MBSS R1	39.2185	76.7414
HO-P-068-231-96	MD DNR	MBSS R1	39.2200	76.7370
HO-P-087-202-95	MD DNR	MBSS R1	39.2205	76.7501
PATL-103-R-2000	MD DNR	MBSS R2	39.1919	76.7421
PATL-105-R-2000	MD DNR	MBSS R2	39.2473	76.6664
PATL-106-R-2000	MD DNR	MBSS R2	39.1636	76.7738
PATL-109-R-2000	MD DNR	MBSS R2	39.3691	76.8700
PATL-111-R-2000	MD DNR	MBSS R2	39.2010	76.7431
PATL-114-R-2000	MD DNR	MBSS R2	39.2058	76.7903
PATL-115-R-2000	MD DNR	MBSS R2	39.3130	76.7731
PATL-116-R-2000	MD DNR	MBSS R2	39.2599	76.7663
PATL-118-R-2000	MD DNR	MBSS R2	39.3296	76.8931
PATL-119-R-2000	MD DNR	MBSS R2	39.2357	76.7272
PATL-124-R-2000	MD DNR	MBSS R2	39.3341	76.8850
PATL-127-R-2000	MD DNR	MBSS R2	39.2553	76.7674
PATL-202-R-2000	MD DNR	MBSS R2	39.1744	76.6971
PATL-207-R-2000	MD DNR	MBSS R2	39.2671	76.7978
PATL-222-R-2000	MD DNR	MBSS R2	39.1925	76.7530
PATL-317-R-2000	MD DNR	MBSS R2	39.1798	76.7361
PAT0195	MD DNR	CORE	39.1419	76.4447
PAT0285	MD DNR	TREND	39.1844	76.4733

2.4 Water Quality Impairment

The Maryland water quality standards surface water use designation for the Patapsco River Lower North Branch and its tributaries is Use I (Water Contact Recreation, and Protection of Nontidal Warmwater Aquatic Life), except for Brice Run, which is designated as Use III (Nontidal Coldwater) (COMAR 2008a,b,c). The water quality impairment of the Patapsco River Lower North Branch watershed addressed by this TMDL is caused by an elevated sediment load beyond a level that the watershed can sustain without causing any sediment related impacts to aquatic health, where aquatic health is based on benthic and fish Index of Biotic Integrity (IBI) scores, as demonstrated via the BSID analysis for the watershed.

The Patapsco River Lower North Branch watershed is listed in Maryland's 2010 Integrated Report as impaired for impacts to biological communities. Greater than 60% of the stream miles in the Patapsco River Lower North Branch watershed are assessed as having degraded biological conditions (when compared to regional reference indices). The biological impairment listing is based on the combined results of MBSS round one (1995-1997) and round two (2000-2004) data, which includes thirty-three stations. Twenty of the thirty-three stations have degraded BIBI/FIBI scores significantly lower than 3.0 (MDE 2010). As mentioned in Section 2.3, however, only MBSS round 2 data were used in the BSID analysis. See Figure 4 and Table 5 for station locations and information.

The results of the BSID analysis for the Patapsco River Lower North Branch watershed are presented in a report entitled *Watershed Report for Biological Impairment of the Patapsco River Lower North Branch Basin in Anne Arundel, Baltimore, Carroll, and Howard Counties and Baltimore City, Maryland Biological Stressor Identification Analysis And Interpretation of Results* (MDE 2009b). The report states that the degradation of biological communities in the Patapsco River Lower North Branch watershed is strongly associated with urban land use and its concomitant effects: altered hydrology, sediment related impacts, and elevated levels of sulfate, chlorides, and conductivity (a measure of the presence of dissolved substances).

The BSID analysis has determined that the biological impairment in the Patapsco River Lower North Branch watershed is due in part to flow/sediment related stressors. Specifically, the analysis confirmed that individual stressors within the sediment and habitat parameter groupings were contributing to the biological impairment in the watershed. Also, the analysis identified the following stressors within the sediment and habitat parameter groupings as having a statistically significant association with impaired biological communities at the respective percentage of degraded sites: channelization (41%), channel alteration (moderate to poor: 59%; poor: 29%), and bar formation (extensive: 28%; moderate: 58%). Overall, sediment and flow stressors within the sediment and habitat parameter groupings were identified at approximately 70% and 41%, respectively, of the degraded sites throughout the watershed (MDE 2009b). Therefore, since sediment is identified as a stressor to the biological communities in the Patapsco River Lower North Branch watershed, a TMDL is required.

As a supplement to the MBSS round two data used in the BSID analysis, the biological monitoring results from the two Maryland DNR Core/trend stations along the mainstem of the Patapsco River Lower North Branch indicate that mainstem water quality can be classified as good (see Table 6). Statistical analysis of the long term Core/Trend data indicates that since 1977, one station has shown improvement and one station has shown no change. Both stations are ranked as having good water quality based on percent EPT, taxa number, biotic index, and diversity index (DNR 2007).

Since both Core/Trend station biological monitoring results on the Patapsco River Lower North Branch mainstem indicate good conditions, it is concluded that upstream sediment loads from the South Branch Patapsco River are not impacting water quality in the Patapsco River Lower North Branch mainstem. Thus, MDE concludes that the sediment impairment identified via the BSID analysis is within the lower order (smaller) streams in the Patapsco River Lower North Branch watershed. Therefore, the South Branch Patapsco River will receive an informational upstream allocation based on current conditions.

Table 6: Patapsco River Lower North Branch Core/Trend Data

Site Number	Current Water Quality Status	Trend Since 1970's
PAT0195	GOOD	Improvement
PAT0285	GOOD	No Change

3.0 TARGETED WATER QUALITY GOAL

The objective of the sediment TMDL established herein is to reduce sediment loads, and subsequent effects on aquatic health, in the Patapsco River Lower North Branch watershed to levels that support the Use I/III designations (Water Contact Recreation, and Protection of Nontidal Warmwater Aquatic Life) (Nontidal Coldwater) (COMAR 2008a,b,c). Assessment of aquatic health is based on Maryland's biocriteria protocol, which evaluates both the amount and diversity of the benthic and fish community through the use of the IBI (Roth et al. 1998, 2000; Stribling et al. 1998; MDE 2010).

Reductions in sediment loads are expected to result from decreased watershed and streambed erosion, which will then lead to improved benthic and fish habitat conditions. Specifically, sediment load reductions are expected to result in an increase in the number of benthic sensitive species present, an increase in the available and suitable habitat for a benthic community, a possible decrease in fine sediment (fines), and improved stream habitat diversity, all of which will result in improved water quality.

The TMDL, however, will not completely resolve the impairment to biological communities within the watershed. Since the BSID watershed analysis identifies other stressors (i.e., chlorides, sulfate, conductivity) as impacting the biological conditions, this impairment remains to be fully addressed through the Integrated Report listing process and the TMDL development process, such that all impairing substances identified as impacting biological communities in the watershed are reduced to levels that will meet water quality standards, as established in future TMDLs for those substances (MDE 2009a).

4.0 TOTAL MAXIMUM DAILY LOADS AND SOURCE ALLOCATION

4.1 Overview

This section describes how the sediment TMDL and the corresponding allocations were developed for the Patapsco River Lower North Branch watershed. Section 4.2 describes the analysis framework for estimating sediment loading rates and the assimilative capacity of the watershed stream system. Section 4.3 summarizes the scenarios that were used in the analysis and presents results. Section 4.4 discusses critical conditions and seasonality. Section 4.5 explains the calculations of TMDL loading caps. Section 4.6 details the load allocations, and Section 4.7 explains the rationale for the margin of safety. Finally, Section 4.8 summarizes the TMDL.

4.2 Analysis Framework

Since there are no specific numeric criteria that quantify the impact of sediment on the aquatic health of nontidal stream systems, a reference watershed approach will be used to establish the TMDL. Furthermore, as the BSID analysis established a link between biological impairment and sediment related stressors, the reference watershed approach will utilize a biological endpoint.

<u>Watershed Model</u>

The watershed model framework chosen for the Patapsco River Lower North Branch watershed TMDL was the CBP P5 long-term average annual watershed model EOS loading rates. The spatial domain of the CBP P5 watershed model segmentation aggregates to the MD 8-digit watersheds, which is consistent with the impairment listing. The EOS loading rates were used because actual time variable CBP P5 calibration and scenario runs are currently being developed and are not yet available. These target-loading rates are used to calibrate the land use EOS loads within the CBP P5 model and thus should be consistent with future CBP modeling efforts.

The nonpoint source and NPDES stormwater baseline sediment loads generated within the Patapsco River Lower North Branch watershed are 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 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 channels (i.e., *sediment delivery ratio* decreases). Details of the data sources for the unit loading rates can be found in Section 2.2 of this report.

The Patapsco River Lower North Branch watershed was evaluated using two watershed TMDL segments (see Figure 5). TMDL Segment 1 represents the sediment loads generated in the northwestern portion of the watershed. It receives upstream load from the South Branch Patapsco River. TMDL Segment 2 represents the sediment loads generated in the southeastern portion of the watershed.

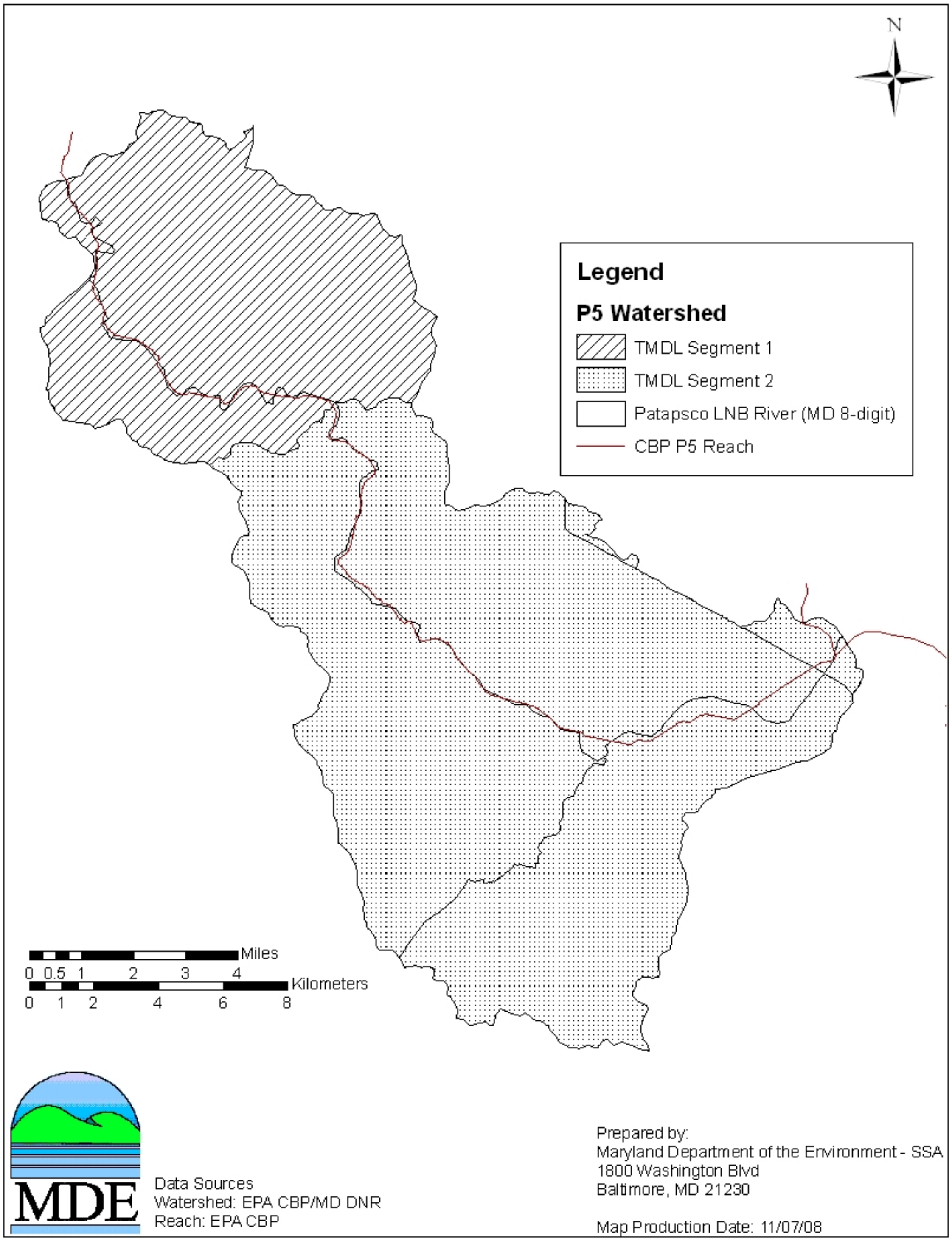

Figure 5: Patapsco River Lower North Branch Watershed TMDL Segmentation

Reference Watershed Approach

Currently in Maryland, there are no specific numeric criteria that quantify the impact of sediment on the aquatic health of non-tidal stream systems. Therefore, in order to quantify the impact of sediment on the aquatic health of non-tidal stream systems, a reference watershed TMDL 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 are degraded. Individual monitoring station impairment is determined based on BIBI/FIBI scores lower than the Minimum Allowable IBI Limit (MAL), which is calculated based on the average annual allowable IBI value of 3.0 (on a scale of 1 to 5). Applying the MAL threshold helps avoid classification errors when assessing biological impairment (Roth et al. 1998, 2000; Stribling et al. 1998; MDE 2010).

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 9 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 TMDL 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 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* in previous nontidal sediment TMDLs. Therefore, the median value of 3.3 was established as the *sediment loading threshold* as an environmentally conservative approach to develop this TMDL (see Appendix A for more details).

The *forest normalized sediment loads* for the Patapsco River Lower North Branch watershed (estimated as 2.8 and 3.9 for TMDL Segments 1 and 2 respectively) were calculated using CBP P5 2005 landuse, to best represent current conditions. Only TMDL segment 2 exceeds the *forest normalized reference sediment load* (also referred to as the *sediment loading threshold*), indicating that it is receiving loads above the maximum allowable load the watershed can sustain without causing any sediment related impacts to aquatic health.

4.3 Scenario Descriptions and Results

The following analyses allow a comparison of baseline conditions (under which water quality problems exist) with future conditions, which project the water quality response to various simulated sediment load reductions. The analyses are grouped according to baseline conditions and future conditions associated with TMDLs.

Baseline Conditions

The baseline conditions are intended to provide a point of reference by which to compare the future scenario that simulates conditions of a TMDL. The baseline conditions typically reflect an approximation of nonpoint source loads during the monitoring time frame, as well as estimated point source loads based on discharge data for the same period.

The Patapsco River Lower North Branch watershed baseline sediment loads are estimated using the CBP P5 target EOS land use sediment loading rates with 2005 land use. Watershed loading calculations, based on the CBP P5 segmentation scheme, are represented by multiple CBP P5 model segments within each TMDL segment. The sediment loads from these segments are combined to represent the baseline condition. The Maryland point source sediment loads are estimated based on the existing permit information. Details of these loading source estimates can be found in Section 2.2 and Appendix B of this report.

Future (TMDL) Conditions

This scenario represents the future conditions of maximum allowable sediment loads whereby there will be no sediment related impacts affecting aquatic health. In the TMDL calculation, the allowable load for the impaired watershed is calculated as the product of the *sediment loading threshold* (determined from watersheds with a healthy biological community) and the Patapsco River Lower North Branch *all forested sediment load* (see Section 4.2). The resulting load is considered the maximum allowable load the watershed can sustain without causing any sediment related impacts to aquatic health.

The TMDL loading and associated reductions are averaged at the MD 8-digit watershed scale, which is consistent with the original listing scale. It is important to recognize that some subwatersheds may require higher reductions than others, depending on the distribution of the land use.

The formula for estimating the TMDL is as follows:

$$TMDL = \sum_{i=1}^{n} Yn_{ref} \cdot y_{forest\ i} \qquad \text{(Equation 4.2)}$$

where
TMDL = allowable load for impaired watershed (ton/yr)
Yn_{ref} = sediment loading threshold = forest normalized reference sediment load (3.3)
$y_{forest\ i}$ = all forested sediment load for segment *i* (ton /yr)
i = CBP P5 model segment
n = number of CBP P5 model segments in watershed

The Patapsco River Lower North Branch TMDL Segment 2 allowable sediment load is estimated using equation 4.2. TMDL segment 1 is given an information allocation equivalent to its baseline load since the current *forest normalized sediment load* for the segment is below the reference watershed *sediment loading threshold*. Additionally, the South Branch Patapsco River watershed is given an informational allocation as well, since sediment loads from the watershed are not impacting downstream water quality conditions in the Patapsco River Lower North Branch mainstem (See Section 2.4).

4.4 Critical Condition and Seasonality

EPA's regulations require TMDLs to take into account seasonality and critical conditions for stream flow, loading, and water quality parameters (CFR 2008b). The intent of this requirement is to ensure that the water quality of the waterbody is protected during times when it is most vulnerable. The biological monitoring data used to determine the reference watersheds reflect the impacts of stressors (i.e., sediment impacts to stream biota) over the course of time and therefore depict an average stream condition (i.e., captures all high and low flow events). Since the TMDL endpoint is based on the median of forest normalized loads from watersheds assessed as having good biological conditions (i.e., passing Maryland's biocriteria), by the nature of the biological data described above, it must inherently include the critical conditions of the reference watersheds. Therefore, since the TMDL reduces the watershed sediment load to a level compatible with that of the reference watersheds, critical conditions are inherently addressed.

Seasonality is captured in two components. First, it is implicitly included through the use of the biological monitoring data as biological communities reflect the impact of stressors over time, as described above. Second, the MBSS dataset included benthic sampling in the spring (March 1 - April 30) and fish sampling in the summer (June 1 - September 30). Benthic sampling in the spring allows for the most accurate assessment of the benthic population, and therefore provides an excellent means of assessing the anthropogenic effects of sediment impacts on the benthic community. Fish sampling is conducted in the summer when low flow conditions significantly limit the physical habitat of the fish community, and it is therefore most reflective of the effects of anthropogenic stressors as well.

4.5 TMDL Loading Caps

This section presents the Patapsco River Lower North Branch watershed average annual sediment TMDL. This load is considered the maximum allowable long-term average annual load the watershed can sustain without causing any sediment related impacts to aquatic health.

TMDL allocations were developed for TMDL Segments 1 and 2 and the South Branch Patapsco River watershed independently. The TMDL Segment 1 allocation is equivalent to its baseline conditions and is considered informational since the current *forest normalized sediment load* for the segment is below the reference watershed *sediment loading threshold*. Furthermore, as described in Section 2.4, DNR Core/Trend monitoring data demonstrates that the Patapsco River Lower North Branch mainstem exhibits good aquatic health conditions. Based on this information, it was concluded that sediment loads from the South Branch Patapsco River watershed do not have a negative impact on the aquatic health of the Patapsco River Lower North Branch mainstem, and therefore the watershed will be given an informational allocation equivalent to its baseline load.

The long-term average annual TMDL was calculated for TMDL Segment 2 (see Figure 5) based on Equation 4.2 and set at a load 3.3 times the all forested condition. In order to attain the TMDL loading cap calculated for the segment, reductions will be applied to the predominant controllable sources. If only these predominant (generally the largest) sources are controlled, the TMDL can be achieved in the most effective, efficient, and equitable manner. Urban land was identified as the most extensive predominant controllable source in TMDL Segment 2.

Currently, MDE requires that Phase I MS4s retrofit 10% of their existing impervious area where there is failing or no stormwater management every permit cycle (5 years) (i.e., Phase I MS4s need to install/institute stormwater management practices to treat runoff from these existing impervious areas) (MDE 2008). By default, these retrofits will also provide treatment of any adjacent urban pervious runoff within the applicable drainage area. Additionally, MDE estimates that future stormwater retrofits will have, on average, a 65% TSS reduction efficiency (Claytor and Schueler 1997; Baldwin et al. 2007; Baish and Caliri 2009). This level of restoration has been determined to be the current maximum feasible, regulated stormwater reduction scenario. Therefore, the reductions applied within this TMDL analysis are consistent with this 10% retrofit requirement to existing impervious land every 5 years with default treatment of adjacent pervious areas and an estimated 65% TSS reduction efficiency from future stormwater BMPs.

If the TMDL still is not achieved after applying the current maximum feasible urban stormwater reductions, then constant reductions will be applied to the remaining predominant controllable sources (i.e., significant contributors of sediment to the stream system), independent of jurisdiction. In addition to urban land, predominant sources typically include high till crops, low till crops, hay, pasture, and harvested forest, but additional sources might need to be controlled in order to ensure that the TMDL is attained.

The Patapsco River Lower North Branch Baseline Load and TMDL are presented in Table 7.

Table 7: Patapsco River Lower North Branch Baseline Load and TMDL

	Baseline Load (ton/yr)	**TMDL** (ton/yr)	**Reduction** (%)
TMDL Segment 1[1]	6,304.8	6,304.8	0.0
TMDL Segment 2	16,403.9	13,920.0	15.1
Total[2]	37,728.1	35,244.2	6.6

Notes:[1] The allocation presented for TMDL Segment 1 is informational only. It is equivalent to the current baseline load of the segment.
[2] The total load summary includes the South Branch Patapsco Upstream Baseline Load of 15,019.4 ton/yr and equivalent TMDL.

4.6 Load Allocations Between Point and Nonpoint Sources

Per EPA regulation, all TMDLs need to be presented as a sum of waste load allocations (WLAs) for point sources and load allocations (LAs) for nonpoint source loads generated within the assessment unit, as well as natural background, tributary, and adjacent segment loads (CFR 2008a). Consequently, the Patapsco River Lower North Branch watershed TMDL allocations are presented in terms of WLAs (i.e., point source loads identified within the watershed) and LAs (i.e., the nonpoint source loads within the watershed and loads from upstream watersheds). The State reserves the right to allocate the TMDL among different sources in any manner that is reasonably calculated to protect aquatic life from sediment related impacts.

As described in Section 4.5, reductions were only applied to the regulated urban stormwater sources in TMDL Segment 2. Furthermore, reductions were only applied to urban areas developed prior to 1985 (i.e., approximate areas with no stormwater management). This is consistent with Phase I MS4 permit requirements for retrofitting existing impervious areas at a rate of 10% every 5 years (MDE 2008), which by default will also provide treatment of any urban pervious runoff adjacent to a retrofitted impervious area. The reduction in sediment loads associated with retrofitting 10% of existing impervious areas every 5 years, with default treatment of adjacent pervious areas and an estimated 65% TSS reduction efficiency, represents the current maximum feasible reduction scenario from the urban land use within the watershed.

In this watershed, in addition to urban land, crop and pasture were identified as the predominant controllable sources; however, no reductions were applied to these sources, since the TMDL is achieved when the current maximum feasible reductions are applied to the regulated urban stormwater sources in TMDL segment 2. Forest is the only non-controllable source, as it represents the most natural condition in the watershed, and no reductions were applied to permitted process water sources because at 0.03% of the total load, such controls would produce no discernable water quality benefit.

Table 8 summarizes the TMDL results for the entire watershed, derived by applying the current maximum feasible reductions to the applicable urban sediment sources in TMDL Segment 2 only. The reductions associated with the current maximum feasible scenario result in sediment loading reductions greater than those needed to achieve the TMDL. Thus, the TMDL results in Table 8 represent a feasible reduction scenario from the applicable urban sediment sources, determined using the current maximum feasible reduction scenario as a basis. Table 9 summarizes the TMDL for TMDL Segment 2 only, as both TMDL Segment 1 and the South Branch Patapsco River watershed received an informational allocation equivalent to their baseline loads. The TMDL results in an overall reduction of 6.6% for the Patapsco River Lower North Branch watershed. For more detailed information regarding the Patapsco River Lower North Branch Watershed TMDL Contribution nonpoint source allocations, please see the technical memorandum to this document entitled "*Significant Sediment Nonpoint Sources in the Patapsco River Lower North Branch*".

Table 8: Patapsco River Lower North Branch TMDL Reductions by Source Category

	Baseline Load Source Categories		Baseline Load (ton/yr)	TMDL Components	TMDL (ton/yr)	Reduction (%)
Patapsco River Lower North Branch Watershed Contribution	Nonpoint Source		7,160.4	LA	7,160.4	0.0
	Point Source	Urban	15,536.8	WLA	13,052.9	16.0
		Process Water	11.5		11.5	0.0
Sub-total			22,708.8		20,224.8	10.9
Upstream	South Branch Patapsco River Watershed		15,019.4	Upstream LA	15,019.4	0.0
Total			**37,728.1**		**35,244.2**[2]	**6.6**

Note: [1] Biological monitoring results from the DNR Core/Trend stations along the mainstem of the Patapsco River Lower North Branch indicate that mainstem water quality can be classified as good. Based on this information, MDE concluded that the sediment impairment in the Patapsco River Lower North Branch watershed is restricted to the lower order (smaller) streams within the watershed. Additionally, the *forest normalized sediment load* for TMDL Segment 1 is below the reference watershed *sediment loading threshold*. Consequently, sediment reductions have been applied to the loads transported via the lower order stream network within TMDL Segment 2 only and not the loads transported to the main channel of the Patapsco River Lower North Branch from the South Branch Patapsco River and TMDL Segment 1.

Table 9: Patapsco River Lower North Branch TMDL Segment 2 Reductions by Source Category

	Baseline Load Source Categories	Baseline Load (ton/yr)	TMDL Components	TMDL (ton/yr)	Reduction (%)
Nonpoint Source		2,760.0	LA	2,760.0	0.0%
Point Source	Urban	13,632.4	WLA	11,148.5	18.2%
	Process Water	11.5		11.5	0.0%
	Total	**16,403.9**		**13,920.0**	**15.1%**

The WLA of the Patapsco River Lower North Branch watershed is allocated to two permitted source categories, Process Water WLA and Stormwater WLA. The categories are described below.

Process Water WLA

Process Water permits with specific TSS limits and corresponding flow information are assigned to the WLA. In this case, detailed information is available to accurately estimate the WLA. If specific TSS limits are not explicitly stated in the process water permit, then TSS loads are expected to be *de minimis*. If loads are *de minimis*, then they pose little or no risk to the aquatic environment and are not a significant source.

Process Water permits with specific TSS limits include:

- Individual industrial facilities
- Individual municipal facilities
- General mineral mining facilities

There are 12 process water sources with explicit TSS limits, which include 4 industrial sources, 2 municipal sources, and 6 mineral mines. The total estimated TSS load from all of the process water sources is based on current permit limits and is equal to 11.5 ton/yr. As mentioned above, no reductions were applied to this source because at 0.03% of the total load, such controls would produce no discernable water quality benefit. For a detailed list of the 12 process water permits including information on their permit limits, please see Appendix B. For information regarding the allocations to individual process water point sources, please see the technical memorandum to this document entitled "*Significant Sediment Point Sources in the Patapsco River Lower North Branch*".

Stormwater WLA

Per EPA requirements, "stormwater discharges that are regulated under Phase I or Phase II of the NPDES stormwater program are point sources that must be included in the WLA portion of a TMDL" (US EPA 2002). Phase I and II permits can include the following types of discharges:

- Small, medium, and large MS4s – these can be owned by local jurisdictions, municipalities, and state and federal entities (e.g., departments of transportation, hospitals, military bases),
- Industrial facilities permitted for stormwater discharges, and
- Small and large construction sites.

EPA recognizes that available data and information are usually not detailed enough to determine WLAs for NPDES regulated stormwater discharges on an outfall-specific basis (US EPA 2002). Therefore, NPDES regulated stormwater loads within the Patapsco River Lower North Branch watershed TMDL will be expressed as a single NPDES stormwater WLA. Upon approval of the TMDL, "NPDES-regulated municipal stormwater and small construction storm water discharges effluent limits should be expressed as BMPs or other similar requirements, rather than as numeric effluent limits" (US EPA 2002).

The Patapsco River Lower North Branch NPDES stormwater WLA is based on reductions applied to the sediment load from the urban land use of the watershed derived from the current maximum feasible stormwater reduction scenario and may include legacy or other sediment sources. Some of these sources may also be subject to controls from other management programs. The Patapsco River Lower North Branch NPDES stormwater WLA requires an overall reduction of 16.0% (see Table 8).

As stormwater assessment and/or other program monitoring efforts result in a more refined source assessment, MDE reserves the right to revise the current NPDES stormwater WLA provided the revisions are reasonably calculated to protect aquatic life from sediment related impacts.

For more information on the methods used to calculate the baseline urban sediment load, see Section 2.2.2. For a detailed list of all of the NPDES regulated stormwater discharges within the watershed, please see Appendix B, and for information regarding the NPDES stormwater WLA distribution amongst these discharges, please see the technical memorandum to this document entitled "*Significant Sediment Point Sources in the Patapsco River Lower North Branch*".

4.7 Margin of Safety

All TMDLs must include a margin of safety to account for any lack of knowledge and uncertainty concerning the relationship between loads and water quality (CFR 2008b). The MOS shall also account for any rounding errors generated in the various calculations used in the development of the TMDL. It is proposed that the estimated variability around the reference watershed group used in this analysis already accounts for such uncertainty. Analysis of the reference group *forest normalized sediment loads* indicates that approximately 75% of the reference watersheds have a value of less than 4.2. Also, 50% of the reference watersheds have a value less than 3.3. Based on this analysis the *forest normalized reference sediment load* (also referred to as the *sediment loading threshold*) was set at the median value of 3.3 (Currey et al. 2006). This is considered an environmentally conservative estimate, since 50% of the reference watersheds have a load above this value, which when compared to the 75% value, results in an implicit margin of safety of approximately 18%.

4.8 Summary of Total Maximum Daily Loads

The average annual Patapsco River Lower North Branch watershed TMDL is summarized in Table 10. The TMDL is the sum of the LAs, NPDES Stormwater WLA, Process Water WLA, and MOS. The LAs include nonpoint source loads generated within the Patapsco River Lower North Branch watershed and upstream loads from the South Branch Patapsco River watershed. The Maximum Daily Load (MDL) is summarized in Table 11 (See Appendix C for more details).

Table 10: Patapsco River Lower North Branch Watershed Average Annual TMDL of Sediment/TSS (ton/yr)

TMDL (ton/yr)	=	**LA**			+	**WLA**			+	**MOS**
		LA_{SB}[1,2]	+	**LA_{PR}**		**NPDES Stormwater WLA_{PR}**	+	**Process Water WLA_{PR}**		
35,244.2		15,019.4		7,160.4		13,052.9		11.5	+	Implicit
		Upstream Load Allocation		Patapsco River Lower North Branch TMDL Contribution						

Notes:[1] Although for the purpose of this analysis the upstream load is referred to as an LA, it could include loads from point and nonpoint sources.
[2] A delivery factor of 1 was used for the Upstream Load Allocation**.**

Table 11: Patapsco River Lower North Branch Maximum Daily Loads of Sediment/TSS (ton/day)

MDL (ton/day)	=	**LA**			+	**WLA**			+	**MOS**
		LA_{SB}[1,2]	+	**LA_{PR}**		**NPDES Stormwater WLA_{PR}**	+	**Process Water WLA_{PR}**		
1,374.2	=	585.7	+	279.3	+	509.1	+	0.1	+	Implicit
		Upstream Load Allocation		Patapsco River Lower North Branch MDL Contribution						

Notes:[1] Although for the purpose of this analysis the upstream load is referred to as an LA, it could include loads from point and nonpoint sources.
[2] A delivery factor of 1 was used for the Upstream Load Allocation**.**

5.0 ASSURANCE OF IMPLEMENTATION

This section provides the basis for reasonable assurances that the sediment TMDL will be achieved and maintained. Section 303(d) of the Clean Water Act and current EPA regulations require reasonable assurance that the TMDL load and wasteload allocations can and will be implemented (CFR 2008b). Maryland has several well-established programs to draw upon, including the Water Quality Improvement Act of 1998 (WQIA) and the Federal Nonpoint Source Management Program (§ 319 of the Clean Water Act).

Potential funding sources available for local governments for implementation include the Buffer Incentive Program (BIP), the State Water Quality Revolving Loan Fund, and the Stormwater Pollution Cost Share Program. Details of these programs and additional funding sources can be found at
http://www.dnr.state.md.us/bay/services/summaries.html.

Potential BMPs for reducing sediment loads and resulting impacts can be grouped into two general categories. The first is directed toward agricultural lands and the second is directed toward urban (developed) lands. Since urban land was identified as the most extensive primary, predominant controllable source of sediment within the watershed (i.e., 69% of the total Patapsco River Lower North Branch Baseline Sediment Load Contribution), and based on current maximum feasible reductions to regulated urban stormwater, the entirety of the required sediment reductions within the Patapsco River Lower North Branch watershed are attributed to urban (developed) land use. The various BMPs applicable to reducing urban sediment loads are discussed below.

Sediment from urban areas can be reduced by stormwater retrofits, impervious surface reduction, street sweeping, inlet cleaning, increases in urban tree canopy cover, and stream restoration. Stormwater retrofits include modification of existing stormwater structural practices to address both water quality and flow control (i.e., riparian buffers for urban areas and watershed reforestation adjacent to the watershed stream system or within a watershed's interior). The majority of the sediment reductions required from the urban areas within the Patapsco River Lower North Branch watershed are attributed to streambank erosion (see section 2.2.1). Therefore, flow controls must be installed to reduce sheer stress and limit bank erosion in order to address this portion of the urban sediment load. Additionally, impervious surface reduction results in a change in hydrology that could also reduce streambank erosion. In terms of upland urban sediment loads, stormwater retrofit reductions range from as low as 10% for dry detention to approximately 80% for wet ponds, wetlands, infiltration practices, and filtering practices (US EPA 2003). It is anticipated that the implementation of the TMDL will include the array of urban BMPs and practices outlined above Implementation is expected to occur primarily via the MS4 permitting process for medium and large municipalities, which requires that these jurisdictions retrofit 10% of their existing impervious area every permit cycle, or 5 years. These Phase I MS4 jurisdictions should work with the other regulated stormwater entities in the watershed (see Appendix B, Table B-5) during the implementation process to achieve the necessary reductions.

It has been estimated that the average TSS removal efficiencies for BMPs installed between the years of 1985-2002 and post 2002, which are reflective of the stormwater management regulations in place during these time periods, is 50% and 80%, respectively (Claytor and Schueler 1997; Baldwin et al. 2007; Baish and Caliri 2009). Based on these average TSS reduction efficiencies, BMP specific reduction efficiencies as estimated by CBP, and best professional judgement, MDE estimates that future stormwater retrofits, which are expected to be implemented as part of the 10% retrofit requirement to existing impervious land every 5 years for all Phase I MS4 jurisdictions (MDE 2008), will have approximately a 65% reduction efficiency for TSS, which is subject to change over time. Additionally, any new development in the watershed will be subject to the Stormwater Management Act of 2007 and will be required to use environmental site design (ESD) to the maximum extent practicable.

In summary, through the use of the aforementioned funding mechanisms and best management practices, there is reasonable assurance that this TMDL can be implemented.

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APPENDIX A – Watershed Characterization Data

Table A-1: Reference Watersheds

MD 8-digit Name	MD 8-digit	Percent stream mile degraded (%)[1,2]	Forest Normalized Sediment Load[3]
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]Percent stream miles degraded within an 8-digit watershed is based on the percentage of impaired MBSS stations within the watershed (MDE 2010).
[2]The percent stream miles degraded threshold to determine if an 8-digit watershed is impaired for impacts to biological communities is based on a comparison to reference conditions (MDE 2010).
[3]Forest normalized sediment loads based on Maryland watershed area only (consistent with MBSS random monitoring data).

APPENDIX B – MDE Permit Information

Table B-1: Permit Summary

Permit #	NPDES	Facility	County	City	Type	TMDL
02DP2635	MD0063924	HERNWOOD LANDFILL - NORTHERN SITE	BALTIMORE	WOODSTOCK	WMA1	Process Water WLA
03DP3442	MD0069094	KOP-FLEX, INC.	ANNE ARUNDEL	HANOVER	WMA1	Process Water WLA
05DP3505	MD0069469	SHA - HANOVER COMPLEX	ANNE ARUNDEL	HANOVER	WMA1	Process Water WLA
06DP1376	MD0054585	MACHADO CONSTRUCTION	BALTIMORE	BALTIMORE	WMA1	Process Water WLA
06DP1231	MD0053082	MES - HOLIDAY MOBILE ESTATES	ANNE ARUNDEL	JESSUP	WMA2	Process Water WLA
99DP0756	MD0023906	MES - WOODSTOCK JOB CORPS	BALTIMORE	WOODSTOCK	WMA2	Process Water WLA
00MM0220	MDG490220	LAFARGE - MARRIOTTSVILLE	BALTIMORE	MARRIOTTSVILLE	WMA5	Process Water WLA
00MM9741A	MDG499741	THE BELLE GROVE CORPORATION	ANNE ARUNDEL	BROOKLYN	WMA5	Process Water WLA
00MM9743	MDG499743	THE BELLE GROVE CORPORATION	ANNE ARUNDEL	FERNDALE	WMA5	Process Water WLA
00MM9770	MDG499770	ROCKVILLE FUEL & FEED	HOWARD	ELKRIDGE	WMA5	Process Water WLA
00MM9703	MDG499703	JONES QUARRIES	BALTIMORE	WOODSTOCK	WMA5	Process Water WLA
00MM9881	MDG499881	VINCI PIT #1	BALTIMORE	RANDALLSTOWN	WMA5	Process Water WLA
02SW0022		WILLIAM T. BURNETT & COMPANY	ANNE ARUNDEL	JESSUP	WMA5SW	Stormwater WLA
02SW0023		C. R. DANIELS, INC.	HOWARD	ELLICOTT CITY	WMA5SW	Stormwater WLA
02SW0283		AMERICAN METASEAL	BALTIMORE	ARBUTUS	WMA5SW	Stormwater WLA
02SW0288		BOND TRANSFER COMPANY, INC.	ANNE ARUNDEL	BALTIMORE	WMA5SW	Stormwater WLA
02SW0452		EDRICH LUMBER INC.	BALTIMORE	BALTIMORE	WMA5SW	Stormwater WLA
02SW0467		R. W. BOZEL TRANSFER, INC.	BALTIMORE	BALTIMORE	WMA5SW	Stormwater WLA
02SW0559		ABF FREIGHT SYSTEM, INC.	HOWARD	ELKRIDGE	WMA5SW	Stormwater WLA
02SW0583		WOODLAWN MOTOR COACH - CATONSVILLE	BALTIMORE	BALTIMORE	WMA5SW	Stormwater WLA
02SW0592		ROADWAY EXPRESS, INC.	BALTIMORE CITY	BALTIMORE	WMA5SW	Stormwater WLA
02SW0616		PJAX, INC.	HOWARD	ELKRIDGE	WMA5SW	Stormwater WLA
02SW0619		WASTE MANAGEMENT OF MARYLAND - BALTIMORE	HOWARD	ELKRIDGE	WMA5SW	Stormwater WLA
02SW0737		RECOVERMAT MID-ATLANTIC	BALTIMORE	BALTIMORE	WMA5SW	Stormwater WLA
02SW0746		U.S. POSTAL SERVICE - HALETHORPE VMF	BALTIMORE	BALTIMORE	WMA5SW	Stormwater WLA

Permit #	NPDES	Facility	County	City	Type	TMDL
02SW0876		WACO PRODUCTS, INC.	BALTIMORE	BALTIMORE	WMA5SW	Stormwater WLA
02SW0881		MAYER BROTHERS, INC.	HOWARD	ELKRIDGE	WMA5SW	Stormwater WLA
02SW0956		J. W. TREUTH & SONS, INC.	BALTIMORE	CATONSVILLE	WMA5SW	Stormwater WLA
02SW0985		UPS GROUND FREIGHT - ELKRIDGE	HOWARD	ELKRIDGE	WMA5SW	Stormwater WLA
02SW0990		SUPERIOR CARRIERS, INC.	BALTIMORE CITY	BALTIMORE	WMA5SW	Stormwater WLA
02SW0992		HANSON PIPE & PRODUCTS, INC.	HOWARD	JESSUP	WMA5SW	Stormwater WLA
02SW0996		BELT'S DISTRIBUTION CENTER	HOWARD	ELKRIDGE	WMA5SW	Stormwater WLA
02SW0997		BPG HOTEL PARTNERS XT, LLC	ANNE ARUNDEL	LINTHICUM	WMA5SW	Stormwater WLA
02SW1192		DHL EXPRESS USA - LINTHICUM	ANNE ARUNDEL	LINTHICUM	WMA5SW	Stormwater WLA
02SW1256		MARYLAND RECYCLE CO. OF	HOWARD	ELKRIDGE	WMA5SW	Stormwater WLA
02SW1273		WILKINS-ROGERS, INC.	BALTIMORE	ELLICOTT CITY	WMA5SW	Stormwater WLA
02SW1291		BALTIMORE REGIONAL YARD	HOWARD	ELKRIDGE	WMA5SW	Stormwater WLA
02SW1358		WARD TRUCKING CORPORATION - BALTIMORE TERMINAL	BALTIMORE	BALTIMORE	WMA5SW	Stormwater WLA
02SW1438		HOWARD COUNTY - MAYFIELD	HOWARD	ELKRIDGE	WMA5SW	Stormwater WLA
02SW1446		CALTON CARS & PARTS	HOWARD	ELKRIDGE	WMA5SW	Stormwater WLA
02SW1489		BIG BOY'S RIGGING SERVICE, LLC	BALTIMORE	BALTIMORE	WMA5SW	Stormwater WLA
02SW1500		B & W OPTICAL COMPANY, INC.	BALTIMORE CITY	BALTIMORE	WMA5SW	Stormwater WLA
02SW1576		HARTMAN MACHINE SERVICE	BALTIMORE	BALTIMORE	WMA5SW	Stormwater WLA
02SW1590		MES TIRE RECYCLING FACILITY	BALTIMORE	HALETHORPE	WMA5SW	Stormwater WLA
02SW1607		MAJESTIC DISTILLING COMPANY,	BALTIMORE	BALTIMORE	WMA5SW	Stormwater WLA
02SW1711		MES - BCRRF WESTERN	BALTIMORE	BALTIMORE	WMA5SW	Stormwater WLA
02SW1723		EUROPARTS EXPRESS	HOWARD	JESSUP	WMA5SW	Stormwater WLA
02SW1742		PARKER HANNIFIN CORPORATION	BALTIMORE	BALTIMORE	WMA5SW	Stormwater WLA
02SW1791		OLD DOMINION FREIGHT LINE, INC.	HOWARD	ELKRIDGE	WMA5SW	Stormwater WLA
02SW1830		C-CARE, LLC02/27/03	ANNE ARUNDEL	LINTHICUM	WMA5SW	Stormwater WLA
02SW1863		ROLLING FRITO-LAY SALES - BALTIMORE DC	BALTIMORE CITY	BALTIMORE	WMA5SW	Stormwater WLA
02SW1914		HALETHORPE INDUSTRIAL, LLC	BALTIMORE	HALETHORPE	WMA5SW	Stormwater WLA
02SW1915		MACHADO CONSTRUCTION	BALTIMORE	BALTIMORE	WMA5SW	Stormwater WLA

Permit #	NPDES	Facility	County	City	Type	TMDL
02SW1916		COMMUNITY COLLEGE OF BALTIMORE COUNTY - CATONSVILLE	BALTIMORE	CATONSVILLE	WMA5SW	Stormwater WLA
02SW1963		BALTIMORE COUNTY HIGHWAY DEPARTMENT - SHOP 1	BALTIMORE	BALTIMORE	WMA5SW	Stormwater WLA
02SW1976		NORTHROP GRUMMAN - ADVANCED TECHNOLOGY	ANNE ARUNDEL	LINTHICUM	WMA5SW	Stormwater WLA
02SW1988		PULLEN'S TOUR SERVICE, INC.	BALTIMORE	HALETHORPE	WMA5SW	Stormwater WLA
02SW1999		CAPTIVE PLASTICS, INC.	ANNE ARUNDEL	HANOVER	WMA5SW	Stormwater WLA
02SW2005		PRECOAT METALS	HOWARD	ELKRIDGE	WMA5SW	Stormwater WLA
02SW2019		BALTIMORE COUNTY PUBLIC SCHOOLS - ARBUTUS BUS LOT	BALTIMORE	HALETHORPE	WMA5SW	Stormwater WLA
02SW2051		AGGREGATE INDUSTRIES - BALTIMORE VEHICLE MAINTENANCE FACILITY	BALTIMORE	HALETHORPE	WMA5SW	Stormwater WLA
02SW2074		DILLON’S BUS SERVICE	ANNE ARUNDEL	MILLERSVILLE	WMA5SW	Stormwater WLA
02SW2079		WM RECYCLE AMERICA OF ELKRIDGE	HOWARD	ELKRIDGE	WMA5SW	Stormwater WLA
04DP3316	MD0068306	ANNE ARUNDEL COUNTY MS4	ANNE ARUNDEL	COUNTY-WIDE	WMA6	Stormwater WLA
05DP3317	MD0068314	BALTIMORE COUNTY MS4	BALTIMORE	COUNTY-WIDE	WMA6	Stormwater WLA
05DP3318	MD0068322	HOWARD COUNTY MS4	HOWARD	COUNTY-WIDE	WMA6	Stormwater WLA
00DP3319	MD0068331	CARROLL COUNTY MS4	CARROLL	COUNTY-WIDE	WMA6	Stormwater WLA
99DP3315	MD0068292	BALTIMORE CITY MS4	BALTIMORE CITY	CITY-WIDE	WMA6	Stormwater WLA
99DP3313	MD0068276	STATE HIGHWAY ADMINSTRATION MS4	ALL PHASE I	STATE-WIDE	WMA6	Stormwater WLA
		MDE GENERAL PERMIT TO CONSTRUCT	ALL	ALL		Stormwater WLA

Notes: [1]TMDL column identifies how the permit was considered in the TMDL allocation.
[2]WTP = Water Treatment Plant
[3]WWTP = Wastewater Treatment Plant

Table B-2: Industrial Permit Data

Facility name	MDE Permit #	NPDES #	Flow (MGD[1])	Permit Avg Monthly Conc. (mg/l[2])	Permit Daily Max Conc. (mg/l)
HERNWOOD LANDFILL - NORTHERN SITE	02DP2635	MD0063924	0.016	15	30
KOP-FLEX, INC.	03DP3442	MD0069094	0.003	30	45
SHA - HANOVER COMPLEX	05DP3505	MD0069469	0.0003	30	60
MACHADO CONSTRUCTION COMPANY, INC.	06DP1376	MD0054585	0.004	30	60

Notes: [1] MGD = Millions of gallons per day
[2] mg/l = Milligram per liter

Table B-3: Municipal Permit Data

Facility name	MDE Permit #	NPDES #	Flow (MGD[1])	Permit Avg Monthly Conc. (mg/l[2])	Permit Avg. Weekly Conc. (mg/l)
MES - HOLIDAY MOBILE ESTATES WWTP	06DP1231	MD0053082	0.125	20	30
MES - WOODSTOCK JOB CORPS WASTEWATER	99DP0756	MD0023906	0.05	30	45

Table B-4: General Mine Permit Data

Facility name	MDE Permit #	NPDES #	Flow (MGD)	Permit Avg Quarterly Conc. (mg/l)	Permit Daily Max Conc. (mg/l)
LAFARGE - MARRIOTTSVILLE QUARRY	00MM0220	MDG490220	0.065	15	31
THE BELLE GROVE CORPORATION	00MM9741A	MDG499741	0.055	30	60
THE BELLE GROVE CORPORATION - THOMAS AVENUE	00MM9743	MDG499743	0.006	30	60
ROCKVILLE FUEL & FEED COMPANY - PLANT 5	00MM9770	MDG499770	0.008	30	60
JONES QUARRIES	00MM9703	MDG499703	0.001	30	66
VINCI PIT #1	00MM9881	MDG499881	0.001	30	66

Table B-5: Stormwater Permits[1]

Permit #	Facility	NPDES Group
02SW0022	WILLIAM T. BURNETT & COMPANY	Phase I
02SW0023	C. R. DANIELS, INC.	Phase I
02SW0283	AMERICAN METASEAL	Phase I
02SW0288	BOND TRANSFER COMPANY, INC.	Phase I
02SW0452	EDRICH LUMBER INC.	Phase I
02SW0467	R. W. BOZEL TRANSFER, INC.	Phase I
02SW0559	ABF FREIGHT SYSTEM, INC.	Phase I
02SW0583	WOODLAWN MOTOR COACH - CATONSVILLE	Phase I
02SW0592	ROADWAY EXPRESS, INC.	Phase I
02SW0616	PJAX, INC.	Phase I
02SW0619	WASTE MANAGEMENT OF MARYLAND - BALTIMORE	Phase I
02SW0737	RECOVERMAT MID-ATLANTIC	Phase I
02SW0746	U.S. POSTAL SERVICE - HALETHORPE VMF	Phase I
02SW0876	WACO PRODUCTS, INC.	Phase I
02SW0881	MAYER BROTHERS, INC.	Phase I
02SW0956	J. W. TREUTH & SONS, INC.	Phase I
02SW0985	UPS GROUND FREIGHT - ELKRIDGE	Phase I
02SW0990	SUPERIOR CARRIERS, INC.	Phase I
02SW0992	HANSON PIPE & PRODUCTS, INC.	Phase I
02SW0996	BELT'S DISTRIBUTION CENTER	Phase I
02SW0997	BPG HOTEL PARTNERS XT, LLC	Phase I
02SW1192	DHL EXPRESS USA - LINTHICUM	Phase I
02SW1256	MARYLAND RECYCLE CO. OF ELKRIDGE, INC.	Phase I
02SW1273	WILKINS-ROGERS, INC.	Phase I
02SW1291	BALTIMORE REGIONAL YARD DEBRIS COMPOSTING	Phase I
02SW1358	WARD TRUCKING CORPORATION - BALTIMORE TERMINAL	Phase I
02SW1438	HOWARD COUNTY - MAYFIELD FACILITY	Phase I

Permit #	Facility	NPDES Group
02SW1446	CALTON CARS & PARTS	Phase I
02SW1489	BIG BOY'S RIGGING SERVICE, LLC	Phase I
02SW1500	B & W OPTICAL COMPANY, INC.	Phase I
02SW1576	HARTMAN MACHINE SERVICE	Phase I
02SW1590	MES TIRE RECYCLING FACILITY	Phase I
02SW1607	MAJESTIC DISTILLING COMPANY, INC.	Phase I
02SW1711	MES - BCRRF WESTERN ACCEPTANCE	Phase I
02SW1723	EUROPARTS EXPRESS	Phase I
02SW1742	PARKER HANNIFIN CORPORATION	Phase I
02SW1791	OLD DOMINION FREIGHT LINE, INC.	Phase I
02SW1830	C-CARE, LLC02/27/03	Phase I
02SW1863	ROLLING FRITO-LAY SALES - BALTIMORE DC	Phase I
02SW1914	HALETHORPE INDUSTRIAL, LLC	Phase I
02SW1915	MACHADO CONSTRUCTION COMPANY, INC.	Phase I
02SW1916	COMMUNITY COLLEGE OF BALTIMORE COUNTY - CATONSVILLE	Phase I
02SW1963	BALTIMORE COUNTY HIGHWAY DEPARTMENT - SHOP 1	Phase I
02SW1976	NORTHROP GRUMMAN - ADVANCED TECHNOLOGY LABORATORIES	Phase I
02SW1988	PULLEN'S TOUR SERVICE, INC.	Phase I
02SW1999	CAPTIVE PLASTICS, INC.	Phase I
02SW2005	PRECOAT METALS	Phase I
02SW2019	BALTIMORE COUNTY PUBLIC SCHOOLS - ARBUTUS BUS LOT	Phase I
02SW2051	AGGREGATE INDUSTRIES - BALTIMORE VEHICLE MAINTENANCE FACILITY	Phase I
02SW2074	DILLON'S BUS SERVICE	Phase I
02SW2079	WM RECYCLE AMERICA OF ELKRIDGE	Phase I
04DP3316	ANNE ARUNDEL COUNTY MUNICIPAL SEPARATE STORM SEWER	Phase I
05DP3317	BALTIMORE COUNTY MUNICIPAL SEPARATE STORM SEWER	Phase I
05DP3318	HOWARD COUNTY MUNICIPAL SEPARATE STORM SEWER	Phase I
00DP3319	CARROLL COUNTY MUNICIPAL SEPARATE STORM SEWER	Phase I
99DP3315	BALTIMORE CITY MS4	Phase I
99DP3313	STATE HIGHWAY ADMINSTRATION MS4	Phase I

Permit #	Facility	NPDES Group
	MDE GENERAL PERMIT TO CONSTRUCT	Phase I/II

Note: [1] Although not listed in this table, some individual permits from Tables B-2 through B-4 incorporate stormwater requirements and are accounted for within the NPDES stormwater WLA (specifically the "Other" Regulated Stormwater Allocation in the Technical Memorandum *Significant Sediment Point Sources in the Patapsco River Lower North Branch Watershed* accompanying this TMDL report) as well additional Phase II permitted MS4s, such as military bases, hospitals, etc.

APPENDIX C – Technical Approach Used to Generate Maximum Daily Loads

Summary

This appendix documents the technical approach used to define maximum daily loads of sediment consistent with the average annual TMDL in the Patapsco River Lower North Branch Watershed, which is considered the maximum allowable load the watershed can sustain without causing any sediment related impacts to aquatic health. The approach builds upon the modeling analysis that was conducted to determine the sediment loadings and can be summarized as follows.

- The approach defines maximum daily loads for each of the source categories.
- The approach builds upon the TMDL modeling analysis that was conducted to ensure that average annual loading targets do not cause any sediment related impacts to aquatic health.
- The approach converts daily time-series loadings into TMDL values in a manner that is consistent with available EPA guidance on generating daily loads for TMDLs (US EPA 2007).
- The approach considers a daily load level of a resolution based on the specific data that exists for each source category.

Introduction

This appendix documents the development and application of the approach used to define maximum daily load values. It is divided into sections discussing:

- Basis for approach
- Options considered
- Selected approach
- Results of approach

Basis for approach

The overall approach for the development of daily loads was based upon the following factors:

- **Average Annual TMDL:** The basis of the average annual sediment TMDL is that cumulative high sediment loading rates have negative impacts on the biological community. Thus, the average annual sediment load was calculated so as to not cause any sediment related impacts to aquatic health.
- **CBP P5 Watershed Model Sediment Loads:** There are two spatial calibration points for sediment within the CBP P5 watershed model framework. First, EOS loads are calibrated to long term EOS target loads. These target loads are the loads used to determine an average annual TMDL. Furthermore, the target loads were used in the TMDL because, as calibration targets, they are expected to

remain relatively unchanged during the final calibration stages of the CBP P5 model, and therefore will be the most consistent with the final CBP P5 watershed model sediment loading estimates. Currently, the CBP P5 model river segments are being calibrated to daily monitoring information for watersheds with a flow greater that 100 cfs, or an approximate area of 100 square miles.

- **Draft EPA guidance document entitled "Developing Daily Loads for Load-based TMDLs":** This guidance document provides options for defining maximum daily loads when using TMDL approaches that generate daily output (US EPA 2007).

The rationale for developing TMDLs expressed as *daily* loads was to accept the existing average annual TMDL, but then develop a method for converting this number to a maximum *daily* load – in a manner consistent with EPA guidance and available information.

Options considered

The draft EPA guidance document for developing daily loads does not specify a single approach that must be adhered to, but rather it contains a range of acceptable options (US EPA 2007). The selection of a specific method for translating a time-series of allowable loads into the expression of a TMDL requires decisions regarding both the level of resolution (e.g., single daily load for all conditions vs. loads that vary with environmental conditions) and level of probability associated with the TMDL.

This section describes the range of options that were considered when developing methods to calculate Patapsco River Lower North Branch Maximum Daily Loads.

<u>Level of Resolution</u>

The level of resolution pertains to the amount of detail used in specifying the maximum daily load. The draft EPA guidance document on daily loads provides three categories of options for level of resolution, all of which are potentially applicable for the Patapsco River Lower North Branch watershed:

1. **Representative daily load:** In this option, a single daily load (or multiple representative daily loads) is specified that covers all time periods and environmental conditions.
2. **Flow-variable daily load:** This option allows the maximum daily load to vary based upon the observed flow condition.
3. **Temporally-variable daily load:** This option allows the maximum daily load to vary based upon seasons or times of varying source or water body behavior (US EPA 2007).

Probability Level

All TMDLs have some probability of being exceeded, with the specific probability being either explicitly specified or implicitly assumed. This level of probability directly or indirectly reflects two separate phenomena:

1. Water quality criteria consist of components describing acceptable magnitude, duration, and frequency. The frequency component addresses how often conditions can allowably surpass the combined magnitude and duration components.
2. Pollutant loads, especially from wet weather sources, typically exhibit a large degree of variability over time. It is rarely practical to specify a "never to be exceeded value" for a daily load, as essentially any loading value has some finite probability of being exceeded.

The draft daily load guidance document states that the probability component of the maximum daily load should be "based on a representative statistical measure" that is dependent upon the specific TMDL and the best professional judgment of the developers (US EPA 2007). This statistical measure represents how often the maximum daily load is expected/allowed to be exceeded. The primary options for selecting this level of protection would be:

1. **The maximum daily load reflects some central tendency:** In this option, the maximum daily load is based upon the mean or median value of the range of loads expected to occur. The variability in the actual loads is not addressed.
2. **The maximum daily load reflects a level of protection implicitly provided by the selection of some "critical" period**: In this option, the maximum daily load is based upon the allowable load that is predicted to occur during some critical period examined during the analysis. The developer does not explicitly specify the probability of occurrence.
3. **The maximum daily load is a value that will be exceeded with a pre-defined probability:** In this option, a "reasonable" upper bound percentile is selected for the maximum daily load based upon a characterization of the variability of daily loads. For example, selection of the 95^{th} percentile value would result in a maximum daily load that would be exceeded 5% of the time.

Selected Approach

The approach selected for defining a Patapsco River Lower North Branch Maximum Daily Load was based upon the specific data that exists for each source category. The approach consists of unique methods for each of the following categories of sources:

- Approach for Nonpoint Sources and Stormwater Point Sources within the Patapsco River Lower North Branch watershed
- Approach for Process Water Point Sources within the Patapsco River Lower North Branch watershed

- Approach for upstream sources

Approach for Nonpoint Sources and Stormwater Point Sources within the Patapsco River Lower North Branch watershed

The level of resolution selected for the Patapsco River Lower North Branch Maximum Daily Load was a representative daily load, expressed as a single daily load for each loading source. This approach was chosen based upon the specific data that exists for nonpoint sources and stormwater point sources within the Patapsco River Lower North Branch watershed. Currently, the best available data is the CBP P5 model daily time series calibrated to long-term average annual loads (per landuse). The CBP reach simulation results are calibrated to daily monitoring information for watershed segments with a flow typically greater that 100 cfs, but they have not been through appropriate peer review. Therefore, it was concluded that it would not be appropriate to apply the absolute values of the reach simulation model results to the TMDL, and the annual loads were used instead. However, it was assumed that the distribution of the daily values was correct, in order to calculate a normalized statistical parameter to estimate the maximum daily loads.

The maximum daily load was estimated based on three factors: a specified probability level, the average annual sediment TMDL, and the coefficient of variation (CV) of the CBP P5 Patapsco River Lower North Branch reach simulation daily loads. The probability level (or exceedance frequency) is based upon guidance from EPA (US EPA 1991) where examples suggest that when converting from a long-term average to a daily value, the z-score corresponding to the 99th percentile of the log-normal probability distribution should be used. The average annual sediment TMDL is estimated from the CBP P5 EOS target loads. The calculation of the CV is described below.

The CBP P5 Patapsco River Lower North Branch reach simulation consisted of a daily time series beginning in 1985 and extending to the year 2005. The CV was estimated by first converting the daily sediment load values to a log distribution and then verifying that the results approximated the normal distribution (see Figure C-1). Next, the CV was calculated using the arithmetic mean and standard deviation results from the log transformation. The log-transformed values were used to reduce the possible influence of outliers. The resulting CV of 7.94 was calculated using the following equation:

$$CV = \frac{\beta}{\alpha} \qquad \text{(Equation C.1)}$$

where:
CV = coefficient of variation
$\beta = \alpha\sqrt{e^{\sigma^2} - 1}$
$\alpha = e^{(\mu + 0.5*\sigma^2)}$
α = mean (arithmetic)
β = standard deviation (arithmetic)
μ = mean of logarithms
σ =standard deviation of logarithms

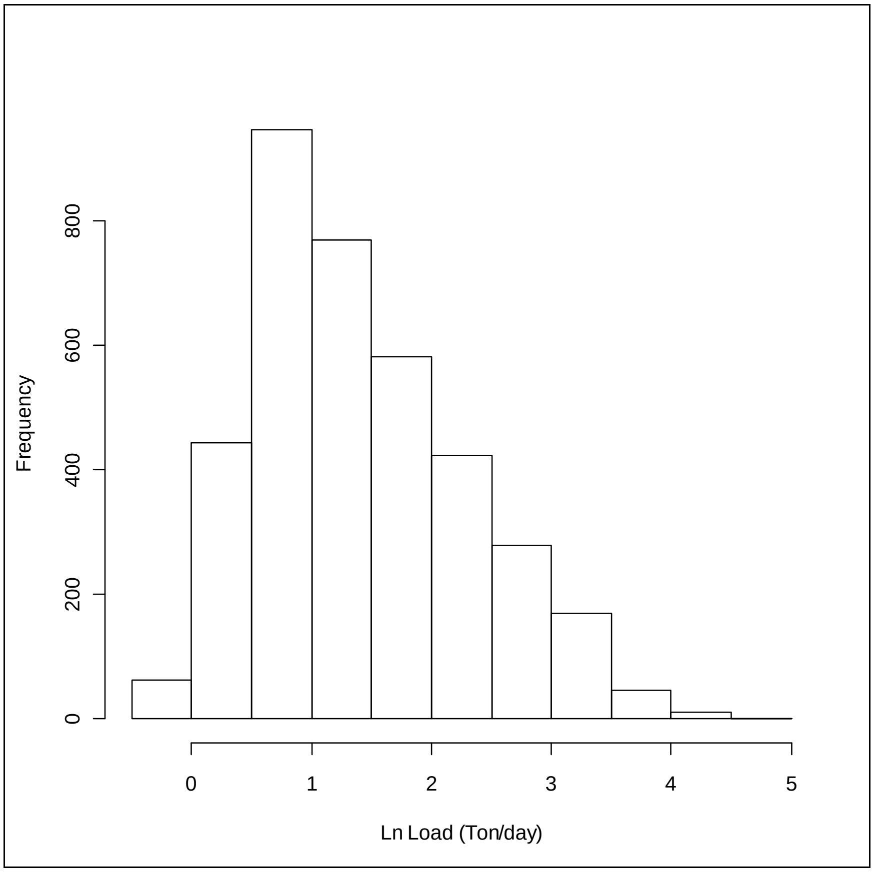

Figure C-1: Histogram of CBP River Segment Daily Simulation Results for the Patapsco River Lower North Branch Watershed

The maximum "daily" load for each contributing source is estimated as the long-term average annual load multiplied by a factor that accounts for expected variability of daily loading values. The equation is as follows:

$$MDL = LTA * e^{(z\sigma - 0.5\sigma^2)} \quad \text{(Equation C.2)}$$

where:
MDL = Maximum daily load
LTA = Long term average (average annual load)
Z = z-score associated with target probability level
$\sigma = \ln(CV^2+1)$
CV = Coefficient of variation based on arithmetic mean and standard deviation

Using a z-score associated with the 99^{th} percent probability, a CV of 7.94, and consistent units, the resulting dimensionless conversion factor from long term average annual loads to a maximum daily load is 14.36. The average annual Patapsco River Lower North Branch TMDL of sediment/TSS is reported in ton/year, and the conversion from ton/year to a maximum daily load in ton/day is 0.039 (e.g. 14.36/365).

Approach for Process Water Point Sources within the Patapsco River Lower North Branch watershed

The TMDL also considers contributions from other point sources (i.e., sources other than stormwater point sources) in the watershed that have NPDES permits with sediment limits. As these sources are generally minor contributors to the overall sediment load, the TMDL analysis that defined the average annual TMDL did not propose any reductions for these sources and held each of them constant at their existing technology-based NPDES permit monthly (or daily if monthly was not specified) limit for the entire year.

The approach used to determine maximum daily loads for these sources was dependent upon whether a maximum daily load was specified within the permit. If a maximum daily limit was specified, then the reported average flow was multiplied by the daily maximum limit to obtain a maximum daily load. If a maximum daily limit was not specified, the maximum daily loads were calculated based on the guidance provided in the Technical Support Document (TSD) for Water Quality-based Toxics Control (US EPA 1991). The long-term average annual TMDL was converted to maximum daily limits using Table 5-2 of the TSD assuming a coefficient of variation of 0.6 and a 99th percentile probability. This results in a dimensionless multiplication factor of 3.11. The average annual Patapsco River Lower North Branch TMDL of sediment/TSS is reported in ton/yr, and the conversion from ton/yr to a maximum daily load in ton/day is 0.0085 (e.g. 3.11/365).

Results of approach

This section lists the results of the selected approach to define the Patapsco River Lower North Branch Maximum Daily Loads.

- Calculation Approach for Nonpoint Sources and Stormwater Point Sources within the Patapsco River Lower North Branch watershed

LA_{PR} (Ton/day) = Average Annual TMDL LA_{PR} (ton/yr) * .039

Stormwater WLA_{PR} (Ton/day) = Average Annual TMDL Stormwater WLA_{PR} (ton/yr) * .039

- Calculation Approach for Process Water Point Sources within the Patapsco River Lower North Branch watershed
    - For permits with a daily maximum limit:

Process Water WLA_{PR} (ton/day) = Permit flow (mgd) * Daily maximum permit limit(mg/l) * 0.0042, where 0.0042 is a combined factor required to convert units to ton/day

- For permits without a daily maximum limit:

Process Water WLA_{PR} (Ton/day) = Average Annual TMDL WLA_{PR} Other (ton/yr)* 0.0085, where 0.0085 is the factor required to convert units to ton/day

- Calculation Approach for Upstream Sources

LA_{SB} (Ton/day) = Average Annual LA_{SB} (ton/yr) * .039

Table C-1: Patapsco River Lower North Branch Maximum Daily Loads of Sediment/TSS (ton/day)

MDL (ton/yr)	=	LA			+	WLA			+	MOS
		LA_{SB}[1,2]	+	LA_{PR}		NPDES Stormwater WLA_{PR}	+	Process Water WLA_{PR}		
1,374.2	=	585.7	+	279.3	+	509.1	+	0.1	+	Implicit
		Upstream Load Allocation		Patapsco River Lower North Branch MDL Contribution						

Notes:[1] Although for the purpose of this analysis the upstream load is referred to as an LA, it could include loads from point and nonpoint sources.
[2] A delivery factor of 1 was used for the Upstream Load Allocation.