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

FINAL

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and

District of Columbia Department of the Environment - Natural Resources Administration

Submitted to:

U.S. Environmental Protection Division, Region III
Watershed Protection Division
1650 Arch Street
Philadelphia, PA 19103-2029

June 2007

EPA Submittal Date: June 22, 2007
EPA Approval Date: July 24, 2007

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ANS-PCER	Academy of Natural Sciences - Patrick Center for Environmental Research
ARCWP	Anacostia River and Tributaries Comprehensive Watershed Plan
AWRC	Anacostia Watershed Restoration Committee
BARC	Beltsville Agricultural Research Center
BMPs	Best Management Practices
BOD	Biochemical Oxygen Demand
CBP	Chesapeake Bay Program
Chla	Chlorophyll *a*
COMAR	Code of Maryland Regulations
CSO	Combined Sewer Overflow
CSS	Combined Storm Sewer And Sanitary Sewer System
CWA	Clean Water Act
CWAP	Clean Water Action Plan
DC	The District of Columbia
DCDOH	District of Columbia Department of Health
DCMR	District of Columbia Municipal Regulations
DCR	District of Columbia Register
DCWASA	District of Columbia Water and Sewer Authority
DDOE	District of Columbia Department of the Environment
DNR	Maryland Department of Natural Resources
EOF	Edge-of-Field
EOS	Edge-of-Stream
EPA	U.S. Environmental Protection Agency
ESD	Environmental Site Design
FDC	Flow Duration Curve
GIS	Geographical Information Systems
HDR	High-Density Residential
HSPF	Hydrologic Simulation Program – FORTRAN
IBI	Index of Biological Integrity
ICPRB	Interstate Commission on the Potomac River Basin
LA	Load Allocation
LBC	Lower Beaverdam Creek
LDR	Low-Density Residential
LID	Low Impact Development
LTCP	Long Term Control Plan
MACS	Maryland's Agricultural Cost Share Program
MBSS	Maryland Biological Stream Survey
MCDEP	Montgomery County Department of Environmental Protection
MD	Maryland
MDE	Maryland Department of the Environment

MDP	Maryland Department of Planning
MDR	Medium-Density Residential
mg/L	Milligrams per Liter
MGD	Million Gallons per Day
M-NCPPC-PG	Maryland National Capital Park and Planning Commission – Prince George's County
MOS	Margin Of Safety
MS4	Municipal Separate Storm Sewer System
MWCOG	Metropolitan Washington Council of Governments
NEB	Northeast Branch of the Anacostia River
NPDES	National Pollutant Discharge Elimination System
NPS	National Park Service
NPS	Nonpoint Source
NRCS	Natural Resources Conservation Service
NRI	National Resource Inventory
NWB	Northwest Branch of the Anacostia River
PCBs	Polychlorinated Biphenyls
PGDER	Prince George's County Department of Environmental Resources
PS	Point Source
SAV	Submerged Aquatic Vegetation
SSC	Suspended Sediment Concentration
STATSGO	State Soil Geographic Data Base
SWM	Stormwater Management
SWMP	Stormwater Management Plan
TAM	Tidal Anacostia Model
TMDL	Total Maximum Daily Load
TSS	Total Suspended Solids
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USFWS	U.S.Fish and Wildlife Service
USGS	U.S. Geological Survey
VIMS	Virginia Institute of Marine Science
WASP	Water Analysis Simulation Program
WLA	Waste Load Allocation
WQIA	Water Quality Improvement Act
WQLS	Water Quality Limited Segment
WQSs	Water Quality Standards
WRAS	Watershed Restoration Action Strategy
WSSC	Washington Suburban Sanitary Commission
µg/L	Micrograms per Liter

EXECUTIVE SUMMARY

This document, upon approval by the U.S. Environmental Protection Agency (EPA), establishes Total Maximum Daily Loads (TMDLs) for sediment/total suspended solids (TSS) in Maryland's (MD) tidal and non-tidal portions of the Anacostia River ("the Anacostia") and the District of Columbia's (DC) tidal Anacostia. Section 303(d) of the federal Clean Water Act (CWA) and 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.

In Maryland, the Anacostia and its tributaries have been variously designated as Use I-P, II, III and IV waters [Code of Maryland Regulations (COMAR) 26.08.02.08O]. The Maryland Department of the Environment (MDE) has identified the Anacostia (MD Basin #02140205) in the State's 303(d) List as impaired by the following (listing years in parentheses): nutrients (1996), sediments (1996), fecal bacteria – non-tidal waters (2002), impacts to biological communities (2002), toxics – polychlorinated biphenyls (PCBs) (2002), toxics – heptachlor epoxide (2002) and fecal bacteria – tidal waters (2004). This document addresses the sediments impairment. Fecal bacteria TMDLs for MD tidal and non-tidal areas of the Anacostia were submitted to EPA for approval in 2006. The listings for other impairments will be addressed separately at a future date.

DC's Section 303(d) List divides the Anacostia within the District's borders into two segments. The lower Anacostia is identified as that portion of the river extending from the mouth of the river to the John Philip Sousa Bridge and Pennsylvania Avenue and the upper Anacostia as that portion from the bridge to the MD border. DC has classified the Anacostia for current and designated uses including category C: "Protection and propagation of fish, shellfish and wildlife." The upper and lower segments of the Anacostia were listed on DC's 1998 Section 303(d) List as impaired by biochemical oxygen demand (BOD), bacteria, organics, metals, TSS, and oil and grease. DC has already developed TMDLs addressing these impairments in the Anacostia. A TSS TMDL was established for the tidal Anacostia River in DC in 2002. The watershed-wide TMDLs developed in this report replace the 2002 DC TSS TMDLs.

The Anacostia River is an interstate watershed: most of the non-tidal tributaries lie within MD, most of the tidal waters within DC's boundaries. This sediment/TSS TMDL for the Anacostia watershed was developed through a cooperative agreement between EPA Region III, the Natural Resources Administration of the District of Columbia Department of the Environment (DDOE), and MDE. This document, upon approval by EPA, establishes TMDLs for sediment/TSS in the tidal and non-tidal portions of the Anacostia watershed in both MD and DC that will allow for attainment of their respective aquatic life-related designated uses. The TMDL will address water clarity problems and associated impacts to aquatic life in the Anacostia caused by high sediment and TSS concentrations.

The objectives of the sediment/TSS TMDLs established in this document are 1) to ensure that aquatic life is protected in the tidal and non-tidal waters of the Anacostia ; 2) to ensure that MD's and DC's sediment-related water quality standards that support aquatic life are met in their respective portions of the watershed; and 3) to ensure in particular that the numeric criteria for water clarity are met in the tidal waters. The endpoint of the TMDL (the most stringent reduction in sediment loads) is DC's tidal Anacostia water clarity criterion. The spatial domain considered for the calculation of the TMDLs is the entire Anacostia watershed that includes the waters of both MD and DC.

The modeling framework used for the analysis was a coupled watershed/hydrodynamic/ water quality model, the Estimator Model, and a reference watershed approach. The watershed model (Hydrologic Simulation Program – FORTRAN (HSPF)) and the Estimator Model provided the nonpoint source (NPS) inputs to the water quality model, which calculates water clarity conditions used to determine attainment of water quality standards in the tidal Anacostia. A reference watershed approach was used to determine the sediment loads required to meet water quality standards in MD's non-tidal waters.

The HSPF model was used to simulate hydrologic and sediment erosion processes in the non-tidal drainage areas of the Anacostia's main tributaries, the Northwest Branch (NWB), the Northeast Branch (NEB), Lower Beaverdam Creek (LBC), and Watts Branch. The primary input data for this model were precipitation and other meteorological measurements from Reagan National Airport, and land use data detailed in Section 2.1.2 of this report. Model calibration data included flow and suspended solids data collected at U.S. Geological Survey (USGS) stream gage stations, and municipal separate storm sewer system (MS4) monitoring data from Montgomery and Prince George's Counties. The HSPF model was calibrated against the loads from the Estimator Model.

In the absence of numerical water quality criteria for sediment in non-tidal waters, the reference watershed approach was used to determine the sediment loads that can support designated uses of the non-tidal Anacostia watershed and, more specifically, support aquatic health. In particular, MDE has identified two Anacostia subwatersheds which are not impaired due to sediment: the upper portion of Paint Branch (above Fairland Road), located in the Piedmont province, and Upper Beaverdam Creek, in the Coastal Plain province.

The coupled hydrodynamic/water quality model, the Tidal Anacostia Model/Water Analysis Simulation Program (TAM/WASP), was used to simulate flows and water clarity conditions in the tidal Anacostia. This model simulates daily values of both total suspended sediment concentrations and water clarity based on inputs including: information on tides, precipitation, and tributary flows; daily estimates of sediment loads from the various sources; DC's MS4s; and combined sewer overflows (CSOs) from DC's combined storm sewer and sanitary sewer system (CSS). The results from these analyses show that the reductions necessary to meet MD's narrative non-tidal water quality standards were much smaller than those required in the TMDL to meet DC's water clarity criterion. Further, MD's tidal numeric water clarity criterion is already met, with the current loads, for the time periods examined in this study. However, the model tends to overpredict secchi depth in MD's portion of the tidal water and underpredict in the middle Anacostia.

The critical condition for water clarity in the tidal Anacostia is the occurrence of high flow events, which cause tributaries and storm sewers to discharge large amounts of sediment into the tidal river. This was accounted for in the TMDL analysis by the choice of simulation period, 1995-1997. This three-year time period includes a dry year, a wet year and an average year, based on precipitation data. Seasonality is captured by the TMDL analysis because these three years account for various hydrological conditions.

All TMDLs must include a margin of safety (MOS) to account for many uncertainties in the understanding and simulation of water quality in natural systems. For this TMDL, the MOS is provided by several implicit conservative assumptions used in the modeling framework of the computer simulations, i.e., by assuming an underestimation of Secchi depths and by omitting consideration of both sediment aging and submerged aquatic vegetation beds, inclusion of which would improve water clarity in the analysis scenarios.

The sediment TMDLs for both MD and DC tidal and non-tidal waters of the Anacostia are: **7097.6 tons/year** annually and **3396.1 tons/growing season** for the growing season April 1 to October 31 (see the following tables for details). The loading caps constitute an 85% overall reduction of sediment/TSS from the baseline loads determined for the TMDL analysis period, 1995-1997 (46,906 tons/year and 22,312 tons/growing season). The TMDLs are distributed between: 1) waste load allocations (WLAs) to National Pollutant Discharge Elimination System (NPDES) municipal and industrial point source (PS) discharges, NPDES MS4s and other regulated stormwater (SW), and DC CSOs; 2) load allocations (LAs) to forest and agricultural lands; and 3) an implicit margin of safety (MOS).

As the following tables indicate, TMDLs have been developed for each of the four listed segments: the MD non-tidal and MD tidal portions of the river, and DC's Tidal Upper Anacostia and Tidal Lower Anacostia segments. Each upstream segment's overall load is rolled into the succeeding downstream segment as "upstream load," resulting in a cumulative, watershed-wide TMDL. Note that the MD non-tidal segment includes an upstream load from DC sources that drain to MD waters in the NWB; similarly, loads from MD's portion of Watts Branch and LBC are added to the upstream load for the DC Tidal Upper segment where they discharge. Loads from DC's portion of those two subwatersheds are included in the MS4-WLA for the DC Tidal Upper Anacostia in the annual and growing season summary TMDL tables, and detailed separately in the tables of maximum daily loads. The first two tables, summarizing average annual and growing season TMDLs, are followed by two additional tables that present maximum daily load calculations for sediment/TSS in the Anacostia watershed, based on the average annual and growing season TMDLs, respectively.

Average Annual Sediment/TSS TMDLs for Anacostia River Watershed (tons/year)

MD Non-Tidal Anacostia

Upstream Load from DC	MD Non-Tidal WLA	MD Non-Tidal LA	MOS	MD Non-Tidal TMDL
27.0[1]	6355.8	246.8	Implicit	6629.6

MD Tidal Anacostia

Upstream Load	MD Tidal WLA	MD Tidal LA	MOS	MD Tidal TMDL (does not include non-tidal loads from Watts Br & LBC)
6117.4[2]	86.4	0	Implicit	6203.8

DC Tidal Upper Anacostia

Upstream Load (all MD loads including Watts Br & LBC)	DC Upper Anacostia MS4 WLA	DC Upper Anacostia CSO WLA	DC Upper Anacostia LA	MOS	DC Tidal Upper TMDL
6716.0[3]	109.4[4]	83.9	29.8	Implicit	6938.9

DC Tidal Lower Anacostia

Upstream Load	DC Lower Anacostia MS4 WLA	DC Lower Anacostia CSO WLA	DC PS WLA	DC Lower Anacostia LA	MOS	TOTAL TMDL
6938.9	46.4	90.8	0.5	20.7	Implicit	7097.4

[1]This load drains to MD waters from DC's portion of the NWB subwatershed

[2]Does not include MD non-tidal loads from Watts Branch (28.5) and Lower Beaverdam Creek (483.7). Since these drain to DC tidal waters, they are included in the upstream load to the DC Tidal Upper Anacostia.

[3]Upstream load comprises all MD tidal and non-tidal loads, including MD loads from Watts Branch (28.5) and LBC (483.7).

[4]Includes loads from DC non-tidal waters in Watts Branch (24.1) and LBC (0.6)

Growing Season Sediment/TSS TMDLs for Anacostia River Watershed (tons/season)

MD Non-Tidal Anacostia

Upstream Load from DC	MD Non-Tidal WLA	MD Non-Tidal LA	MOS	MD Non-Tidal TMDL
20.7[1]	3005.8	25.1	Implicit	3051.6

MD Tidal Anacostia

Upstream Load	MD Tidal WLA	MD Tidal LA	MOS	MD Tidal TMDL (does not include non-tidal loads from Watts Br & LBC)
2734.8[2]	62.0	0	Implicit	2796.8

DC Tidal Upper Anacostia

Upstream Load (includes all MD loads from Watts Br & LBC)	DC Upper Anacostia MS4 WLA	DC Upper Anacostia CSO WLA	DC Upper Anacostia LA	MOS	DC Tidal Upper TMDL
3113.5[3]	76.3[4]	61.7	20.9	Implicit	3272.5

DC Tidal Lower Anacostia

Upstream Load	DC Lower Anacostia MS4 WLA	DC Lower Anacostia CSO WLA	DC PS WLA	DC Lower Anacostia LA	MOS	TOTAL TMDL
3272.5	33.6	74.6	.3	14.9	Implicit	3395.8

[1]This load drains to MD waters from DC's portion of the NWB subwatershed

[2]Does not include MD non-tidal loads from Watts Branch (16.5) and Lower Beaverdam Creek (300.2). Since these drain to DC tidal waters, they are included in the upstream load to the DC Tidal Upper Anacostia.

[3]Upstream load comprises all MD tidal and non-tidal loads, including MD loads from Watts Branch (16.5) and LBC (300.2).

[4]Includes loads from DC non-tidal waters in Watts Branch (15.5) and LBC (0.4)

Summary of Annually-Based Maximum Daily Loads of Sediment/TSS for the Anacostia River Watershed (tons/day)

Non-Tidal Anacostia River

Flow Range (m^3/s)	Upstream (max, avg)	MD Non-Tidal MS4-WLA	MD Non-Tidal Other PS-WLA	MD Non-Tidal LA	MOS	Non-Tidal TMDL (max, avg)
< 0.89	0.003, 0.002	0.505	0.349	0.0007	Implicit	0.858, 0.199
0.89 - 2.34	0.009, 0.003	2.581	0.349	0.016	Implicit	2.955, 0.381
2.34 - 3.48	0.020, 0.005	20.870	0.349	0.041	Implicit	21.28, 0.800
3.48 - 10.75	0.279, 0.013	44.617	0.349	0.459	Implicit	45.70, 3.016
> 10.75	19.23, 0.676	3828.51	0.349	244.45	Implicit	4092.54, 168.86

MD Tidal Anacostia River

Flow Range (m^3/s)	Upstream (max, avg)	MD Tidal MS4-WLA	MD Tidal LA	MOS	TMDL to MD/DC Border (max, avg)
All	4092.54, 18.15	18.85	0.11	Implicit	4111.50, 18.95

Summary of Annually-Based Maximum Daily Loads of Sediment/TSS for the Anacostia River Watershed (cont'd.) (tons/day)

DC Tidal Upper Anacostia River

Non-Tidal Lower Beaverdam Creek

Flow Range (m^3/s)	Upstream (max, avg)	DC LBC MS4-WLA (max, avg)	DC LBC LA (max, avg)	MOS	Total TMDL (max, avg)
All	106.01, 1.324	0.0954, 0.0016	-, -	Implicit	106.105, 1.326

Non-Tidal Watts Branch

Flow Range (m^3/s)	Upstream (max, avg)	DC WB MS4-WLA (max, avg)	DC WB LA (max, avg)	MOS	Total TMDL (max, avg)
All	4.338, 0.1314	3.425, 0.1114	-, -	Implicit	7.763, 0.2428

DC Tidal Upper Anacostia

Flow Range (m^3/s)	Upstream (max, avg)	DC Upper Anacostia MS4-WLA (max, avg)	DC Upper Anacostia CSO-WLA (max, avg)	DC Upper Anacostia LA (max, avg)	MOS	TMDL to Upper / Lower Boundary (max, avg)
All	4111.50, 18.95	18.35, 0.78	84.61, 24.37	6.33, 0.28	Implicit	4220.79, 44.38

DC Tidal Lower Anacostia River

Flow Range (m^3/s)	Upstream (max, avg)	DC Lower Anacostia MS4-WLA (max, avg)	DC Lower Anacostia Other PS-WLA	DC Lower Anacostia CSO-WLA (max, avg)	DC Lower Anacostia LA (max, avg)	MOS	TOTAL TMDL (max, avg)
All	4220.79, 44.38	10.24, 0.43	0.0043	67.10, 25.85	4.52, 0.19	Implicit	4302.65, 70.85

Summary of Seasonally-Based Maximum Daily Loads of Sediment/TSS for the Anacostia River Watershed (tons/day during growing season)

Non-Tidal Anacostia River

Flow Range (m^3/s)	Upstream (max, avg)	MD Non-Tidal MS4-WLA	MD Non-Tidal Other PS-WLA	MD Non-Tidal LA	MOS	Non-Tidal TMDL (max, avg)
< 0.89	0.003, 0.0023	0.500	0.302	0.0007	Implicit	0.806, 0.156
0.89 - 2.34	0.009, 0.0037	2.580	0.302	0.006	Implicit	2.897, 0.369
2.34 - 3.48	0.020, 0.0071	20.870	0.302	0.022	Implicit	21.21, 1.016
3.48 - 10.75	0.279, 0.0236	44.620	0.302	0.168	Implicit	45.37, 4.854
> 10.75	19.23, 1.0981	1393.24	0.302	9.500	Implicit	1422.27, 158.69

MD Tidal Anacostia River

Flow Range (m^3/s)	Upstream (max, avg)	MD Tidal MS4-WLA	MD Tidal LA	MOS	TMDL to MD/DC Border (max, avg)
All	1422.27, 14.23	18.85	0.0005	Implicit	1441.12, 15.44

Summary of Seasonally-Based Maximum Daily Loads of Sediment/TSS for the Anacostia River Watershed (cont'd) (tons/day during growing season)

DC Tidal Upper Anacostia River

Non-Tidal Lower Beaverdam Creek

Flow Range (m^3/s)	Upstream (max, avg)	DC LBC MS4-WLA (max, avg)	DC LBC LA (max, avg)	MOS	Total TMDL (max, avg)
All	66.01, 1.403	0.0930, 0.0020	-, -	Implicit	66.10, 1.405

Non-Tidal Watts Branch

Flow Range (m^3/s)	Upstream (max, avg)	DC WB MS4-WLA (max, avg)	DC WB LA (max, avg)	MOS	Total TMDL (max, avg)
All	3.65, 0.1406	3.425, 0.1318	-, -	Implicit	7.075, 0.2724

DC Tidal Upper Anacostia

Flow Range (m^3/s)	Upstream (max, avg)	DC Upper Anacostia MS4-WLA (max, avg)	DC Upper Anacostia CSO-WLA (max, avg)	DC Upper Anacostia LA (max, avg)	MOS	TMDL to Upper / Lower Boundary (max, avg)
All	1441.12, 15.44	18.35, 1.18	84.61, 21.94	6.33, 0.41	Implicit	1550.41, 38.97

DC Tidal Lower Anacostia River

Flow Range (m^3/s)	Upstream (max, avg)	DC Lower Anacostia MS4-WLA (max, avg)	DC Lower Anacostia Other PS-WLA	DC Lower Anacostia CSO-WLA (max, avg)	DC Lower Anacostia LA (max, avg)	MOS	TOTAL TMDL (max, avg)
All	1550.41, 38.97	10.24, 0.66	0.0043	67.10, 25.85	4.52, 0.291	Implicit	1632.27, 65.77

The TMDLs presented above have been developed to meet DC and MD water quality standards in their respective waters of the Anacostia River and, in particular, to meet DC's numeric water clarity criteria specified in this report. DC also has a numeric criterion for chlorophyll *a* in the tidal Anacostia, which is a seasonal segment average (July through September) of 25 µg/L. The sediment TMDLs proposed in this report will not meet DC's chlorophyll *a* criterion without nutrient reductions determined elsewhere. However, MD and DC are planning to develop a TMDL for nutrients and BOD in the Anacostia River that will meet DC's criterion for chlorophyll *a*.

The CWA and current EPA regulations require reasonable assurance that TMDL load allocations will be implemented. Sediment and erosion problems in highly urbanized watersheds are primarily caused by uncontrolled or inadequately controlled runoff from high percentages of impervious surfaces, leading to alterations in natural hydrology. MD and DC will work with an active coalition of local, state and federal agencies, environmental organizations and citizens groups in the watershed to restore the river and its tributaries. MD and DC intend for the required reductions 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.

The DC Water and Sewer Authority (DCWASA) has established a Long Term Control Plan (LTCP) for the reduction of CSOs and the sediment loads associated with them. Under its MS4 NPDES permit, DC is implementing a stormwater management plan to control the discharge of pollutants from separate storm sewer outfalls. DC is also implementing a nonpoint source management plan through its Nonpoint Source Management and Chesapeake Bay Implementation programs.

MD and DC have several well-established programs to draw upon, including the Water Quality Improvement Act of 1998 (WQIA) in MD, the Erosion and Sedimentation Control Amendment Act of 1994 and DC Law 5-188 (Storm Water Management Regulations – 1988) of the District of Columbia Water Pollution Control Act of 1984 in DC, and the Federal Nonpoint Source Management Program (Section 319 of the Clean Water Act). Pursuant to the 2000 Maryland Stormwater Design Manual, MDE requires an 80% reduction of sediments for new development. Additionally, for existing development, MDE's NPDES stormwater permits require watershed assessments and restoration based on impervious surface area. Currently, Prince George's and Montgomery Counties are required to restore 10% of their impervious areas.

In MD, Sediment and Erosion Control Programs are operated at the local level, where local governments have shown the ability to enforce the provisions of their ordinances relating to soil erosion and sediment control. MDE conducts periodic reviews of local programs to ensure that implementation is acceptable and has the authority to suspend delegation and take over any program that does not meet State standards.

There is also an active coalition of local, state, and federal agencies, environmental organizations and citizens groups working together to restore the river and its tributaries; this coalition can help to ensure the implementation of the sediment TMDLs. In 1987, the Anacostia Watershed Restoration Agreement was signed by MD, DC, and Montgomery and Prince George's Counties, resulting in the formation of the Anacostia Watershed Restoration Committee (AWRC). Several sediment reduction strategies have been implemented and are ongoing under this agreement. For example, regular stream assessment monitoring and MS4 monitoring for constituents including TSS have been conducted in Prince George's and Montgomery Counties and in DC. Various sediment reduction/controlling strategies are also ongoing in the watershed, including: street sweeping, storm drain-inlet cleaning, stormpipe cleaning in urban areas, stormwater ponds, and Environmental Site Design (ESD)/Low Impact Development (LID) projects.

MD and DC intend for the required reductions to be implemented in an iterative process, which includes the existing stormwater management program and cooperation with AWRC. The iterative implementation of best management practices (BMPs) in the watershed has several benefits: tracking of water quality improvements following BMP implementation through follow-up stream monitoring; providing a mechanism for developing public support through periodic updates on BMP implementation; and helping to ensure that the most cost-effective practices are implemented first.

1.0 INTRODUCTION

Section 303(d)(1)(C) of the Federal Clean Water Act (CWA) and the U.S. Environmental Protection Agency's (EPA) implementing regulations direct each state to develop a Total Maximum Daily Load (TMDL) for each impaired water quality limited segment (WQLS) on the Section 303(d) List, taking into account seasonal variations and a protective margin of safety (MOS) to account for uncertainty. 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, 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.

In Maryland, the Anacostia River ("the Anacostia") and its tributaries have been variously designated as Use I-P, II, III and IV waters [Code of Maryland Regulations (COMAR) 26.08.02.08 O]. The Maryland Department of the Environment (MDE) has identified the Anacostia on the State's 303(d) List as impaired by the following (listing years in parentheses): nutrients (1996); sediments (1996); fecal bacteria (non-tidal waters in 2002, tidal waters in 2004); impacts to biological communities (2002); and toxics (polychlorinated biphenyls and heptachlor epoxide) in 2002. Fecal bacteria TMDLs for MD tidal and non-tidal areas were submitted to EPA for approval in 2006. This document addresses the sediments impairment. All other impairments in MD's tidal and non-tidal portions of the Anacostia will be addressed at a future date.

The District of Columbia (DC) has classified the Anacostia for current and designated uses including category Class C: "Protection & Propagation of fish, shellfish and wildlife." DC's 303(d) List divides the Anacostia within the District's borders into two segments. The lower Anacostia is identified as that portion of the river extending from the mouth of the river to the John Philip Sousa Bridge and Pennsylvania Avenue and the upper Anacostia from the bridge to the Maryland border. The upper and lower segments of the Anacostia were listed on DC's 1998 Section 303(d) List as impaired by biochemical oxygen demand (BOD), bacteria, organics, metals, total suspended solids (TSS), and oil and grease. DC has already developed TMDLs addressing these impairments in the Anacostia. A TSS TMDL was established for the tidal Anacostia in DC in 2002. The watershed-wide TMDLs developed in this report replace the 2002 DC TSS TMDLs.

This document, upon EPA approval, establishes TMDLs of sediment/TSS in the tidal and non-tidal portions of the Anacostia watershed in both MD and DC that will allow for the attainment of their respective designated uses. The TMDL will address water clarity problems and associated impacts to aquatic life in the Anacostia caused by high sediment and TSS concentrations.

Excessive sediment has been identified by the EPA as the leading cause of impairment of our nation's waters, and as contributing to the decline of populations of aquatic life in North America (USEPA 2003a). Suspended sediment in streams may reduce visibility and prevent fish from seeing their prey, and may clog gills and filter feeding mechanisms of fish and benthic (bottom-dwelling) organisms. Excessive deposition of sediment on streambeds may bury eggs or larvae of fish and benthic macroinvertebrates, or degrade habitat by clogging the interstitial spaces between sand and gravel particles. Suspended sediment also reduces the amount of light reaching aquatic plants and can cause a decline or disappearance of communities of submerged aquatic vegetation (SAV), an important component of tidal ecosystems.

The Anacostia is an interstate watershed: most of the non-tidal tributaries lie within MD, most of the tidal waters within DC's boundaries. This sediment/TSS TMDL for the Anacostia watershed was developed through a cooperative agreement between EPA Region III, the Natural Resources Administration of the District of Columbia Department of the Environment (DDOE), and MDE. This document, upon EPA approval, establishes TMDLs for sediment that: 1) are protective of aquatic life in the tidal and non-tidal waters of the Anacostia; 2) meet MD's and DC's sediment-related water quality standards in their respective portions of the river; and 3) specifically meet the numeric criteria for water clarity in the tidal waters.

2.0 SETTING AND WATER QUALITY DESCRIPTION

2.1 Background and General Setting

The Anacostia River watershed comprises a 173 square mile drainage area that includes highly urbanized areas in DC, old and newly developing suburban neighborhoods in the surrounding metropolitan area, croplands and pastures at the U.S. Department of Agriculture's Beltsville Agricultural Research Center (BARC), and forested parklands throughout the watershed. The Anacostia and many of its tributaries cross interstate boundaries, with 145 square miles of the watershed (84%) lying in MD, and 28 square miles (16%) in DC. The location of the watershed is shown in Figure 1.

The main channel of the Anacostia is 8.4 miles (13.5 kilometers) in length, extending from the confluence of its two largest tributaries, the Northwest Branch (NWB) and the Northeast Branch (NEB), in Bladensburg, MD, to the location where the Anacostia discharges into the Potomac River in DC. The main channel of the Anacostia is an estuary with a variation in water level of approximately three feet over a tidal cycle. Tidal influence extends into the lower reaches of the river's tributaries to approximately the locations of the U.S. Geological Survey (USGS) gage stations 01649500 on the NEB and 01651800 on Watts Branch, and to the bridge at U.S. Route 1 (Rhode Island Avenue) on the NWB, as indicated in Figure 2. Approximately 70% of the watershed is drained by the two largest tributaries, the NWB and the NEB. The other two major tributaries of the Anacostia, Lower Beaverdam Creek (LBC) and Watts Branch, drain highly urbanized areas in Prince George's County and DC.

2.1.1 Geology and soils

The watershed lies within two physiographic provinces, the Piedmont and the Coastal Plain, whose division runs approximately along the line dividing Montgomery and Prince George's Counties, MD. The upper northwestern portion of the watershed is in the Piedmont Plateau province, characterized by steep stream valleys and well-drained loamy soils underlain by metamorphic rock. The Piedmont portion of the watershed ranges in elevation from 200 to 400 feet above sea level, and streambeds tend to be rocky, with relatively steep gradients. The remainder of the basin lies within the Coastal Plain province, a wedge-shaped mass of primarily unconsolidated sediments covered by sandy soils. The Coastal Plain portion of the watershed, ranging from 0 to 200 feet above sea level, is characterized by lower relief, and is drained by slowly meandering streams with shallow channels and gentle slopes.

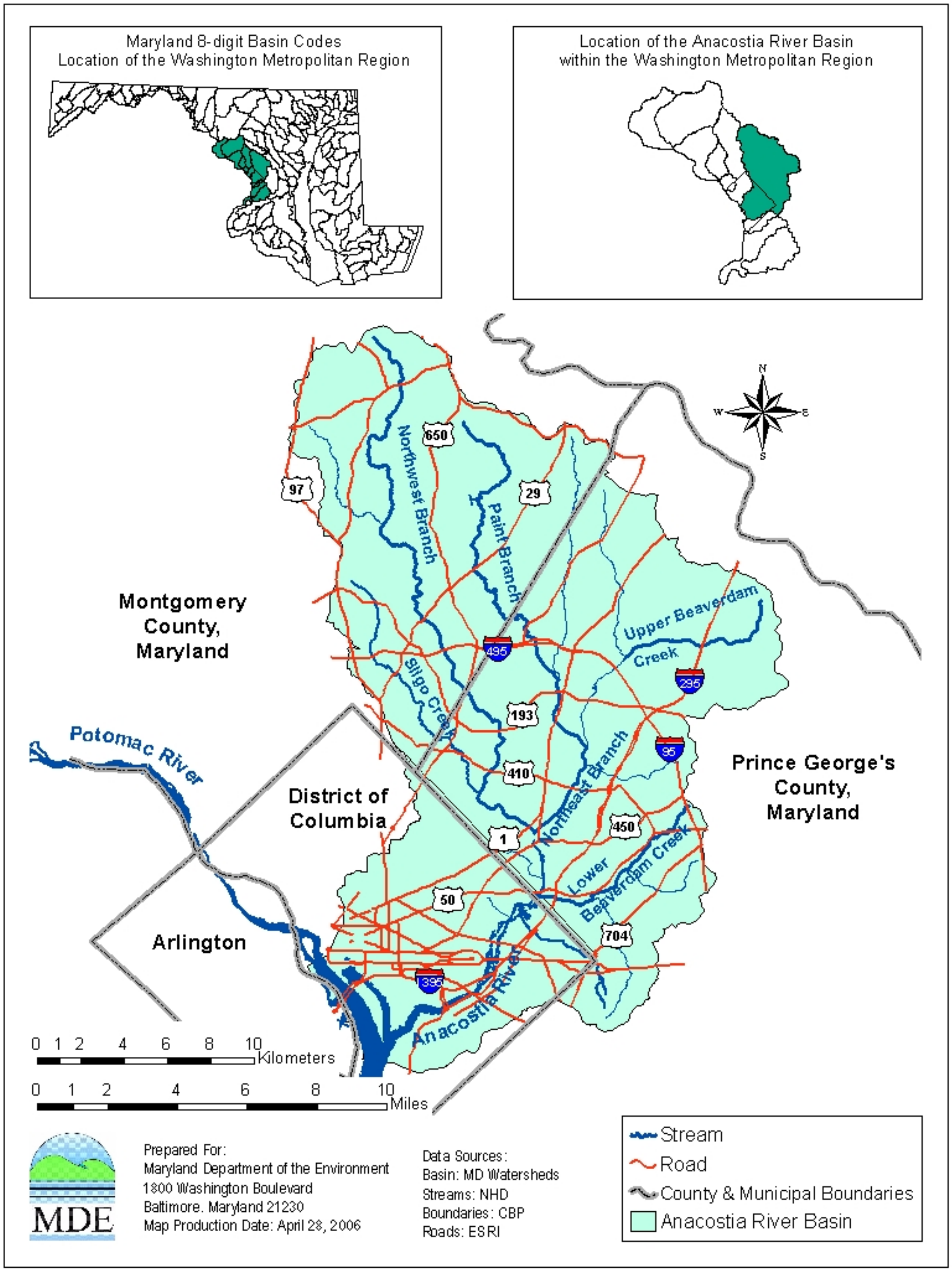

Figure 1. Location map of the Anacostia River watershed

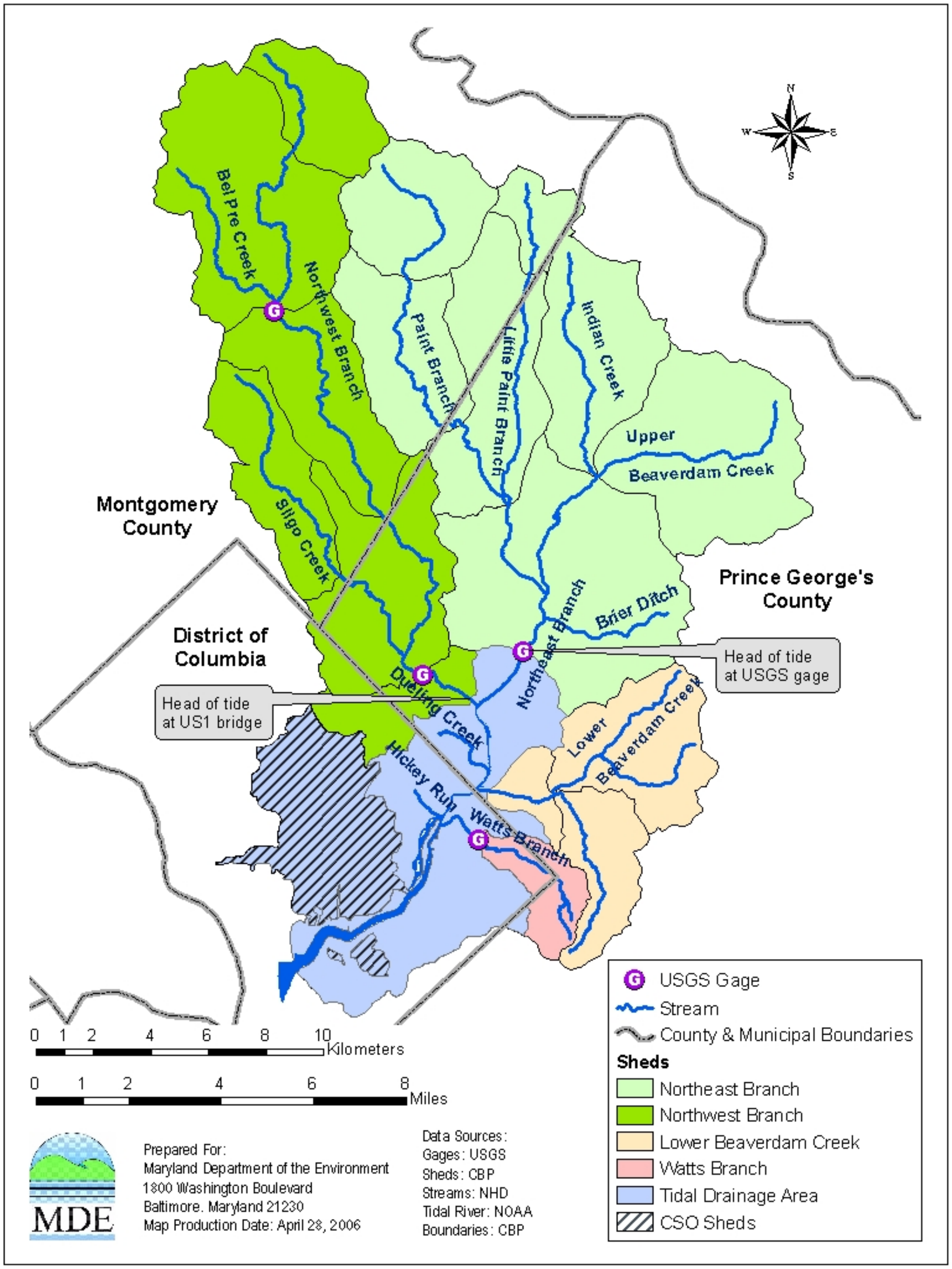

Figure 2. Anacostia River subwatersheds

The NWB tributary lies predominantly in the Manor-Glenelg-Chester soil series. Soils in this series are fine-loamy, mixed, mesic Typic Hapludults and are very deep and well-drained (Maryland Soil Conservation Service, Montgomery County, MD 1995). The NEB lies mostly in the Sunnyside-Christiana-Muirkirk soil series. The Sunnyside soils are mostly red, deep, and well-drained. The Christiana-Muirkirk are also red and deep soils but are less permeable than the Sunnyside soils (Maryland Soil Conservation Service Prince George's County, MD 1967). The portion of the watershed below the NWB and NEB drainage areas lies mainly in the Sunnyside-Christiana-Muirkirk soil series, and the Beltsville-Croom-Sasafras soil series (STATSGO). These soils are gently sloping to steep and dominantly gravelly soils (Maryland Soil Conservation Service, Prince George's County, MD 1967).

2.1.2 Land use

An updated analysis of Anacostia basin land use was done for this project in order to improve consistency in results for Prince George's and Montgomery Counties. The Maryland Department of Planning (MDP) Geographical Information Systems (GIS) land use data were used to determine land use area boundaries. MDP land use types were aggregated by the Interstate Commission on the Potomac River Basin (ICPRB) into the categories shown in Figure 3. Percent imperviousness, by land use category, was calculated for each Anacostia subwatershed (see Figure 2), based on GIS data on building footprints, paved roads, and parking lots provided by Montgomery County DEP and by the Maryland National Capital Park and Planning Commission – Prince George's County (M-NCPPC-PG). For portions of the watershed lying within DC, data from the Metropolitan Washington Council of Governments (MWCOG) DC Planned Land Use Cover (Warner et al. 1997) were used.

Land use in the watershed is predominantly urban, with 23% of the watershed covered by impervious surfaces such as rooftops, paved roads, and parking lots. Urban land (primarily residential, commercial, and industrial) occupies approximately 75% of the watershed, with 20% of the watershed forested, and 5% in agricultural use. Virtually all of the agricultural land in the basin is associated with the BARC, located primarily in the Upper Beaverdam Creek subwatershed. A summary of land use by major subwatershed is given in Table 1, where "Urban" land represents the categories: Low-density residential (LDR), Medium-density residential (MDR), High-density residential (HDR), Commercial, and Industrial. "Agricultural" land represents Cropland and Pasture.

Table 1. Summary of Anacostia Watershed land use (acres)

	Urban	Agricultural	Forest	Total	Impervious	Connected Impervious	%Connected Impervious
NWB	27,276	1,103	5,332	33,711	6,794	5,880	17%
NEB	28,326	3,756	14,210	46,291	8,490	7,710	17%
LBC	7,580	85	1,966	9,631	2,660	2,514	26%
Watts	1,823	28	269	2,119	578	558	26%
Tidal	19,155	0	166	19,321	7,447	7,447	39%
Total	84,160	4,971	21,943	111,073	25,968	24,108	22%
%Total	75%	5%	20%	100%			

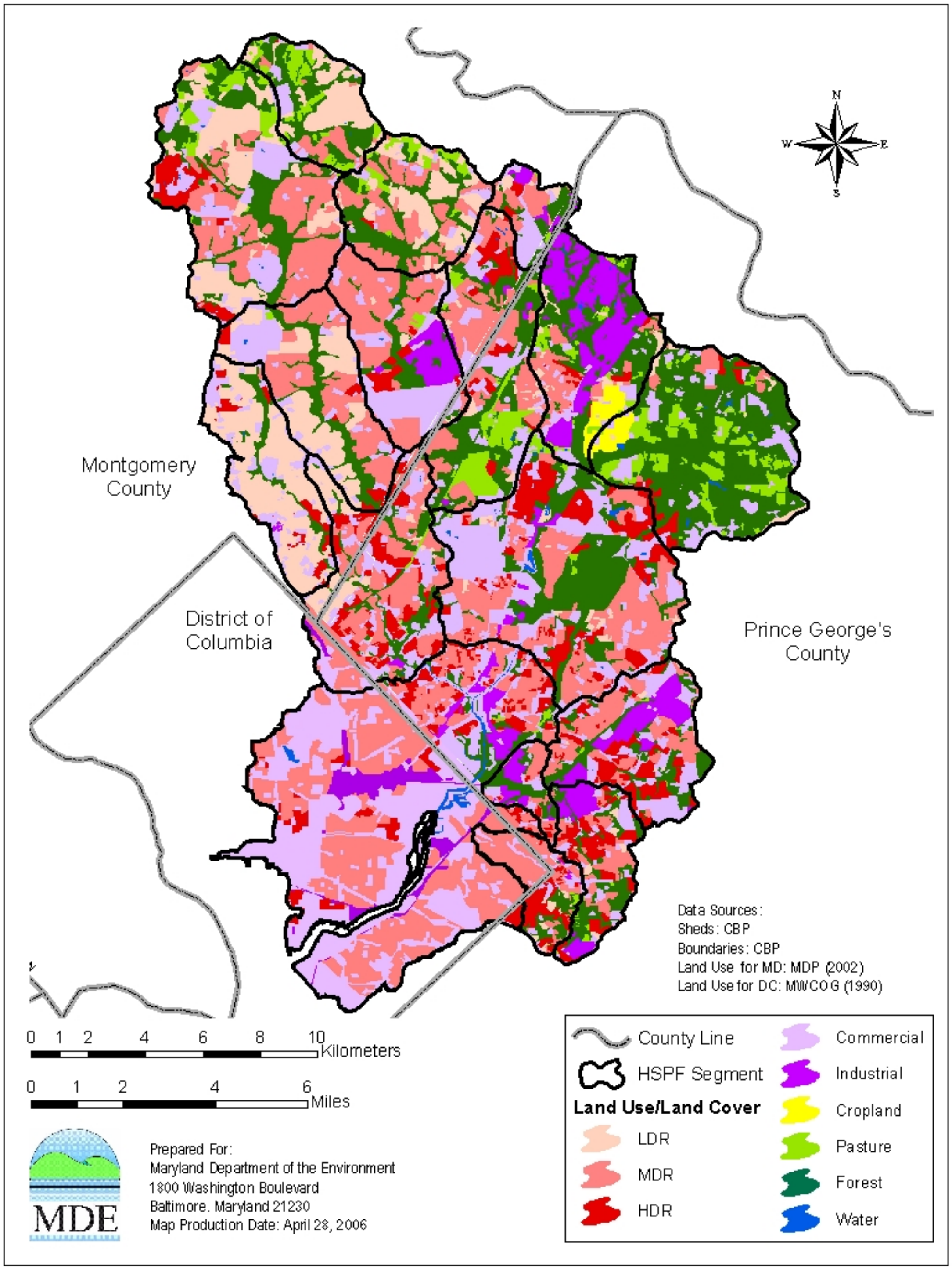

Figure 3. Land use in the Anacostia watershed (LDR, MDR, and HDR denote low-, medium-, and high-density residential)

The amount of *connected* impervious surface is an important factor in understanding potential sediment problems in an urban watershed and in determining the extent to which alterations to the natural watershed hydrology may have occurred. Connected impervious surfaces do not allow infiltration into the ground and discharge stormwater runoff to nearby streams, either directly or via a storm sewer system, leading to excessive stream flows during storm events. Conversely, *disconnected* impervious surfaces discharge stormwater runoff to nearby pervious surfaces, providing infiltration. Some examples are: rooftops whose runoff is collected by rain barrels and then discharged at a slow rate to nearby gardens and lawns; rooftop gardens which soak up and hold rain water; driveways or parking lots whose runoff is directed into rain gardens; and roadways which discharge into stormwater detention ponds.

In the portion of the Anacostia watershed lying in MD, it is estimated that approximately 19% of the area is covered by impervious surfaces. Of the total impervious acreage, approximately 36% is accounted for by buildings, 27% by parking lots, 36% by roads, and 2% by sidewalks. In this study's hydrologic analyses determining flow to watershed streams and to the tidal Anacostia, it is assumed that buildings in low-density residential areas are disconnected impervious surfaces, because rooftop runoff in these areas tends to discharge to adjacent lawns and eventually percolate into the ground. Additionally, impervious surfaces in forest and agricultural land in the Anacostia are assumed to be disconnected. Though Environmental Site Design (ESD)/Low Impact Development (LID) practices, such as rain gardens, rain barrels, and rooftop gardens, are beginning to be implemented throughout the Anacostia basin, at the present time their use is too limited to have a significant impact on watershed hydrology. Therefore, all impervious surfaces in medium-density residential, high-density residential, commercial and industrial lands are assumed to be connected in this study.

2.2 Source Assessment

In this section, both historical and current sediment sources are discussed. Historically, agricultural activities, sand and gravel mining, and construction activities contributed significant loads. Stream channel erosion is the most significant current source, and is primarily caused by altered hydrology due to urbanization of the watershed. The role of tidal re-suspension of bed sediment on water clarity in the tidal river is also discussed. A summary of estimated current sediment loads entering the tidal river, by source category, is given in Table 2. This table contains both annual load estimates, and estimates of the seven-month growing season, April 1-October 31, averaged over the three-year time period used in the TMDL analyses, 1995-1997.

Table 2. Summary of sediment loads by source

	Area (acres)	Annual Load (tons)	% Annual Load	7-Month GS Load (tons)	% GS Load	Annual Yield (tons/ acre)
Agricultural land	4,971	1,290	3%	150	1%	0.24
Forest	21,942	357	1%	16	0.1%	0.02
Urban land	77,017	9,331	20%	6,483	30%	0.12
Construction sites	198	624	1%	364	2%	3.15
Stream channel erosion		34,250	73%	14,565	65%	0.31
Municipal/Industrial point sources		2	0.2%	1	0.2%	
CSOs	6,945	1052	2%	733	1%	
Total	111,073	46,906	100%	22,312	100%	0.42

2.2.1 Historical Causes of Sedimentation in the Anacostia Watershed

As the Anacostia watershed was settled in the late 1700s and early 1800s, forested land was cleared for agricultural use, primarily for growing tobacco. Eroded soils carried by runoff from this agricultural land were transported downstream to the tidal river, causing sedimentation problems and reduced navigability. Bladensburg, MD, established in 1742, was an important port in Colonial times, but by the mid-1800s, it is believed that sediment deposition had reduced the river's depth in the Bladensburg vicinity from approximately 40 feet to only 8 feet at high tide (WSSC 1958). Today, agricultural activities are conducted on only 5% of the basin's land area, and no longer contribute significantly to sediment problems in the watershed.

Historically, surface mining was believed to be a significant source of sediment in the Anacostia basin. A study published in 1981 (Century Engineering 1981) estimated that sand and gravel mines covered approximately 4% of the watershed in the 1970s, and that these land areas accounted for 48% of the watershed's total sediment load. A later study (Century Engineering 1985) reported that the acreage of sand and gravel mines in the watershed was: 1000 acres in Indian Creek, 250 acres in Paint Branch, and 300 acres in Little Paint Branch. This study also noted that many other mines had shut down before the Surface Mining Control and Reclamation Act of 1977 took effect, "and thus may have had exposed surfaces under combined mining and post-mining times for more than 20 years." At the present time, sand and gravel mining is conducted under permit by the Maryland Department of Environment on 733 acres (personal communication, Molly Edsall, MDE) in the Anacostia watershed. Sediment in process water discharged from these sites is now limited by National Pollutant Discharge Elimination System (NPDES); sediment in stormwater runoff from these sites is not. Therefore, the remaining amount of acres in the basin on which surface mining activities are conducted, though much smaller than in the past, is still a potential source of sediment.

Conditions and activities at construction sites may lead to excessive erosion and transport of sediment to nearby streams. In a study of construction sites in eight small subwatersheds in the headwaters of the Northwest Branch and Rock Creek in the 1960s and early 1970s (Yorke and Herb 1976; 1978), it was found that sediment yields from construction sites averaged 73 tons per acre. In their 1981 report, Century Engineering estimated that construction sites occupied only 1% of the land area in the Anacostia watershed, but were responsible for 13% of the sediment load. In recent years, construction activity has decreased in the Anacostia watershed because most areas have already undergone development. Also, at the present time Montgomery County, Prince George's County, and DC all require that erosion and sediment control measures be implemented at construction sites to reduce sediment yields from these areas.

2.2.2 Current Nonpoint Sources of Sediment in the Anacostia

<u>Land surfaces</u>

When precipitation flows over land surfaces, soil may be eroded, and the eroded sediment particles may be carried to nearby streams, either directly, or via storm sewer systems. In the analysis of loads from the non-tidal tributaries, load estimates are given for the four general land use categories: agricultural land, forest, urban land, and construction sites. These were computed by averaging loads for the three-year time period used in the TMDL analyses, 1995-1997, and are presented in Table 2. The results indicate that the load from urban land (residential, commercial, and industrial) is significantly greater than the loads from agricultural land, forest, or construction sites. Table 2 indicates that construction sites produce more than 20 times the amount of sediment per acre than urban land; however, the total load from construction sites is relatively low, due to the low number of acres on which construction is occurring in this highly developed watershed.

<u>Streambank erosion</u>

The largest source of sediment in the Anacostia is believed to be stream channel erosion due to alterations in hydrology that have occurred in the urbanized portions of the watershed. In most urbanized watersheds, small stream channels have been replaced by sewer pipes. As a result, impervious surfaces such as rooftops, parking lots, and road surfaces have been connected directly to the storm sewer system. Because a greater portion of precipitation flows rapidly into streams during storms, less water remains to soak into the ground and recharge groundwater. This altered urban hydrology causes atypically high flows in streams during storms, and atypically low flows during dry periods. The high flows occurring during storm events cause excessive erosion of streambanks and streambeds, leading to the degraded stream channel conditions that can be observed in many areas of the Anacostia watershed today. The high storm flows transport this eroded sediment downstream to the main tributaries and, eventually, to the tidal Anacostia River. Approximately 73 % of the current total annual sediment load in the Anacostia watershed is attributed to stream channel erosion (see Table 2). This estimate is based on analyses described by Mandel et al. (2007), which use the Anacostia HSPF watershed model in conjunction with the Penn State University streambank erosion equation (Evans et al. 2003).

Many studies have documented the relationship between high amounts of connected impervious surfaces, increases in storm flows, and stream degradation (Schueler 1994; Arnold and Gibbons 1996). Several studies were conducted by the USGS in the headwaters of the Northwest Branch in the 1960s and 1970s to document changes occurring in the Anacostia watershed due to development. Keller used flow data and suspended sediment data from two locations in the NWB and found that sediment yield was four times greater in urbanized portions of the watershed (Keller 1962; Leopold 1968). Yorke and Davis studied flow and sediment yield from the 1.7 mi^2 drainage basin of upper Bel Pre Creek, from 1963-1967 (Yorke and Davis 1971). The area was predominantly pasture and woodland prior to March 1965 (with 1.6% urban land), after which time construction of residential housing and a new golf course began. They found a 30% increase in storm runoff after development.

A second analysis was done for this study in order to quantify the effect of altered urban hydrology on Anacostia sediment loads, as described in Appendix B. Changes in hydrology in the Anacostia watershed can be characterized using daily flow data from the USGS gage stations on the NWB and the NEB, which is available from 1938 through the present time. The long-term changes over time in the flow duration curves (FDCs) for each of these stations is quantified using a type of statistical analysis known as “quantile regression,” and the portion of the FDC representing the highest flows is determined to have increased significantly over time. Also, a “sediment rating curve,” i.e., a relationship between suspended sediment concentration and flow, is computed for each of these tributaries and used with the FDCs to estimate annual sediment loads before and after the alteration in hydrology. According to the results of this analysis, approximately 75% of today’s sediment loads from the NWB and the NEB are due to alterations in hydrology.

2.2.3 Current Point Sources of Sediment in the Anacostia

Most stormwater runoff from urban lands in the Anacostia watershed enters the municipal separate storm sewer systems (MS4s) of the three jurisdictions, Montgomery County, Prince George’s County, and DC. Although MS4s transport nonpoint sources of pollutants in stormwater, they are legally categorized as point sources under NPDES regulation. All three jurisdictions in the watershed are regulated by NPDES MS4 permits.

There are two municipal and six industrial facilities in MD with NPDES permits regulating the discharge of sediment/solids in the Anacostia watershed. These facilities are listed in Table 3 along with available information on the flow and TSS concentrations of discharge water. There are also three industrial facilities in DC with NPDES permits regulating the discharge of sediment/solids, as shown in Table 3.

Table 3. Municipal and Industrial NPDES Permit Holders in the Anacostia Watershed with sediment/solids discharge limits

Maryland Municipal Facilities

	Season	NPDES Permit No.	MDE Permit No.	Shed	Facility Name	Discharge Points	County	Flow (mgd)	TSS monthly average permit value(mg/l)	TSS weekly average permit value(mg/L)
1	Oct – Mar	MD0020842	05DP2525	NEB	BARC East Side WWTP	Beaverdam Cr	PG	0.62	30	45
	Apr – Sept							0.62	17	26
2	Oct – Mar	MD0020851	05DP2787	NEB	Beltsville USDA West WWTP	Little Paint Br	PG	0.2	30	45
	Apr – Sept							0.2	20	30

Maryland Industrial Facilities

	NPDES Permit No.	MDE Permit No.	Shed	Permit Type	Facility Name	Discharge Points	County	Flow (mgd)	TSS monthly average permit value(mg/L)	TSS daily max permit value (mg/L)
1	MD0001953	02DP0219	NEB	Industrial	Laurel Sand & Gravel	MULTIPLE	PG	0.001	30	60
2	MD0059161	05DP1941	NEB	Industrial	U of MD Fire & Rescue	1	PG	0.05	Report	45
3	MD0065625	00DP2867	NEB	Industrial	MD State Military Facility	1	MO,PG	0.045	Report	60
4	MD0065871	04DP2904	NEB	Industrial	National Archives at UMCP	MULTIPLE	MO,PG	0.01	Report	45
5	MD0067482	04DP3156	NEB	Industrial	NASA Goddard Center	MULTIPLE	PG	0.08	30	45
6	MDG499863	00MM9863	NEB	General – Mineral Mine	Percontee, Inc			0.242	45	60

DC Industrial Facilities

	NPDES Permit No.	Shed	Permit Type	Facility Name	Discharge Points	Flow (mgd)	TSS max (mg/L)
1	DC0000175	NWB	Industrial	Aggregate Super Concrete Industries	MULTIPLE	0.006 and 0.013	39 and 35.6
2	DC0000191	ANA	Industrial	CTIDC	MULTIPLE	0.011	30
3	DC0000094	ANA	Industrial	PEPCO Benning Road	MULTIPLE	Varies (mostly stormwater)*	30

*Because most of the flow from the PEPCO-Benning facility is stormwater, it is included as part of the urban loads in the TMDL analysis.

2.2.4 Re-suspension of bed sediment in the tidal river

Water and suspended sediment from the non-tidal streams eventually flow into the tidal Anacostia River. It is estimated that approximately 85% of the sediment discharged into the tidal river by tributaries and storm sewer systems remains and is eventually deposited onto the riverbed, and approximately 15% leaves the Anacostia and enters the Potomac River (Scatena 1986; Schultz 2003). When sediment-laden water discharges into the tidal river, sediment particles remain suspended and reduce water clarity for a period of time before settling to the riverbed. However, because the Anacostia is subject to the daily rise and fall of the tides, tidal currents continuously erode and re-suspend sediment from the riverbed. Tidal flow velocities, measured in the river during non-storm conditions, range from 0 to 0.3 meters per second (Katz et al. 2000; Schultz and Velinsky 2001). Model simulation results indicate that under hypothetical conditions where no new sediment is entering the tidal river, median TSS values of approximately 5.0 mg/L occur in the mid-river due to re-suspension of bed sediment by tidal currents.

2.2.5 Summary of Baseline Loads

For the TMDL analysis period, 1995-1997, the calculated baseline loads of sediment/TSS from all sources in the Anacostia River watershed are **46,906 tons/year** annually and **22,312 tons/season** for the growing season, April 1-October 31.

2.3 Water Quality Characterization

This section gives an overview of current water quality conditions related to sediment in both the tidal and non-tidal Anacostia watershed. In the tidal river, water quality data related to water clarity are discussed, because water quality standards of both MD and DC contain numeric criteria for water clarity in the tidal Anacostia. In the non-tidal watershed, suspended solids data provide a measure of the quantity of sediment discharged from non-tidal streams into the tidal river. Suspended solids can also serve as a surrogate measure of sediment-related water quality conditions that affect the health of aquatic organisms in non-tidal streams.

On August 29, 2005, the EPA approved revisions to MD’s water quality standards, including a new standard related to sediment, the “Water Clarity Criteria for Seasonal Shallow-Water Submerged Aquatic Vegetation,” supporting MD’s Designated Use II: “Support of Estuarine and Marine Aquatic Life” for the tidal Anacostia River. MD’s new water clarity standard for the tidal Anacostia is a numeric criterion based on Secchi depth.

A DC TMDL for TSS in the tidal Anacostia was completed and established by EPA on March 1, 2002, based on a narrative standard for sediment defined in the DC water quality standards in effect at that time. On February 15, 2006, EPA approved revisions to DC’s water quality standards, which include a numeric criterion for water clarity in the tidal Anacostia based on Secchi depth, supporting the designated use of waters categorized as Class C: "Protection & Propagation of fish, shellfish and wildlife." The DC water quality standards also specify a seasonal segment average (July-September) for chlorophyll *a* of 25 µg/L.

2.3.1 Tidal waters

Water quality data related to suspended solids and water clarity in the tidal portion of the Anacostia are available from routine monitoring programs conducted by the Maryland Department of Natural Resources (DNR) and DC, and from several special studies. Data are available for the following water quality parameters used in this TMDL analysis: total suspended solids (TSS), chlorophyll *a* (Chla), and Secchi depth. TSS are a measure of the dry weight of particulate matter suspended in the water column, per unit volume of water. The Chla concentration of a water sample is a measure of the amount of algae present. Secchi depth is a simple measure of water clarity based on the visibility of a "Secchi disk," an eight-inch diameter disk with black and white quadrants. Secchi depth is defined as the depth at which a submerged Secchi disk is no longer visible. Data are also available for a fourth water quality parameter, turbidity, a commonly available measure of water clarity that can be correlated with TSS and the inverse of Secchi depth.

At the time this report was prepared, routine monitoring data for the tidal Anacostia were available through 2002. Other water quality data sets used for the tidal river analysis, described in more detail in Mandel et al. (2007), are from a study of sediment re-suspension by the Academy of Natural Sciences-Patrick Center for Environmental Research (ANS-PCER) and ICPRB for the DC Department of Health (DCDOH), a 1999-2000 wet weather survey by the DC Water and Sewer Authority (DCWASA) for the Combined Sewer Overflow (CSO) Long Term Control Plan (LTCP), and 1998 and 2002 studies on toxics contaminants by the ANS-PCER. Information on parameter values available in each data set is given in Table 4. Locations of the main routine monitoring stations are depicted in Figure 4. The monitoring stations are shown in the TAM/WASP modeling framework, which is discussed later in this report.

Table 4. Water Quality Data Sets Used in TMDL Development

Study	Year	Secchi	Turbidity	TSS	Chla
DC routine monitoring program	Routine since 1984	x	x	x	x [1]
DNR routine monitoring program	Routine since 1986		x	x	x
ANS-PCER toxics study	1998		x	x	
ANS-PCER/ICPRB suspended sediment study	1999	x	x	x	x
LTCP wet weather study	2000			x	
ANS-PCER toxics study	2002			x	x

[1] Only available for the years, 1999-2002

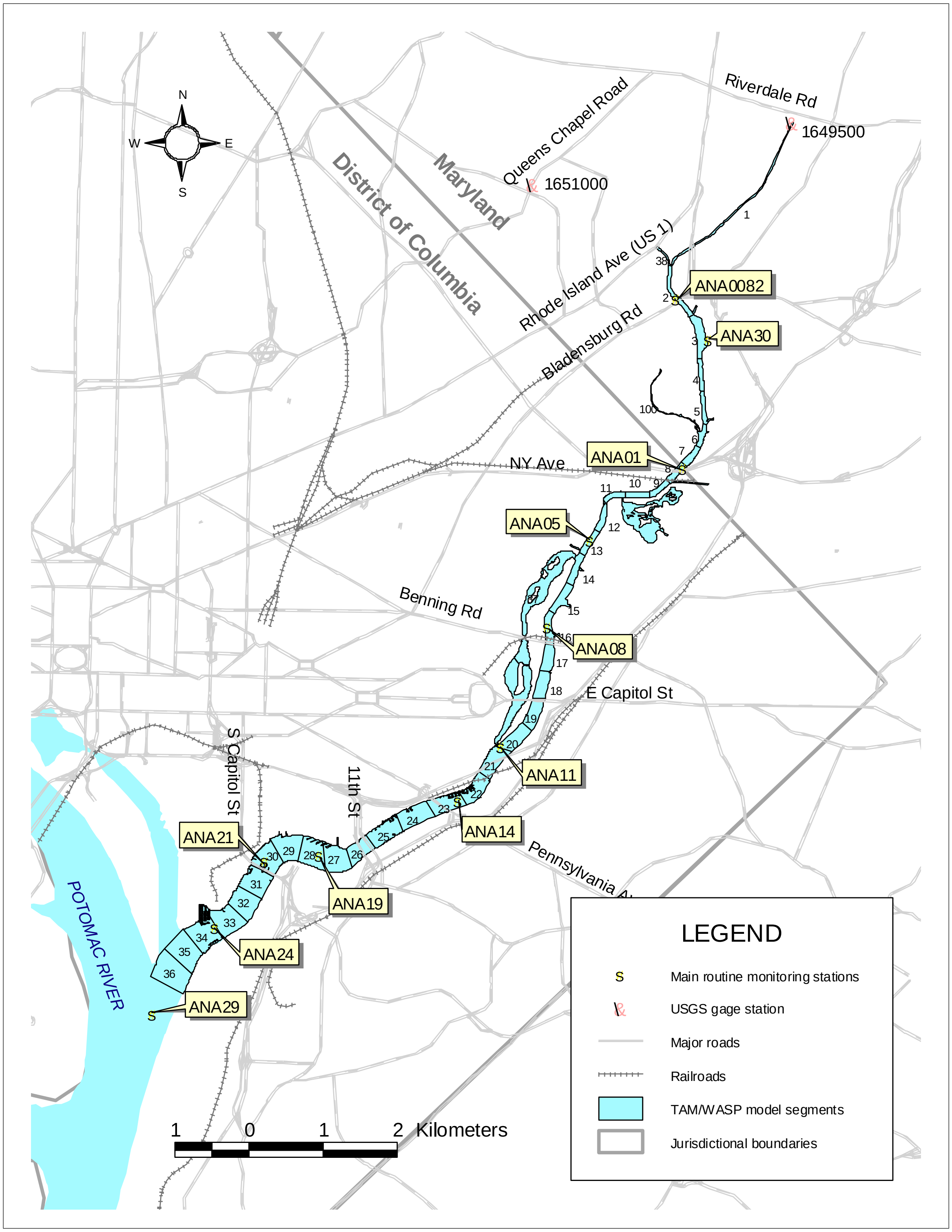

Figure 4. Tidal Anacostia River, with Monitoring Locations, and TAM/WASP Model Segmentation

Long-term growing season medians of 1995-2002 routine monitoring data are shown in Figure 5. Medians depicted in this graph were computed from data for the April 1-October 31 growing season specified in DC water quality standards (see below). However, for the three upstream stations in or adjacent to MD waters (stations ANA0082, ANA30, and ANA01), all values plotted are identical to medians computed for the April 1-October 1 growing season specified in MD's water quality standards. This figure illustrates the spatial pattern of water clarity conditions in the tidal Anacostia, with poor light conditions typically occurring in the middle portion of the river. It is evident from Figure 5 that medians of TSS, turbidity, and inverse Secchi depth are all well-correlated along the length of the tidal river's main channel.

Long-term growing season medians of Secchi depth measurements in the tidal Anacostia are plotted in Figure 6. Following Chesapeake Bay Program (CBP) guidance, the water clarity criteria assessment is based on growing season Secchi depth medians computed for a three-year time period[1]. Long-term Secchi depth growing season medians for the most upstream segments, representing water clarity conditions from the confluence of the Northeast and Northwest Branches in MD to the New York Avenue bridge at approximately the MD-DC line, are at or above 0.4 meters, the MD criterion. Long-term Secchi depth medians depicted in Figure 6 for the two most downstream stations, from Buzzards Point to the confluence with the Potomac River, are 0.8 meters, the DC water clarity criterion. In the middle portion of the river, the Secchi depth medians are less than 0.8.

[1] *Based on ICPRB's interpretation of CBP guidance documents.*

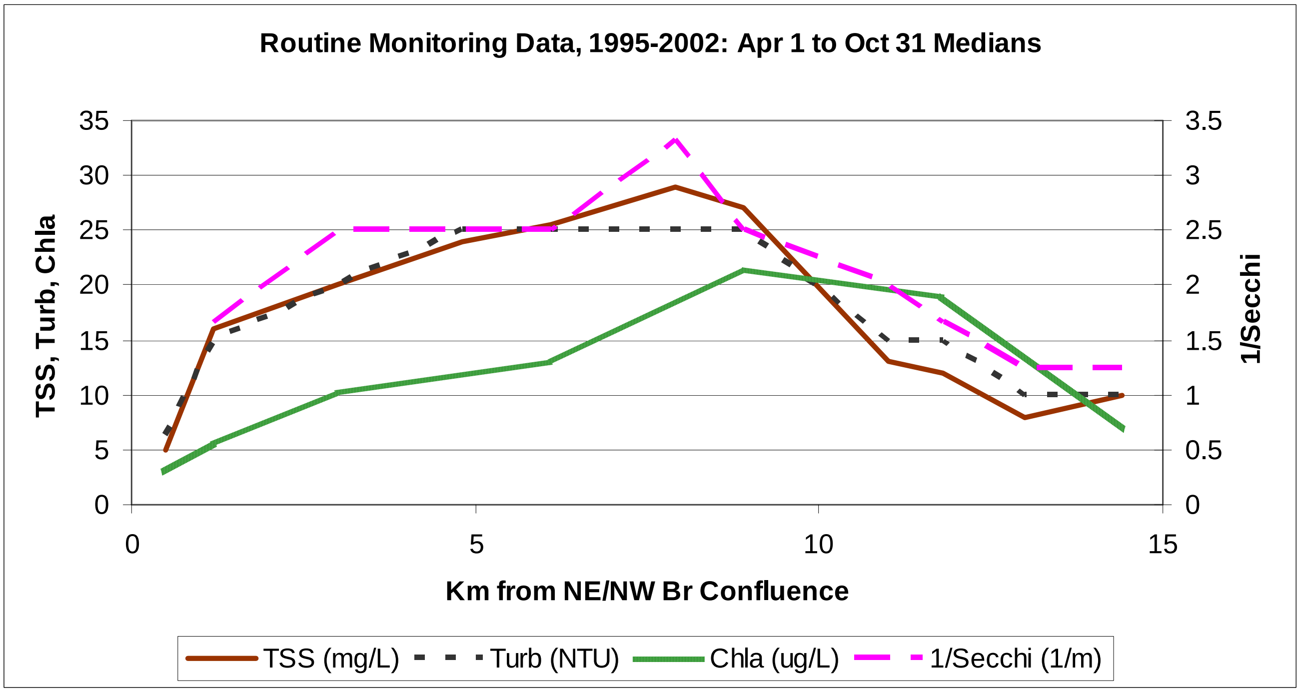

Figure 5. Long-term Growing Season Medians of Water Quality Parameters in the Tidal Anacostia River

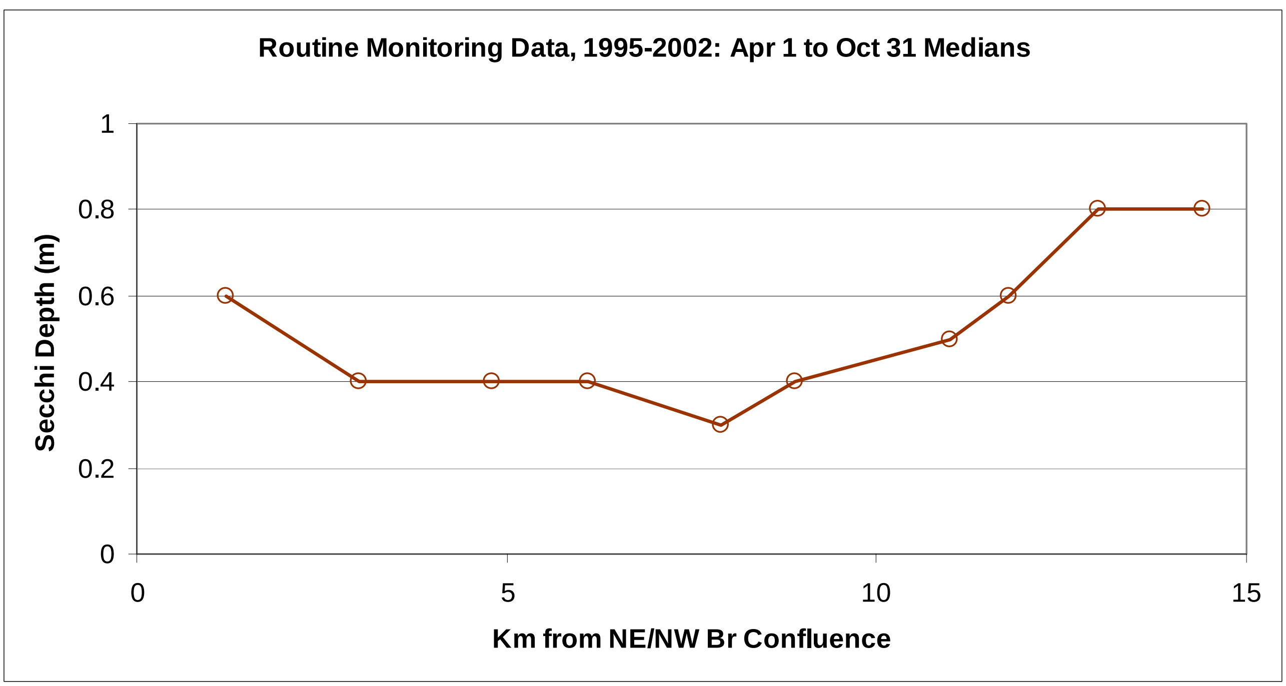

Figure 6. Long-term Growing Season Medians of Secchi Depth in the Tidal Anacostia River

The health of submerged aquatic vegetation (SAV) beds is an important indication of water quality conditions in the tidal Anacostia. Aquatic plants consume nutrients contributing to excessive algal growth, release oxygen as they grow, and provide habitat and food for many aquatic animals. SAV depends on good light conditions, and both MD's and DC's water clarity criteria have been set based on CBP's determination of light requirements for SAV.

SAV in the Anacostia includes wild celery, coontail, hydrilla, water stargrass, and milfoil. According to a recent report by the U.S. Army Corps of Engineers (USACE), several hundred acres of SAV were present in the Anacostia historically (USACE 2005). By the mid-1980s, SAV in the Anacostia had reportedly disappeared completely, but in the 1990s small areas had returned to the lower portion of the river. The graph in Figure 7, taken from the MWCOG website, www.anacostia.net, and based on information from the Virginia Institute of Marine Science (VIMS), shows that up to seven acres of SAV were observed in the Anacostia in the mid-1990s.

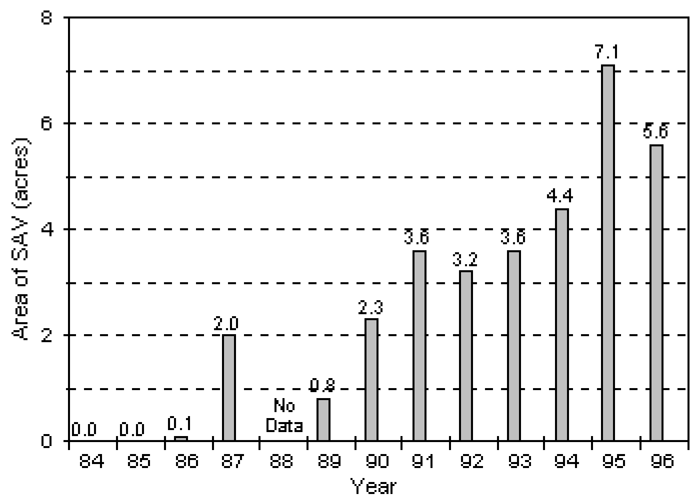

Figure 7. Submerged Aquatic Vegetation in the Tidal River

2.3.2 Non-tidal waters

A number of monitoring programs collect data that can be used to characterize water quality related to sediment in the non-tidal streams of the Anacostia watershed, including biological monitoring data and measurements of suspended solids in water samples. Biological assessment and stream habitat data are collected on a regular basis by DNR's "Maryland Biological Stream Survey" (MBSS) program, the Montgomery County Department of Environmental Protection (MCDEP), and the Prince George's County Department of Environmental Resources (PGDER). Using indices of biological integrity (IBIs) developed by each of these organizations to assess the condition of biological communities, the condition of benthic communities at most monitoring sites in Anacostia subwatersheds has been categorized as poor to very poor. The condition of the fish communities ranges from very poor to good.

IBI scores derived from biological assessment data can serve as a measure of the health of biological communities. However, these biological measures do not provide information on causes of impairments. Conditions in urban streams typically reflect the impact of more than one environmental stressor, which may include toxic chemicals, nutrients, high storm flows from altered hydrology, and loss of forest canopy. Therefore, the magnitude and extent of sediment problems in Anacostia subwatersheds cannot be determined from IBI scores.

Physical habitat data are also collected in stream assessment programs, including information on streambank stability, which is an indicator of bank erosion, and streambed embeddedness, an indicator of excessive sedimentation. Values observed for these parameters indicate that sediment and erosion are problems at many locations in non-tidal Anacostia streams. Monitoring by a citizen's group, the Anacostia Watershed Society, is providing comprehensive documentation of streambank erosion in several Anacostia tributaries (see http://www.anacostiaws.org/SCA-survey.html). Additionally, the local jurisdictions and the Metropolitan Washington Council of Governments have identified significant areas of erosion and set priorities for restoration.

Measurements of suspended solids present in water samples collected from non-tidal streams provide a third type of data that can be used to characterize water quality problems related to sediment in Anacostia tributaries. Suspended solids data, reported either as TSS or suspended sediment concentration (SSC)[2], are collected in Anacostia non-tidal streams by MDE, DNR, USGS, MCDEP, and PGDER. Additional data are available from special studies done by other organizations. These data are important because they can be used, along with information on streamflow, to estimate the total suspended sediment load, i.e., the mass of sediment transported from a given subwatershed past the sampling location. See Appendix A for descriptions of the suspended solids data sets used in this study.

The majority of the suspended solids data from Anacostia non-tidal streams have been collected at the two USGS gage stations located on the lower NWB and the lower NEB: Station 01651000 at Queens Chapel Road in Hyattsville, MD, and Station 01649500 at Riverdale Road in Riverdale, MD (see Figure 2). Because the sum of the drainage areas above these two locations, 49.4 mi^2 and 72.8 mi^2 respectively, is approximately 70% of the watershed, these data provide valuable information on the quantities of sediment leaving the non-tidal portion of the watershed and entering the tidal river. In the time period of interest for this TMDL analysis, 1995-2004, approximately 130 suspended solids concentration measurements are available for each of these two locations from six monitoring studies. The most recent of these studies was initiated in 2003 to provide data

[2] Analytical techniques used for SSC measurements differ from those used for TSS, and results are often found to be not comparable (Gray et al. 2000). See Appendix A for a discussion of comparability of the TSS and SSC data sets used in this study.

support for MDE's Anacostia sediment TMDL. The sampling was conducted by the USGS with funding from MDE and from Prince George's County. The study used automated sampling devices to facilitate the collection of samples during storm flow events. Other suspended solids data sets used in this TMDL analysis are described in more detail in Appendix A.

Suspended solids concentrations data from the USGS gage stations on the lower NWB and lower NEB are plotted in Figure 8 and Figure 9 against flow percentiles. A percentile of 5%, *e.g.*, corresponds to the value of the flow that is exceeded only 5% of the time. These plots, or load duration curves, show that the highest suspended solids concentrations tend to occur only at the highest flows. This indicates that storm events are responsible for a large portion of the suspended sediment load in the watershed. First, they discharge the largest volumes of water, and second, the quantity of sediment carried by a given volume of water is higher during high flows.

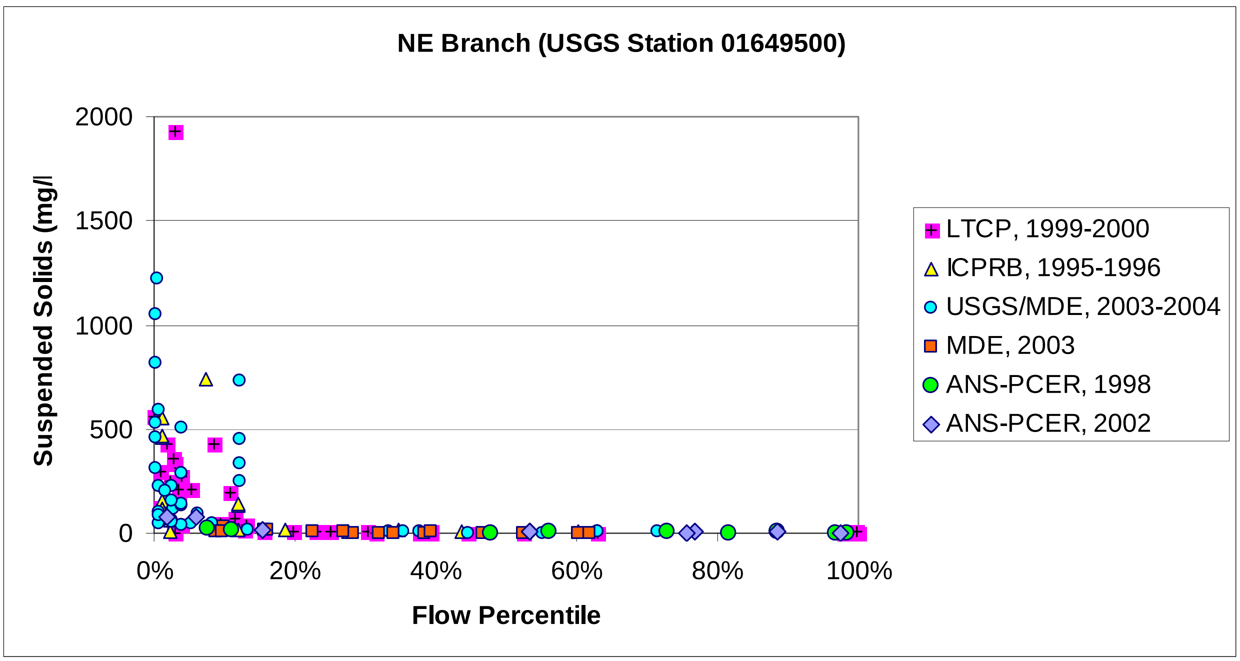

Figure 8. Suspended Solids Data for NEB, 1995-2004, versus Flow Percentile

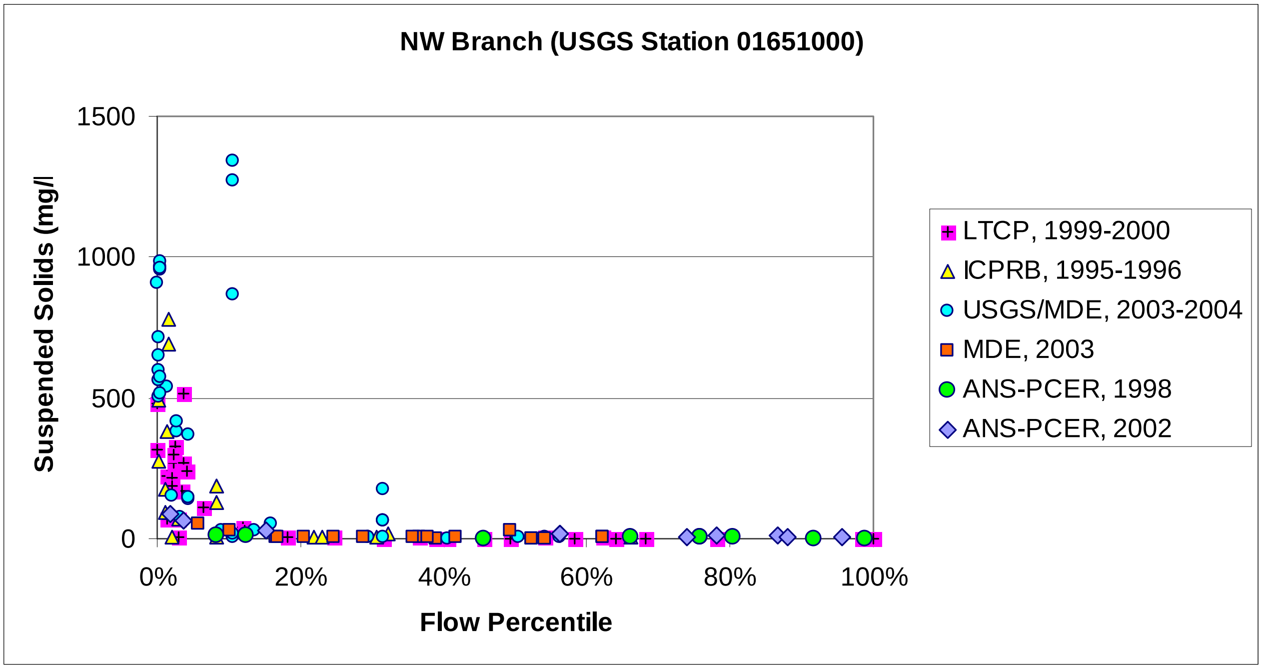

Figure 9. Suspended Solids Data for NWB, 1995-2004, versus Flow Percentile

2.4 Water Quality Impairment

Water quality impairments have been identified in both the tidal and non-tidal waters of the Anacostia basin, as discussed below. The results of the analyses presented in Section 4.0 of this report show that the impairment requiring the most stringent reduction in sediment loads is the water clarity condition in the DC portion of the tidal Anacostia.

2.4.1 Designated Uses and Water Quality Standards

The Maryland water quality standards Surface Water Use Designations for this watershed area are Use I-P – Water Contact Recreation, Protection of Aquatic Life and Public Drinking Supply; Use II - Support of Estuarine and Marine Aquatic Life and Shellfish Harvesting; Use III – Natural Trout Waters; and Use IV – Recreational Trout Waters (COMAR 26.08.02.08 O). DC has classified the Anacostia for current and designated uses including category Class C: "Protection & Propagation of fish, shellfish and wildlife." The State of Maryland and the District of Columbia have both established water quality standards (WQSs) that protect the streams and estuaries in their respective portions of the Anacostia watershed and support the designated beneficial uses of these waters. A summary of the designated uses and WQSs applicable to the Anacostia are given in Table 5. Analyses done for this TMDL show that sediment load reductions required to meet DC's water clarity criterion for DC tidal waters are significantly larger than load reductions required to meet MD's water quality standards for sediment related to aquatic life in the Anacostia watershed. The Anacostia is an interstate watershed, and the TMDLs developed in this report must meet both MD and DC WQSs. Therefore, DC's water clarity criterion for tidal waters is the standard that will determine the TMDL load reductions presented in Section 4.0 of this document.

Tidal Waters

The water clarity standards of both MD and DC are in place to allow the growth of healthy communities of SAV in tidal waters. In both jurisdictions, water clarity standards were developed largely based upon the body of research and analysis done for and by the CBP in its effort to promote the regeneration of SAV in Chesapeake Bay tidal waters, which include the Anacostia River. The CBP determined that one of the primary causes of the decline in SAV is "increased suspended sediments in the water and the associated reduction of light" (USEPA 2003b). Both MD and DC water clarity criteria are based on CBP's determination of light requirements for underwater bay grasses.

MD WQSs are available in the Code of Maryland Regulations (COMAR) 26.08.02. MD has designated the tidal Anacostia for Use II: "Support of Estuarine and Marine Aquatic Life." The "Water Clarity Criteria for Seasonal Shallow-Water Submerged Aquatic Vegetation" specify that for the tidal Anacostia (CBP segment ANATF) a numeric water clarity criterion will be assigned based on an application depth of 0.5 meters. This results in a criterion for Secchi depth of 0.4 meters, applicable throughout the growing season, defined in the MD regulations as April 1 to October 1. MDE has determined that three-year growing season medians are appropriate to use to assess attainment of its Secchi depth criterion, as indicated in CBP guidance documents (USEPA 2003b).

DC's WQSs, Chapter 11 of Title 21 of the DC Municipal Regulations (DCMR) specify a numeric criterion for water clarity, applicable to the tidal Anacostia River. DC classifies surface waters "on the basis of their (i) current uses, and (ii) future uses to which the waters will be restored." DC has classified the Anacostia for current and designated uses including category Class C: "Protection & Propagation of fish, shellfish and wildlife." The water clarity criterion, applicable to Class C waters, and limited to the Anacostia River, specifies a seasonal segment average (April-October 31) Secchi depth of 0.8 meters. DC has determined that the seasonal segment average applies to each year growing season median in a three-year study period to assess attainment of its Secchi depth criterion as it relates to the CBP guidance document (USEPA 2003b). A second DC WQS related to water clarity in the tidal Anacostia is the standard for Chla. The WQSs specify a seasonal segment average (July through September) for Chla of 25 µg/L.

Non-tidal Waters

Section 1104.1 of DC's WQSs list several narrative criteria designed to protect existing and designated uses, including the following, which is specific to Class C designation: "The surface waters of the District shall be free from substances attributable to point or nonpoint sources discharged in amounts that…impair the biological community which naturally occurs in the waters or depends on the waters for their survival and propagation." MD has designated its portion of the non-tidal Anacostia watershed as Use I-P – Water Contact Recreation, Protection of Aquatic Life and Public Drinking Supply; Use III – Natural Trout Waters; and Use IV – Recreational Trout Waters (COMAR 26.08.02.08O). MD's general narrative water quality criteria prohibit pollution of waters of the State by any material in amounts sufficient to create a nuisance or interfere with the designated uses (COMAR 26.08.02.03B(2)). The targeted water quality goal for all non-tidal waters in the Anacostia watershed is to ensure that the sediment loads and resulting effects support designated uses of the non-tidal Anacostia watershed and, more specifically, support aquatic health.

Table 5. Designated Uses and Sediment-Related Water Quality Standards for the Anacostia Watershed

	Designated Use	**Waterbody**	**Water Quality Standards**
MD non-tidal	Use I-P: Water contact recreation, protection of non-tidal warmwater aquatic life, public drinking supply	All non-tidal MD streams except those designated Use III and IV	Narrative criterion – protection of aquatic life
	Use III: Non-tidal cold water (supporting self-sustaining trout populations)	Paint Branch above Interstate 495 (Capital beltway)	Narrative criterion – protection of aquatic life
	Use IV: Recreational trout waters	NWB above highway 410	Narrative criterion – protection of aquatic life
MD tidal	Use II: Support of estuarine and marine aquatic life and shellfish harvesting – seasonal shallow water SAV subcategory	MD portion of tidal Anacostia	Secchi depth criterion: seasonal application depth greater than or equal to 0.4 meters (Apr 1 through Oct)
DC non-tidal	Class 3: Protection & propagation of fish, shellfish and wildlife	All non-tidal DC streams	Narrative criterion – protection of aquatic life
DC tidal	Class 3: Protection & propagation of fish, shellfish and wildlife	DC portion of tidal Anacostia	Secchi depth criterion: seasonal segment average greater than or equal to 0.8 meters (Apr 1 through Oct 31)

2.4.2 Assessment of tidal waters

Both MD and DC have numeric criteria for water clarity in the tidal Anacostia. MD standards require a seasonal growing season (April 1 – September 30) median Secchi depth of 0.4 meters, and DC requires a seasonal growing season (April 1 – October 31) Secchi depth segment average of 0.8 meters. For TMDL analyses, the median is used as the measure of central tendency, and it is computed over the entire spatial domain of each jurisdiction's tidal waters. For MD, the median is computed over a three-year period, and for DC, the median is computed for each year of the three-year period. Growing season Secchi depth medians, computed with data collected over the time interval 1995-2002 and plotted in Figure 6, provide a picture of water clarity conditions in the tidal Anacostia during the study period. Also, growing season Secchi depth medians computed 1995-2002 over all available routine monitoring stations are given in Table 6. These results show that water clarity standards are met in the MD portion of the tidal Anacostia but not in the DC portion.

Table 6. Growing season Secchi depth medians, computed from routine monitoring data

MD Tidal Assessment		**DC Tidal Assessment**	
Three-year time period	**MD stations (ANA30 only) (Apr 1 – Sep 30) criterion ≥ 0.4 m**	**Year**	**DC stations (Apr 1 – Oct 31) criterion ≥ 0.8 m**
1995-1997	0.4 m	1995	0.5 m
1996-1998	0.6 m	1996	0.3 m
1997-1999	0.7 m	1997	0.5 m
1998-2000	0.7 m	1998	0.4 m
1999-2001	0.5 m	1999	0.5 m
2000-2002	0.6 m	2000	0.4 m
		2001	0.5 m
		2002	0.5 m

2.4.3 Assessment of non-tidal waters

The targeted water quality goal for non-tidal waters in the Anacostia watershed is to ensure that the sediment loads and resulting effects are at a level to support designated uses of the non-tidal Anacostia watershed, and more specifically support aquatic health. To provide a water quality characterization of the non-tidal Anacostia watershed, it must first be determined how elevated sediment loads are linked to degraded stream water quality. As outlined in the Maryland 2004 303(d) report, degraded stream water quality resulting in a sediment impairment is characterized by erosional impacts, depositional impacts and decreased water clarity.

Because of the variation in land uses and other activities throughout the watershed, the extent of erosion and sediment-related problems varies at the subwatershed level. To evaluate the presence of sediment impairments in Anacostia subwatersheds, MDE has used a "weight-of-evidence" approach. Qualitative and quantitative assessments of raw biological and physical habitat data, analyses of long-term time trends in flow data, interviews with scientists with extensive field experience in the Anacostia watershed, information from special studies, and analyses of land use in Anacostia subwatersheds have been used to determine the existence of sediment impairments.

In the absence of numerical water quality criteria for sediment in non-tidal waters, the reference watershed approach was used to determine the sediment loads that can support designated uses of the non-tidal Anacostia watershed, and more specifically support aquatic health. In particular, based on biological indices of biotic integrity, MDE has identified two Anacostia subwatersheds which are not impaired due to sediment: the upper portion of the Paint Branch (above Fairland Road), located in the Piedmont province, and Upper Beaverdam Creek, in the Coastal Plain province (see Appendix C for details).

As mentioned before, the results of the analyses presented in Section 4.0 show that the impairment requiring the most stringent reduction in sediment loads is the water clarity condition in the DC portion of the tidal Anacostia. Therefore, the load reduction required using the reference watershed approach is not used in the TMDL allocation calculation.

3.0 TARGETED WATER QUALITY GOAL

The objectives of the sediment TMDLs established in this document are 1) to ensure that aquatic life is protected in the tidal and non-tidal waters of the Anacostia River; 2) to ensure that MD's and DC's sediment-related water quality standards that support aquatic life are met in their respective portions of the river; and 3) to ensure in particular that the numeric criteria for water clarity are met in the tidal waters. The endpoint of the TMDL (the most stringent reduction in sediment loads) is DC's tidal Anacostia water clarity criterion for Secchi depth during the seven-month growing season, April 1 through October 31. Analyses presented in this document indicate that meeting this criterion ensures that all applicable sediment-related water quality standards that support aquatic life in the tidal and non-tidal portions of the Anacostia watershed will be met.

4.0 TOTAL MAXIMUM DAILY LOADS AND ALLOCATIONS

4.1 Overview

The proposed TMDL allocations presented in this section are designed to be protective of aquatic life in the non-tidal waters of the Anacostia River, to meet MD's and DC's sediment-related WQSs that support aquatic life in the tidal waters, and to meet DC's numeric criterion for water clarity. Other supporting analyses discussed in this section were done to demonstrate that these load reductions are also protective of the non-tidal tributaries. Analyses performed to determine the TMDL load allocations were based primarily on data available for the time period 1995-2004. Data for the tidal simulation were only available up through 2002 at the time this analysis was undertaken. The three-year time period 1995-1997 was chosen as the simulation period for load reduction scenarios to meet tidal water clarity criteria. This period was selected because it represents a relatively dry year, wet year, and average year, based on precipitation data.

The study period, 1995-2004, represents a wide range of hydrologic conditions. An analysis of annual mean upstream flows (combined NEB and NWB flows) showed that 2002 had the lowest combined flow and 2003 had the highest combined flow for the period of record, 1939-2004. The time period, 1998-2002, was a period of prolonged drought throughout the eastern portion of the United States. Graphs of annual precipitation and annual mean upstream flow for the study period, compared with long-term means, are shown in Figures 10 and 11.

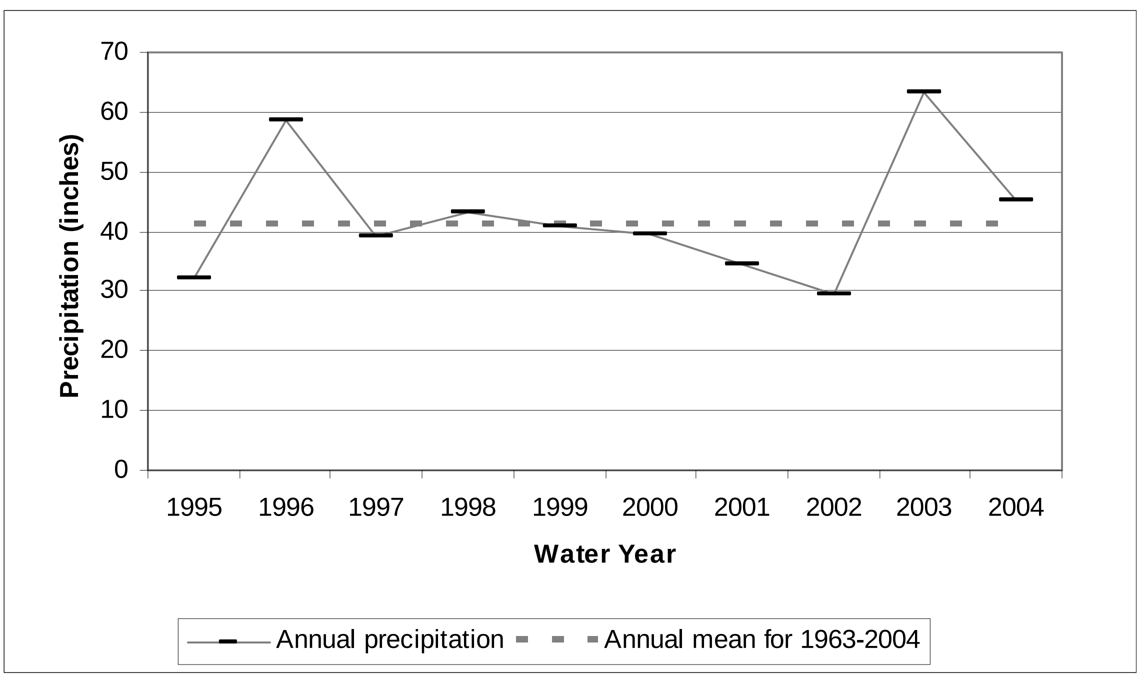

Figure 10. Annual precipitation at Reagan National Airport

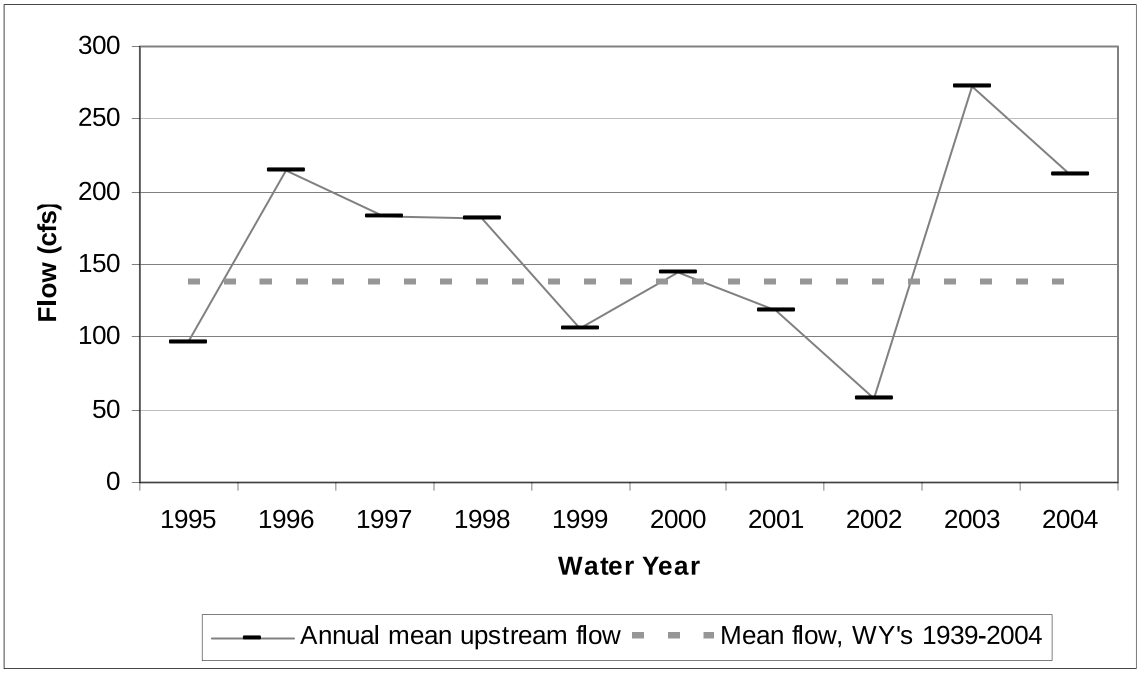

Figure 11. Annual combined mean flow for Northeast and Northwest Branch tributaries

4.2 Analysis Framework

The modeling framework used for the analysis was a coupled watershed/hydrodynamic/ water quality model (Mandel et al. 2007). The hydrodynamic/water quality component of this framework is the TAM/WASP model, which has been used in previous TMDL efforts for the tidal Anacostia (Mandel and Schultz 2000; Schultz 2003; Behm et al. 2003). TAM/WASP was used to calculate water clarity conditions to determine attainment of water quality standards in the tidal Anacostia. The watershed model (Hydrologic Simulation Program – FORTRAN, (HSPF)) and the USGS's ESTIMATOR model (Cohn et al. 1989; 1992) (see Appendix A for details) provided the nonpoint source inputs to the water quality model. A reference watershed approach was used to determine the sediment loads required to meet water quality standards in MD's non-tidal waters.

The HSPF model was used to simulate hydrologic and sediment erosion processes in the non-tidal drainage areas of the Anacostia's main tributaries, NWB, NEB, LBC, and Watts Branch (Mandel et al. 2007). The HSPF model was calibrated against the loads from ESTIMATOR for the study period, 1995 through 2004. The HSPF model results provided daily flow and sediment load inputs for the TAM/WASP model, as well as a breakdown of the sediment loads by source, i.e., from the various land uses (agriculture, forest, or urban) or from streambank erosion. NEB and NWB sediment load inputs for TAM/WASP were computed directly by ESTIMATOR.

In the absence of numerical water quality criteria for sediment in non-tidal waters, the reference watershed approach was used to determine the sediment loads that can support designated uses of the non-tidal Anacostia watershed and, more specifically, to support aquatic health. In particular, MDE has identified two Anacostia subwatersheds which are not impaired due to sediment: the upper portion of the Paint Branch (above Fairland Road), located in the Piedmont province, and Upper Beaverdam Creek, in the Coastal Plain province (see details in Appendix C; also Mandel et al. 2007).

The coupled hydrodynamic/water quality model, the Tidal Anacostia Model/Water Analysis Simulation Program (TAM/WASP), was used to simulate flows and water clarity conditions in the tidal Anacostia River (Mandel et al. 2007). The TAM/WASP model was calibrated for the years 1995 through 2002, the portion of the study period for which tidal Anacostia water column data were available at the time this study was initiated.

The results from these analyses show that the reductions necessary to meet MD’s non-tidal water quality standards were much smaller than those required in the TMDL to meet DC’s water quality standards, specifically the water clarity criterion. Further, MD's tidal numeric water clarity criterion is already met, with the current loads, for the time periods examined in this study. However, the model tends to overpredict secchi depth in the MD's portion of the tidal water and underpredict in the middle Anacostia.

4.2.1 Tidal analysis

The objective of the tidal analysis was to determine what reductions in suspended sediment loads to the tidal Anacostia result in water clarity improvements sufficient to support growth of SAV, by meeting the water clarity standards of MD and DC in their respective portions of the tidal river, i.e., a seasonal median Secchi depth of 0.4 meters in MD (three-year median) and 0.8 meters in DC (one-year medians for each of three years). The TAM/WASP computer simulation model of sediment transport and water clarity (see Mandel et al. 2007) simulates daily values of both total suspended sediment concentrations and water clarity based on inputs including: tides, precipitation, and tributary flows; daily estimates of sediment loads from the various sources, including the NEB, NWB, LBC, and Watts Branch tributaries; DC’s MS4; and combined sewer overflows (CSOs).

The TAM/WASP modeling framework was originally developed for use in DC’s TMDL program, and was upgraded and recalibrated for the MD sediment TMDL analysis. It contains the following four coupled components that allow it to simulate light conditions in the tidal river (see Figure 12):

- A load routine, which provides daily estimates of water volumes and loads of sediment and other constituents discharging to each model segment from major tributaries, DC MS4s, and CSOs.

- A hydrodynamic model, which simulates flows and changes in water levels in the river due to tidal currents and water discharging into the river from tributaries and sewer systems.
- The WASP-Toxi model for sediment transport, one of the EPA's two WASP (Water Analysis Simulation Program) water quality models, which simulates daily concentration of TSS in the tidal river. The TAM/WASP modeling framework uses an ICPRB-modified version of WASP-Toxi that is capable of simulating flow-dependent sediment settling and re-suspension.
- The WASP-Eutro model, which simulates daily concentrations of algae, dissolved oxygen, and nutrients in the tidal river. The TAM/WASP modeling framework uses an ICPRB-modified version of WASP-Eutro that simulates algal growth based on a light attenuation coefficient computed from the daily solids concentration predicted by the WASP-Toxi component.

The relationship between suspended solids and water clarity is complicated by the interaction between water clarity and the growth of algae: good water clarity is one factor that promotes algal growth, but excessive algal growth tends to reduce water clarity, because algae itself is a form of suspended solid material. The TAM/WASP modeling framework used in this TMDL analysis has been designed to capture some of the complexity of this feedback interaction. As depicted in Figure 12, WASP-Toxi simulates the settling and re-suspension of total suspended solids, as well as the longitudinal movement of suspended solids along the length of the tidal river. Predicted daily TSS concentrations from WASP-Toxi are read by the WASP-Eutro component of the model, which predicts daily concentrations of nutrients, algae, and dissolved oxygen. WASP-Eutro uses its prediction of algal concentration at a given point in the day, along with the daily TSS concentration obtained from WASP-Toxi, to compute a measure of water clarity referred to as the light attenuation coefficient. The light attenuation coefficient is used in turn to compute the model's estimate of algae growth and the resulting algal concentration at the subsequent model time step.

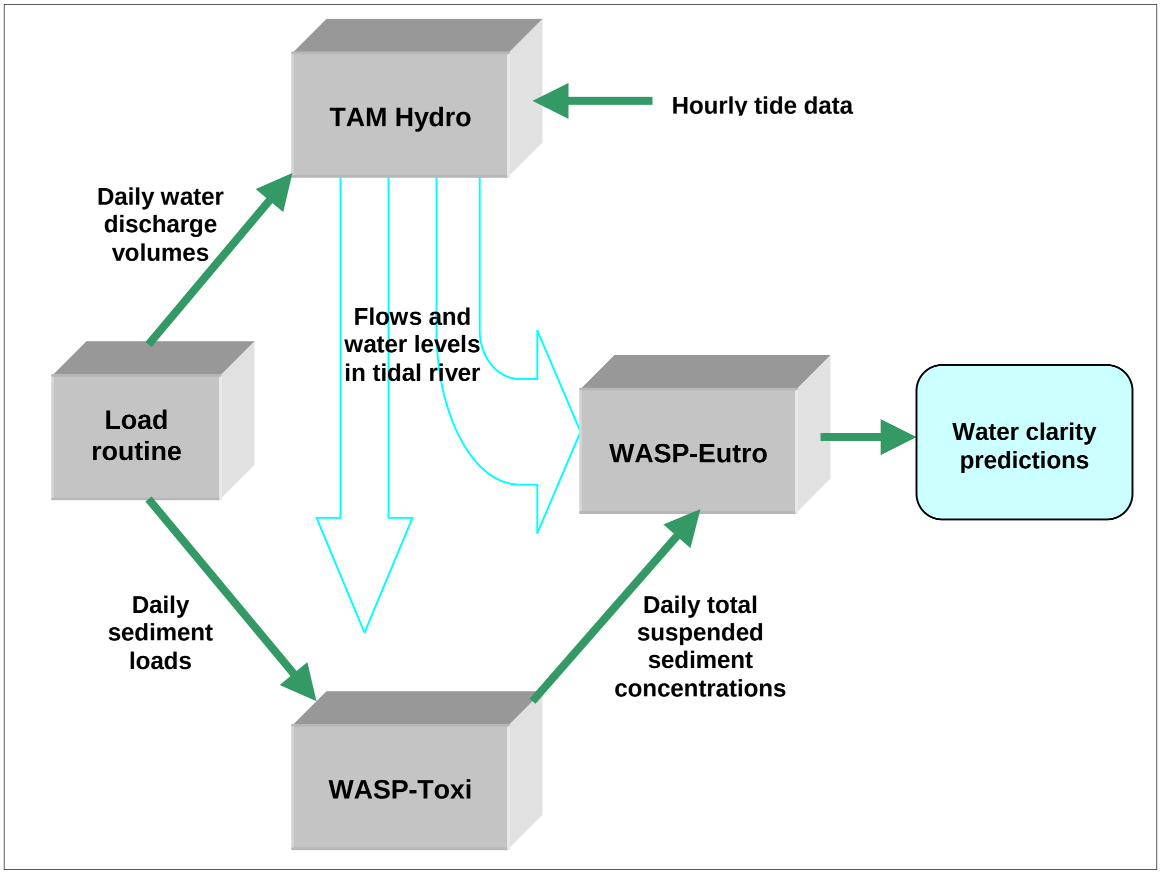

Figure 12. Schematic diagram of TAM/WASP modeling framework

The relationships between the light extinction coefficient, Secchi depth, and TSS used in this study are as follows:

Secchi depth is inversely proportional to the light extinction coefficient, Ke (Walker, 1982),

$$Ke = 1.45/\text{Secchi depth}$$

where the coefficient of proportionality used in this study, 1.45, is specified in MD water quality standards.

The light extinction coefficient is assumed to be a linear function of non-algal solids concentration and chlorophyll *a*, corresponding to the Smith light option available in the WASP-Eutro model:

$$Ke = a + b * naSS + 0.017 * Cchla$$

where

naSS = non-algal suspended solids concentration (mg/L)
Cchla = chlorophyll *a* concentration (μg/L)

Non-algal solids are computed from TSS and chlorophyll a concentrations using the relationship,

$$naSS = (TSS - V_{VSS:POC} * 1c * Cchla/1000), \quad (TSS - V_{VSS:POC} * 1c * Cchla/1000) > 5$$

$$naSS = 5, \text{ for} \quad (TSS - V_{VSS:POC} * 1c * Cchla/1000) < 5$$

where

$V_{VSS:POC}$ = ratio of volatile organic solids to particulate organic carbon, assumed to be 2.5 (Cerco *et al*., 2004)
1c = carbon/chla ratio (mg C/mg chla), computed by WASP eutro model based on light conditions

The first line of the equation for naSS simply expresses the fact, in units of mg C/L, that total solids is the sum of algal solids and non-algal solids. The second line is added to partially account for the incomplete coupling of the sediment and eutrophication components of the water clarity model (see Mandel et al. 2007).

The coefficients used in this study to compute the light extinction coefficient as a function of TSS and chla are a = 0.45 and b = 0.13. These values were determined based on WASP-Eutro model calibration results (see Mandel et al. 2007). During this portion of the calibration, the parameters, a and b, were varied while model predictions for daily chlorophyll *a* concentrations and median Secchi depths (over the calibration period, 1995-2002) were compared with values from available data. The final parameter values, a = 0.45 and b = 0.13, produced daily chlorophyll *a* concentrations which matched observed values reasonably well. These values also minimized the mean error of observed vs. predicted median Secchi depths at DC water quality monitoring stations, and came close to minimizing the corresponding mean square error of Secchi medians.

4.2.2 Non-tidal analysis

HSPF model

An HSPF model was used to simulate hydrologic and sediment erosion processes in the non-tidal drainage areas of the Anacostia's main tributaries, the NWB, the NEB, LBC, and Watts Branch (Mandel et al. 2007). For model simulations, these tributaries, with the exception of Watts Branch, were further divided into smaller subwatersheds as depicted in Figure 2 (page 5). The primary input data for this model were precipitation and other meteorological measurements from Reagan National Airport, and the land use data described in Section 2.1.2. Model calibration data included flow and suspended solids data collected at the USGS stream gage stations shown in Figure 2, and MS4 monitoring data from Montgomery and Prince George's Counties.

The HSPF model was calibrated by comparing model predictions with available data for the ten-year time period, 1995–2004. Daily flow and suspended solids data collected at the NWB and NEB USGS stream gage stations were used to estimate daily, monthly, and annual sediment loads at these two locations using the USGS's statistical model, ESTIMATOR (Cohn et al. 1989; 1992) (see Appendix A for details). The HSPF model was calibrated against edge-of-stream (EOS) sediment yield targets for individual land uses and against total monthly sediment loads at the NEB and NWB gages from ESTIMATOR. The EOS targets for urban land uses were based on average flow-weighted concentrations from Montgomery and Prince George's County monitoring locations used in their MS4 permits. EOS targets for forest, pasture, and cropland were based on edge-of-field (EOF) targets used in the CBP Phase 5 Watershed Model and a sediment delivery ratio based on subwatershed area. The Phase 5 targets are derived from National Resource Inventory (NRI) statistical estimates of EOF erosion rates for cropland and pasture in Montgomery and Prince George's County.

For each tributary, the total simulated load is equal to the total EOS load plus the load from streambank erosion. Model parameters governing streambank erosion were adjusted by matching the predicted total sediment load at the NEB and NWB gages with the monthly sediment loads computed with ESTIMATOR. Simulated streambank erosion was distributed among the subwatersheds in proportion to an independent estimate of streambank erosion derived from Evans et al. (2003). Evans et al.'s streambank erosion equation was also used to set target rates for streambank erosion in LBC and Watts Branch.

Flow duration curve/quantile regression analysis

The long-term changes over time in the flow duration curves (FDCs) for the NEB and NWB daily flow observations were quantified using a quantile regression analysis, and used to estimate current-day sediment loads due to altered hydrology (see Appendix B). Quantile regression allows the estimation of the response of the quantiles of a conditional probability distribution as a function of one or more predictor variables. In the analysis done for this study, time was used as a predictor variable and changes over time in percentile values of the FDC over the period of record (1939 to present) were computed for both the NEB and NWB. Modern-day sediment rating curves were also computed for these streams based on ESTIMATOR model results (see Appendix B for details). The annual load can be computed as the integral of the product of the FDC and the sediment rating curve (Miller 1951). Therefore, this analysis provides an estimate of annual sediment loads for these two tributaries for recent years, and an estimate of the annual sediment load that could be achieved by returning to pre-urbanization hydrology.

A map prepared by the University of Maryland (1973), depicts urbanized areas of the Anacostia basin for the years 1915, 1937, 1949, 1955, and 1970. This map indicates that urbanized land was on the order of 5% of the non-tidal drainage area in 1937, compared to approximately 75% today. This suggests that, as a very rough estimate, 90% of the watershed's impervious surfaces would need to be disconnected in order to return the watershed back to hydrologic conditions existing in 1939.

4.3 Scenario Descriptions and Results

These analyses allow a comparison of baseline conditions (under which water quality problems exist), with TMDL conditions that calculate the maximum average annual sediment load required to support the designated uses related to aquatic life. The analyses are grouped according to baseline conditions, and to conditions associated with TMDLs for both tidal and non-tidal areas.

4.3.1 Baseline Conditions Scenario for Tidal Anacostia

The TAM/WASP model was used to simulate baseline water clarity conditions during the three-year time period used for the TMDL analysis, 1995 through 1997. Model simulations of a variety of water quality parameters, including TSS, Chla and dissolved oxygen, are compared with observed values in Mandel et al. (2007). Baseline conditions are depicted in Figure 13, which shows model predictions of median growing season (April 1–October 31) Secchi depth along the length of the tidal river for the TMDL analysis period, 1995-1997.

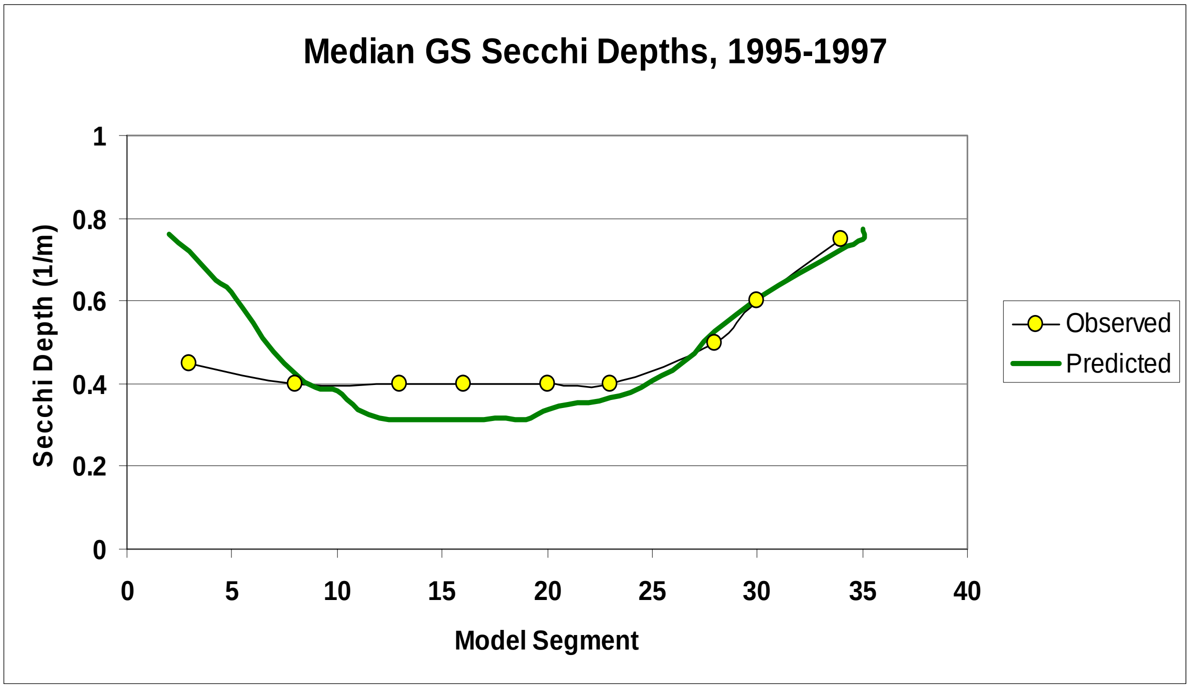

Figure 13. 1995-1997 median growing season Secchi depth in tidal Anacostia River: predicted by calibrated model vs. observed

Average annual and growing season baseline sediment loads were computed using a combination of results from the ESTIMATOR model and the HSPF model analyses. Results for the three-year time period used in the TMDL, 1995-1997, appear in Table 2, the summary of sediment load by source. Details concerning baseline load estimates are given in Mandel et al. (2007).

NWB and NEB total annual and total growing season loads were obtained from the ESTIMATOR-predicted daily loads and daily discharge data from the USGS gage stations, 01649500 and 01651000. NWB and NEB loads were apportioned to the three land use categories, agricultural, forest, and urban land, and to streambank erosion, based on HSPF model results. In order to account for loads from the portion of the non-tidal NWB below gage station 01649500, scale factors were used, based on relative areas for each land use (see Figure 2), with streambank erosion assumed to be negligible.

Loads for LBC and Watts Branch were obtained directly from HSPF output. Loads from the remaining portion of the watershed, the "tidal drainage area" depicted in Figure 2, were computed using daily Watts Branch loads per land use type per unit area, with streambank erosion assumed to be negligible.

4.3.2 TMDL Conditions Scenario for Tidal Anacostia

Model simulations of sediment load reduction scenarios were run using hydrologic inputs for the 1995-1997 time period, in conjunction with hypothetically reduced daily sediment load inputs representing the effects of the implementation of watershed management practices. In the final TMDL scenario run, sediment loads were reduced by 85% from most sources. The exceptions were: (1) Watts Branch, which had reductions based on DC's 2003 TMDL for TSS in Watts Branch; (2) CSOs, which had reductions based on predicted flows under DC's Long Term Control Plan; and (3) municipal and industrial point sources, which were simulated at their design flows and weekly or daily maximum concentration limits, respectively, to facilitate calculations of their daily maximum loads.

Initial model simulations indicate that reductions in sediment loads led to improvements in water clarity, but also led to increases in Chla concentrations, due to increased algae growth. To account for the potential decrease in water clarity caused by increased algal growth, a 50% reduction of nitrogen and phosphorus was applied in the sediment TMDL scenario. Nutrient reductions of this magnitude served to maintain model-predicted Chla concentrations at approximately pre-TMDL levels (Mandel et al. 2007).

The TMDL scenario included a model "spin-up" period of nine years at the reduced sediment load levels, allowing bed sediments to adjust to the change in loads. At the simulated reduced loads, bed sediment became more sandy over time in most portions of the tidal river. This sandier bed had less clay content, and therefore produced somewhat lower concentrations of water column TSS from tidal resuspension processes (Mandel et al. 2007).

Under the TMDL Conditions Scenario, the median of all simulated daily growing season Secchi depths for the respective jurisdictions met DC's water clarity criterion of 0.8 meters on an annual basis and met MD's water quality criterion of 0.4 meters over the three-year simulation period.

4.3.3 TMDL Conditions Scenario for Non-tidal Anacostia

Two methods were used to estimate the magnitude of target sediment loads that would support a healthy aquatic ecosystem in the non-tidal Anacostia. First, target loads were estimated with HSPF model simulations based on conditions in two reference subwatersheds, that is, subwatersheds judged by biological characterization to be unimpaired by sediment. Second, quantile regression statistics were used to estimate pre-urbanization and post-urbanization NEB and NWB flow duration curves, and these were used in conjunction with sediment rating curves to estimate the portion of modern-day sediment loads due to altered hydrology. The results of both of these analyses indicate that the load reductions required by the tidal water clarity standard are as stringent or more stringent than the load reductions required in the non-tidal Anacostia. Therefore, the final TMDL allocations are based on results of the tidal analysis.

The reference watershed approach is commonly used in the absence of numerical water quality criteria. In this study, it was used to determine the sediment loads that can support designated uses of the non-tidal Anacostia watershed, and more specifically support aquatic health. In particular, MDE has identified two Anacostia subwatersheds which are not impaired due to sediment: the upper portion of the Paint Branch (above Fairland Road), located in the Piedmont province, and Upper Beaverdam Creek, in the Coastal Plain province (Appendix C).

Target loads were calculated for the four major tributaries, NWB, NEB, LBC, and Watts Branch, based on HSPF model simulation results for the reference watersheds. The reference watershed loads were determined by adapting the procedures for determining reference loads in the benthic TMDL for Lower Opequon Creek, VA (BSE 2003). Load reductions necessary to meet target loads were found to be: 37% for NWB, 42% for NEB, 37% for LBC, and 13% for Watts Branch.

The long-term changes over time in the FDCs for the NEB and NWB were quantified using a quantile regression analysis (see Appendix B). This analysis showed a significant increase over time in the portion of the FDCs representing the highest flows. FDCs for two points in time, 1939 and 2002, were chosen to represent flow conditions before and after the occurrence of urbanization. The two sets of FDCs were used in conjunction with estimates of current-day NEB and NWB sediment rating curves to estimate annual sediment loads before and after alteration in hydrology due to urbanization. According to the results of this analysis, roughly 75% of today's sediment loads from the NWB and the NEB are due to alterations in hydrology. Since alterations in hydrology are believed to be the primary cause of sediment problems in the non-tidal Anacostia, this estimate provides an approximate target for support of a healthy ecosystem.

4.4 Critical Condition and Seasonality

The critical condition and seasonality was accounted for in the TMDL analysis by the choice of simulation period, 1995-1997. This three-year time period represents a relatively dry year, wet year, and average year, based on precipitation data and accounts for various hydrological conditions.

4.5 TMDL Loading Caps and Allocations

The sediment/TSS TMDLs for both MD and DC tidal and non-tidal waters of the Anacostia River are: **7097.6 tons/year** annually and **3396.1 tons/growing season** for the growing season April 1-October 31. The loading caps constitute an 85% overall reduction of sediment/TSS from the baseline loads determined for the TMDL analysis period, 1995-1997 (46,906 tons/year and 22,312 tons/growing season). The potential TMDL allocations include waste load allocations (WLAs) for point sources, CSOs and stormwater (areas with MS4 permits), and the load allocation (LA) for nonpoint sources.

Because it results primarily from the altered hydrology associated with urban impervious surfaces connected directly to storm sewer systems, the estimated streambank erosion load is included in the MS4-WLA. Loads from forest and agricultural lands were calculated based on standard loading factors, loads from developed land were calculated based on the monitoring data from MS4 permits, and point source discharges were calculated from required monitoring. Streambank erosion was determined by subtracting these loads from the monitored total load. Thus, the estimated streambank erosion load includes legacy sediment, current erosion and background loads. At this time, these components cannot be determined separately. As data generated by assessments of stream restoration projects and other monitoring efforts produce more refined estimates of streambank loads in the future, MDE may determine to calculate the TMDL or reallocate loads within the TMDL.

The margin of safety (MOS) is implicit and not specific as a separate term. Potential TMDL allocations in the Anacostia River watershed are based on DC water clarity criteria in the tidal Anacostia River. Model simulation results for the tidal river show that an accompanying 50% reduction in nitrogen and phosphorus loads is also necessary in order to decrease algal growth promoted by improving water clarity conditions. The State and the District reserve the right to revise these allocations provided the revisions are consistent with achieving water quality standards.

Recommended allocations, both annual and for the seven-month growing season, are given for agricultural and forest land uses, and streambank erosion; and for municipal and industrial facilities, MS4s and other regulated stormwater (SW) and DC CSOs. (See the technical memoranda entitled “Significant Sediment/TSS Nonpoint Sources in the Anacostia Watershed” and “Significant Sediment/TSS Point Sources in the Anacostia River Watershed.”) Loads from urban land uses are broken down by MS4 jurisdiction. These urban loads also include loads from construction sites. The wastewater and industrial process water loads are estimated using permitted flows and TSS limits where available. If TSS limits are not specified, then TSS concentrations are estimated on a case-by-case basis. The TMDL allocations for each major tributary/subwatershed are shown in Table 7.

Table 7. Sediment/TSS TMDL Loading Caps and Allocations for the Anacostia Watershed

Sediment/TSS TMDLs		Annual (tons/year)					
		MD WLA	MD LA	DC WLA	DC LA	MOS	TMDL
Non-tidal	NWB	2,254	23	27	0	Implicit	2,304
	NEB	3,595	218			Implicit	3,814
	LBC	479	5	1	0	Implicit	484
	Watts Br	28	1	24	0	Implicit	53
	NT Total	6,356	247	51	0	Implicit	6,655
Tidal		86	0	306	51	Implicit	443
TOTAL		**6,442**	**247**	**357**	**51**	**Implicit**	**7,097**

Sediment/TSS TMDLs		Growing season (Apr 1 - Oct 31) (tons/season)					
		MD WLA	MD LA	DC WLA	DC LA	MOS	TMDL
Non-tidal	NWB	1,216	3	21	0	Implicit	1,240
	NEB	1,473	22			Implicit	1,495
	LBC	300	0	0	0	Implicit	301
	Watts Br	17	0	16	0	Implicit	32
	NT Total	3,006	25	37	0	Implicit	3.068
Tidal		62	0	231	36	Implicit	328
TOTAL		**3,068**	**25**	**267**	**36**	**Implicit**	**3,396**

4.6 Margin of Safety

A margin of safety (MOS) is required as part of a TMDL in recognition of many uncertainties in the understanding and simulation of water quality in natural systems. In the computer simulations used to compute this TMDL, the MOS is provided by several implicit conservative assumptions used in the modeling framework.

1. The 1995-1997 simulation of growing season Secchi depth medians under existing conditions (Figure 13) underestimates the minimum Secchi depth. This implies that Secchi depths computed for load reduction scenarios are also underestimated.
2. The TAM/WASP sediment transport model does not simulate the process of "sediment aging." Sediment recently deposited on the riverbed is more subject to tidal re-suspension than older sediment, which has had time to become compacted. The simulation of sediment aging is difficult and requires data not currently available in the Anacostia, so it was not included in the TAM/WASP sediment transport model. Because a greater fraction of the surficial sediment bed is "older" in simulations of load reduction scenarios, the inclusion of sediment aging in the model would have led to greater improvements in water clarity.
3. SAV beds lead to improvements in water clarity by slowing and trapping suspended material, and this phenomenon was not accounted for in the water clarity simulations.
4. Municipal WWTPs and industrial point sources (PS) were simulated using their weekly maximum and daily maximum permitted concentrations, respectively, but were given annual WLAs based on their monthly permitted concentrations.

4.7 Summary of Sediment/TSS TMDLs for the Anacostia Watershed

The sediment/TSS TMDLs for both MD and DC non-tidal and tidal waters of the Anacostia River are: **7097.6 tons/year** annually and **3396.1 tons/growing season** for the growing season April 1-October 31 (see Tables 7-11 for details). The loading caps constitute an 85% overall reduction of sediment/TSS from the baseline loads determined for the TMDL analysis period, 1995-1997. The TMDLs are distributed between: 1) waste load allocations (WLAs) to National Pollutant Discharge Elimination System (NPDES) municipal and industrial PS discharges, NPDES MS4s and other regulated stormwater (SW), and DC CSOs; 2) load allocations (LAs) to forest and agricultural lands; and 3) an implicit margin of safety (MOS).

As Tables 8-11 indicate, TMDLs have been developed for each of the four listed segments: the MD non-tidal and MD tidal portions of the river, and DC's Tidal Upper Anacostia and Tidal Lower Anacostia segments. Each upstream segment's overall load is rolled into the succeeding downstream segment as an "upstream load," resulting in a cumulative, watershed-wide TMDL. Note that the MD non-tidal segment includes an upstream load from DC sources that drain to MD waters in the NWB; similarly, loads from MD's portion of Watts Branch and Lower Beaverdam Creek are added to the upstream load for the DC Tidal Upper segment where they discharge. Loads from DC's portion of those two subwatersheds are included in the MS4-WLA for the DC Tidal Upper Anacostia in the annual and growing season summary TMDL tables, and detailed separately in the tables of maximum daily loads.

Tables 8 and 9 present the average annual and growing season TMDLs for the Anacostia watershed. Tables 10 and 11 present maximum daily loads for sediment/TSS based on the average annual and growing season TMDLs, respectively. See Appendix D for a detailed explanation of the technical methods used to determine these daily expressions.

Table 8. Summary of Annual Sediment/TSS TMDLs for the Anacostia Watershed (tons/year)

MD Non-Tidal Anacostia

Upstream Load from DC	MD Non-Tidal WLA	MD Non-Tidal LA	MOS	MD Non-Tidal TMDL
27.0[1]	6355.8	246.8	Implicit	6629.6

MD Tidal Anacostia

Upstream Load	MD Tidal WLA	MD Tidal LA	MOS	MD Tidal TMDL (does not include non-tidal loads from Watts Br & LBC)
6117.4[2]	86.4	0	Implicit	6203.8

DC Tidal Upper Anacostia

Upstream Load (all MD loads including Watts Br & LBC)	DC Upper Anacostia MS4 WLA	DC Upper Anacostia CSO WLA	DC Upper Anacostia LA	MOS	DC Tidal Upper TMDL
6716.0[3]	109.4[4]	83.9	29.8	Implicit	6938.9

DC Tidal Lower Anacostia

Upstream Load	DC Lower Anacostia MS4 WLA	DC Lower Anacostia CSO WLA	DC PS WLA	DC Lower Anacostia LA	MOS	TOTAL TMDL
6938.9	46.4	90.8	0.5	20.7	Implicit	7097.4

[1]This load drains to MD waters from DC's portion of the NWB subwatershed

[2]Does not include MD non-tidal loads from Watts Branch (28.5) and Lower Beaverdam Creek (483.7). Since these drain to DC tidal waters, they are included in the upstream load to the DC Tidal Upper Anacostia.

[3]Upstream load comprises all MD tidal and non-tidal loads, including MD loads from Watts Branch (28.5) and LBC (483.7).

[4]Includes loads from DC non-tidal waters in Watts Branch (24.1) and LBC (0.6)

Table 9. Summary of Growing Season Sediment/TSS TMDLs for the Anacostia Watershed (tons/growing season)

MD Non-Tidal Anacostia

Upstream Load from DC	MD Non-Tidal WLA	MD Non-Tidal LA	MOS	MD Non-Tidal TMDL
20.7[1]	3005.8	25.1	Implicit	3051.6

MD Tidal Anacostia

Upstream Load	MD Tidal WLA	MD Tidal LA	MOS	MD Tidal TMDL (does not include non-tidal loads from Watts Br & LBC)
2734.8[2]	62.0	0	Implicit	2796.8

DC Tidal Upper Anacostia

Upstream Load (all MD loads including Watts Br & LBC)	DC Upper Anacostia MS4 WLA	DC Upper Anacostia CSO WLA	DC Upper Anacostia LA	MOS	DC Tidal Upper TMDL
3113.5[3]	76.3[4]	61.7	20.9	Implicit	3272.5

DC Tidal Lower Anacostia

Upstream Load	DC Lower Anacostia MS4 WLA	DC Lower Anacostia CSO WLA	DC PS WLA	DC Lower Anacostia LA	MOS	TOTAL TMDL
3272.5	33.6	74.6	.3	14.9	Implicit	3395.8

[1]This load drains to MD waters from DC's portion of the NWB subwatershed

[2]Does not include MD non-tidal loads from Watts Branch (16.5) and Lower Beaverdam Creek (300.2). Since these drain to DC tidal waters, they are included in the upstream load to the DC Tidal Upper Anacostia.

[3]Upstream load comprises all MD tidal and non-tidal loads, including MD loads from Watts Branch (16.5) and LBC (300.2).

[4]Includes loads from DC non-tidal waters in Watts Branch (15.5) and LBC (0.4)

Table 10. Summary of Annually-Based Maximum Daily Loads of Sediment/TSS for the Anacostia River Watershed (tons/day)

Non-Tidal Anacostia River

Flow Range (m^3/s)	Upstream (max, avg)	MD Non-Tidal MS4-WLA	MD Non-Tidal Other PS-WLA	MD Non-Tidal LA	MOS	Non-Tidal TMDL (max, avg)
< 0.89	0.003, 0.002	0.505	0.349	0.0007	Implicit	0.858, 0.199
0.89 - 2.34	0.009, 0.003	2.581	0.349	0.016	Implicit	2.955, 0.381
2.34 - 3.48	0.020, 0.005	20.870	0.349	0.041	Implicit	21.28, 0.800
3.48 - 10.75	0.279, 0.013	44.617	0.349	0.459	Implicit	45.70, 3.016
> 10.75	19.23, 0.676	3828.51	0.349	244.45	Implicit	4092.54, 168.86

MD Tidal Anacostia River

Flow Range (m^3/s)	Upstream (max, avg)	MD Tidal MS4-WLA	MD Tidal LA	MOS	TMDL to MD/DC Border (max, avg)
All	4092.54, 18.15	18.85	0.11	Implicit	4111.50, 18.95

Table 10 (cont'd). Summary of Annually-Based Maximum Daily Loads of Sediment/TSS for the Anacostia River Watershed (tons/day)

DC Tidal Upper Anacostia River

Non-Tidal Lower Beaverdam Creek

Flow Range (m^3/s)	Upstream (max, avg)	DC LBC MS4-WLA (max, avg)	DC LBC LA (max, avg)	MOS	Total TMDL (max, avg)
All	106.01, 1.324	0.0954, 0.0016	-, -	Implicit	106.105, 1.326

Non-Tidal Watts Branch

Flow Range (m^3/s)	Upstream (max, avg)	DC WB MS4-WLA (max, avg)	DC WB LA (max, avg)	MOS	Total TMDL (max, avg)
All	4.338, 0.1314	3.425, 0.1114	-, -	Implicit	7.763, 0.2428

DC Tidal Upper Anacostia

Flow Range (m^3/s)	Upstream (max, avg)	DC Upper Anacostia MS4-WLA (max, avg)	DC Upper Anacostia CSO-WLA (max, avg)	DC Upper Anacostia LA (max, avg)	MOS	TMDL to Upper / Lower Boundary (max, avg)
All	4111.50, 18.95	18.35, 0.78	84.61, 24.37	6.33, 0.28	Implicit	4220.79, 44.38

DC Tidal Lower Anacostia River

Flow Range (m^3/s)	Upstream (max, avg)	DC Lower Anacostia MS4-WLA (max, avg)	DC Lower Anacostia Other PS-WLA	DC Lower Anacostia CSO-WLA (max, avg)	DC Lower Anacostia LA (max, avg)	MOS	TOTAL TMDL (max, avg)
All	4220.79, 44.38	10.24, 0.43	0.0043	67.10, 25.85	4.52, 0.19	Implicit	4302.65, 70.85

Table 11. Summary of Seasonally-Based Maximum Daily Loads of Sediment/TSS for the Anacostia River Watershed (tons/day during growing season)

Non-Tidal Anacostia River

Flow Range (m^3/s)	Upstream (max, avg)	MD Non-Tidal MS4-WLA	MD Non-Tidal Other PS-WLA	MD Non-Tidal LA	MOS	Non-Tidal TMDL (max, avg)
< 0.89	0.003, 0.0023	0.500	0.302	0.0007	Implicit	0.806, 0.156
0.89 - 2.34	0.009, 0.0037	2.580	0.302	0.006	Implicit	2.897, 0369
2.34 - 3.48	0.020, 0.0071	20.870	0.302	0.022	Implicit	21.21, 1.016
3.48 - 10.75	0.279, 0.0236	44.620	0.302	0.168	Implicit	45.37, 4.854
> 10.75	19.23, 1.0981	1393.24	0.302	9.500	Implicit	1422.27, 158.69

MD Tidal Anacostia River

Flow Range (m^3/s)	Upstream (max, avg)	MD Tidal MS4-WLA	MD Tidal LA	MOS	TMDL to MD/DC Border (max, avg)
All	1422.27, 14.23	18.85	0.0005	Implicit	1441.12, 15.44

Table 11 (cont'd). Summary of Seasonally-Based Maximum Daily Loads of Sediment/TSS for the Anacostia River Watershed (tons/day during growing season)

DC Tidal Upper Anacostia River

Non-Tidal Lower Beaverdam Creek

Flow Range (m^3/s)	Upstream (max, avg)	DC LBC MS4-WLA (max, avg)	DC LBC LA (max, avg)	MOS	Total TMDL (max, avg)
All	66.01, 1.403	0.0930, 0.0020	-, -	Implicit	66.10, 1.405

Non-Tidal Watts Branch

Flow Range (m^3/s)	Upstream (max, avg)	DC WB MS4-WLA (max, avg)	DC WB LA (max, avg)	MOS	Total TMDL (max, avg)
All	3.65, 0.1406	3.425, 0.1318	-, -	Implicit	7.075, 0.2724

DC Tidal Upper Anacostia

Flow Range (m^3/s)	Upstream (max, avg)	DC Upper Anacostia MS4-WLA (max, avg)	DC Upper Anacostia CSO-WLA (max, avg)	DC Upper Anacostia LA (max, avg)	MOS	TMDL to Upper / Lower Boundary (max, avg)
All	1441.12, 15.44	18.35, 1.18	84.61, 21.94	6.33, 0.41	Implicit	1550.41, 38.97

DC Tidal Lower Anacostia River

Flow Range (m^3/s)	Upstream (max, avg)	DC Lower Anacostia MS4-WLA (max, avg)	DC Lower Anacostia Other PS-WLA	DC Lower Anacostia CSO-WLA (max, avg)	DC Lower Anacostia LA (max, avg)	MOS	TOTAL TMDL (max, avg)
All	1550.41, 38.97	10.24, 0.66	0.0043	67.10, 25.85	4.52, 0.291	Implicit	1632.27, 65.77

5.0 ASSURANCE OF IMPLEMENTATION

Section 303(d) of the Clean Water Act and current EPA regulations require reasonable assurance that the TMDL load allocations will be implemented.

Land use in the Anacostia River watershed is 75% urban. Sediment and erosion problems in such a highly urbanized watershed are primarily caused by high percentages of impervious surface, leading to alterations in natural hydrology. Potential best management practices (BMPs) for reducing sediment loads from urban areas and resulting impacts can be summarized in three general categories: stormwater retrofits, impervious surface reduction, and stream restoration. Stormwater retrofits include modification of existing stormwater structural practices to address water quality. Reductions range from as low as 10% for dry detention to approximately 80% for wet ponds, wetlands, infiltration practices and filtering practices. Impervious surface reduction results in a change in hydrology that could reduce stream erosion (USEPA-CBP 2003).

All forested land uses (20% in the Anacostia watershed) can benefit from improved riparian buffer systems. A riparian buffer reduces the effects of upland sediment sources through trapping and filtering. Riparian buffer efficiencies vary depending on type (grass or forested), land use (urban or agriculture) and physiographic region. In agricultural areas (5% in the Anacostia watershed) comprehensive soil conservation plans can be developed that meet criteria of the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Field Office Technical Guide. Such Soil conservation plans help control erosion by modifying cultural and structural practices.

The regulatory agencies in MD and DC will continue to work with an active coalition of local, state and federal agencies, environmental organizations and citizens groups in the watershed to restore the river and its tributaries. MD and DC intend 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.

The DC Water and Sewer Authority (DCWASA) has established a Long Term Control Plan (LTCP) for the reduction of CSOs and the sediment loads associated with them. Under its MS4 NPDES permit, DC is implementing a stormwater management plan (SWMP) to control the discharge of pollutants from separate storm sewer outfalls. DC is also implementing a nonpoint source management plan through its Nonpoint Source Management and Chesapeake Bay Implementation programs.

MD and DC have several well-established programs to draw upon, including the Water Quality Improvement Act of 1998 (WQIA) in MD, the Erosion and Sedimentation Control Amendment Act of 1994 and DC Law 5-188 (Storm Water Management Regulations – 1988) of The District of Columbia Water Pollution Control Act of 1984 in

DC, and the Federal Nonpoint Source Management Program (Section 319 of the Clean Water Act).

In DC, in conjunction with voluntary activities to control nonpoint source pollution through the Nonpoint Source Management and Chesapeake Bay Implementation programs, various activities are supported to regulate land disturbing activities, stormwater management, and flood plain management. DC, under authority of various laws, implements a number of action plans that involve reviewing and approving construction plans for stormwater runoff control measures, flood plain intrusion, unstable soils, topography compatibility, erosion and sediment control measures, and landscaping; conducting routine and programmed inspections at construction sites; and providing technical assistance to developers and DC residents; and conducting investigations of citizen complaints related to drainage and erosion and sediment control.

In 1983, the EPA Nationwide Urban Runoff Program found that stormwater runoff from urban areas contains the same general types of pollutants found in wastewater, and that 30% of identified cases of water quality impairment were attributable to stormwater discharges. In November 1990, EPA required jurisdictions with a population greater than 100,000 to apply for NPDES permits for stormwater discharges. The two MD jurisdictions where the Anacostia River watershed is located, Montgomery and Prince George's Counties, are required to participate in the NPDES stormwater program, and to comply with NPDES permit regulations for stormwater discharges. Pursuant to the 2000 Maryland Stormwater Design Manual, MDE requires an 80% reduction of sediments for new development. For existing development, MDE's NPDES stormwater permits require watershed assessments and restoration based on impervious surface area. The permit-required management programs, including restoration of 10% of their impervious areas, are being implemented in both counties to meet locally established watershed protection and restoration goals and to control stormwater discharges to the maximum extent.

In Maryland, Sediment and Erosion Control Programs are operated at the local level, where local governments have shown the ability to enforce the provisions of their ordinances relating to soil erosion and sediment control. MDE conducts periodic reviews of local programs to ensure that implementation is acceptable and has the authority to suspend delegation and take over any program that does not meet State standards. Potential funding available for local governments includes 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.

Additional potential funding sources for implementation include Maryland's Agricultural Cost Share Program (MACS) which provides grants to farmers to help protect natural resources, and the Environmental Quality and Incentives Program, which focuses on implementing conservation practices and BMPs on land involved with livestock and production.

In 2000, the Maryland DNR initiated the Watershed Restoration Action Strategy (WRAS) Program as one of several new approaches to implementing water quality and habitat restoration and protection. The WRAS Program encouraged local governments to focus on priority watersheds for restoration and protection. Since the program's inception, local governments have received grants and technical assistance from DNR for 25 WRAS projects in which local people identify local watershed priorities for restoration, protection and implementation. MDE has directed the WRAS Program since January 2005. The WRAS project area in Prince George's County, Maryland totals about 86 square miles including portions of municipalities that are in the watershed. In the WRAS, the County has identified and prioritized local restoration and protection needs associated with water quality and habitat (MDE - WRAS Program, 2005). More information about the WRAS Program may be found at: http://www.dnr.state.md.us/watersheds/wras/index.html

There is also an active coalition of local, state, and federal agencies, environmental organizations and citizens groups working together to restore the river and its tributaries; this coalition can help to assure the implementation of the sediment TMDLs (see Table 12). In 1987, the Anacostia Watershed Restoration Agreement was signed by MD, DC, and Montgomery and Prince George's Counties, resulting in the formation of the Anacostia Watershed Restoration Committee (AWRC). Several sediment reduction strategies have been implemented and are ongoing under this agreement. For example, regular stream habitat assessment monitoring and limited MS4 monitoring for constituents including TSS have been conducted in Prince George's and Montgomery Counties, and in DC. Several sediment reduction/controlling strategies are ongoing as part of various programs, including: street sweeping, storm drain-inlet cleaning, storm drain cleaning in urban areas, stormwater pond, and ESD/LID projects.

MD and DC intend for the required reductions to be implemented in an iterative process, including the existing stormwater management program and cooperation with AWRC. The iterative implementation of BMPs in the watershed has several benefits: tracking of water quality improvements following BMP implementation through follow-up stream monitoring; providing a mechanism for developing public support through periodic updates on BMP implementation; and helping to ensure that the most cost-effective practices are implemented first.

Table 12. Anacostia River restoration activities by Signatories of the Anacostia Watershed Restoration Agreement, and other assisting organizations

Maryland Department of the Environment	1. Stormwater Management: Through the 2000 Maryland Stormwater Design Manual, MDE requires 80% sediment reduction for new development. For existing development, MDE's NPDES stormwater permits require watershed assessments and restoration based on impervious surface area. Currently, Prince George's and Montgomery Counties are required to restore 10% of their impervious areas. 2. Sediment and Erosion Control Program: Operated at the local level where local governments have shown the ability to enforce the provisions of their ordinances relating to soil erosion and sediment control. In other cases, the state has retained enforcement responsibilities. MDE conducts periodic reviews of local programs to ensure that implementation is acceptable and it has the authority to suspend delegation and take over any program that does not meet State standards.
Montgomery County	1. Conducts regular biological and physical habitat stream assessment monitoring. 2. Conducts NPDES MS4 permit monitoring for constituents including TSS. 3. Has added a flow gauge on Upper Good Hope; will be adding long-term USGS flow gauge on Lower Paint Branch. 4. Conducting source control and trash management pilot project in Paint Branch using EPA grant funding ($500,000) in partnership with PGDER. 5. Has spent $15 million to purchase 300 acres of stream valley parkland in Upper Paint Branch. 6. Restored habitat for ¾ mi. section of NWB and 2 mi. section of Paint Branch. 7. Completed Wheaton Branch SWM facility, controlling > 800 acres in Sligo Creek watershed, and SWM pond at Sligo Creek Golf Course, controlling runoff from ~ 70 acres. 8. Completed numerous stream valley improvements, new stormwater management retrofits, and existing pond retrofits. For further information: http://www.montgomerycounty.gov/content/Publications/pdf/anacostia_restoration.
Prince George's County	1. Conducts regular stream assessment monitoring and MS4 monitoring for constituents including TSS. 2. Conducts programs of street-sweeping, storm drain-inlet cleaning, and storm pipe cleaning in urban areas. 3. Conducting the Anacostia LID demonstration project, in partnership with the Anacostia Watershed Toxics Alliance, with $1 million in funding from a Congressional appropriation
District of Columbia	1. Conducts regular stream assessment monitoring and MS4 monitoring for constituents including TSS. 2. Restored 15 acres of river fringe wetlands 3. Restored 42 acres of wetlands at Kingman Lake 4. BMPs and LIDs are planned at and near RFK stadium 5. An agreement has been signed with U.S. National Park Service (NPS) for installation of LID type stormwater management in two large parking lots within Ft. Dupont watershed as well as LID to treat stormwater from a 500-yd section of Ridge Road adjacent to the park. A contract to design and

District of Columbia, continued	build these facilities has been issued and construction is expected in the near future. 6. Completed designs of Watts Branch stream habitat restoration project in partnership with U.S.Fish and Wildlife Service (USFWS) and U.S. Army Corps of Engineers. Restoration will begin in 2007 as a partnership between DDOE and USFWS. Final restoration designs will incorporate natural channel modifications that will help improve the stream's water quality, stabilize its banks, improve instream habitat, and enhance its aesthetic qualities. 7. Installing BMPs/SWM controls in Hickey Run watershed. Stream restoration projects are also planned.
U.S. Army Corps of Engineers	Completed Anacostia River and Tributaries Comprehensive Watershed Plan (ARCWP), a reconnaissance study initiated March 2004 in response to September 8, 1988 resolution of the Committee on Public Works and Transportation, United States House of Representatives.
MWCOG	Completed Anacostia Watershed Indicators and Targets, a "suite of measurable and publicly supportable environmental restoration indicators."
Maryland State Highway Administration	Has created a comprehensive set of avoidance, minimization and mitigation measures to protect the environment as an integral component of the proposed Intercounty Connector (ICC) project. Plans include: - 74,000 linear feet of stream restoration in Northwest Branch, Indian Creek and the Paint Branch and Upper Paint Branch watersheds; - 1500 linear feet of fish passage work; - More than 83 acres of new wetlands at seven major sites; - Approximately 4300 acres of water quality and stormwater management improvements; - More than 700 acres of reforested land to create new forest habitat; - Over 775 acres of new parkland to mitigate 88 acres used for ICC.

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Appendix A – ESTIMATOR Model Results for Northwest Branch and Northeast Branch Sediment Loads

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Appendix B – Flow Duration Curve/Quantile Regression Analysis of Effects of Urban Hydrology

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

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Appendix D – Technical Approach Used to Generate Maximum Daily Loads