Total Maximum Daily Load of Sediment in the Seneca Creek Watershed, Montgomery County, Maryland

FINAL

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List of Abbreviations

BIBI	Benthic Index of Biotic Integrity
BIP	Buffer Incentive Program
BMP	Best Management Practices
BSID	Biological Stressor Identification
CBP P5.2	Chesapeake Bay Program Phase 5.2
CBP P4.3	Chesapeake Bay Program Phase 4.3
cfs	Cubic feet per second
CV	Coefficient of Variation
CWA	Clean Water Act
DNR	Maryland Department of Natural Resources
EOF	Edge-of-Field
EOS	Edge-of-Stream
EPA	Environmental Protection Agency
EPSC	Environmental Permit Service Center
ESD	Environmental Site Design
ETM	Enhanced Thematic Mapper
FDC	Flow Duration Curve
FIBI	Fish Index of Biotic Integrity
GIS	Geographic Information System
HSPF	Hydrological Simulation Program – FORTRAN
IBI	Index of Biotic Integrity
LA	Load Allocation
m	meter
MAL	Minimum Allowable IBI Limit
MBSS	Maryland Biological Stream Survey
MD 8-Digit	Maryland 8-digit Watershed
MDE	Maryland Department of the Environment
MDL	Maximum Daily Load
MGD	Millions of Gallons per Day
mg/l	Milligrams per liter

MOS	Margin of Safety
MS4	Municipal Separate Storm Sewer System
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resource Conservation Service
NRI	Natural Resource Inventory
PSU	Primary Sampling Unit
RESAC	Regional Earth Science Applications Center
SCS	Soil Conservation Service
TM	Thematic Mapper
TMDL	Total Maximum Daily Load
Ton/yr	Tons per Year
TSD	Technical Support Document
TSS	Total Suspended Solids
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WLA	Waste Load Allocation
WQA	Water Quality Analysis
WQIA	Water Quality Improvement Act
WQLS	Water Quality Limited Segment
WWTP	Wastewater Treatment Plant

EXECUTIVE SUMMARY

This document, upon approval by the U.S. Environmental Protection Agency (EPA), establishes a Total Maximum Daily Load (TMDL) for sediment in the Seneca Creek watershed (basin number 02140208) (2010 *Integrated Report of Surface Water Quality in Maryland Assessment Unit ID*: MD-02140208). Section 303(d) of the federal Clean Water Act (CWA) and the EPA's implementing regulations direct each state to identify and list waters, known as water quality limited segments (WQLSs), in which current required controls of a specified substance are inadequate to achieve water quality standards. For each WQLS, the State is required to either establish a TMDL of the specified substance that the waterbody can receive without violating water quality standards, or demonstrate that water quality standards are being met (CFR 2009b).

The Maryland Department of the Environment (MDE) has identified the waters of the Seneca Creek watershed on the State's 2010 Integrated Report as impaired by sediments (1996, Clopper Lake - 1998), nutrients – phosphorus (1996, Clopper Lake - 1998, and Little Seneca Lake - 1998), chlorides (2010), ammonia (2010), and impacts to biological communities (2002) (MDE 2010b). The designated use of the Seneca Creek mainstem and its tributaries is Use I-P (Water Contact Recreation, Protection of Aquatic Life, and Public Water Supply), except for 1) Little Seneca Creek and its tributaries, from the outlet of Little Seneca Lake to the stream's confluence with Bucklodge Branch, and Wildcat Branch and its tributaries, which are designated as Use III-P (Nontidal Coldwater and Public Water Supply), and 2) Little Seneca Creek and its tributaries upstream of Little Seneca Lake, which are designated as Use IV-P (Recreational Trout Waters and Public Water Supply) (COMAR 2009a,b,c,d,e,f).

The TMDL established herein by MDE will address the Maryland 8-digit (MD 8-digit) watershed 1996 sediments listing, for which a data solicitation was conducted, and all readily available data from the past five years have been considered. A Water Quality Analysis (WQA) for eutrophication to address the MD 8-digit watershed nutrients/phosphorus listing was approved by the EPA in 2009. A TMDL of phosphorus and sediments for Clopper Lake was approved by the EPA in 2002, and a WQA for eutrophication to address the Little Seneca Lake nutrients/phosphorus listing was approved by the EPA in 2006. The general listing for impacts to biological communities was removed due to a stressor identification analysis completed in 2009, and as a result, , the 2010 Integrated Report now identifies chlorides, ammonia, and sediments as specific stressors impairing aquatic life (MDE 2010b).

The Seneca Creek watershed aquatic life assessment scores, consisting of the Benthic Index of Biotic Integrity (BIBI) and Fish Index of Biotic Integrity (FIBI), indicate that the biological metrics for the watershed exhibit a significant negative deviation from reference conditions based on Maryland's biocriteria listing methodology. The biocriteria listing methodology assesses the condition of MD 8-digit watersheds by measuring the percentage of sites, translated into watershed stream miles, that are assessed as having BIBI and/or FIBI scores significantly lower than 3.0 (on a scale of 1 to 5), and then calculating whether this percentage differs significantly from reference conditions (i.e., unimpaired watershed: <10% of stream miles differ from reference conditions) (Roth et al. 2005; MDE 2010b). The objective of the TMDL established herein is to ensure that watershed sediment loads are at a level to support the Use I-P/III-P/IV-P designations for the Seneca Creek watershed, and more specifically, at a level to support aquatic life.

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

The BSID analysis for the Seneca Creek watershed concludes that biological communities are likely impaired due to flow/sediment related stressors. Individual stressors within the sediment and habitat parameter groupings that are associated with sediment related impacts and an altered hydrologic regime were identified as being probable causes of the biological impairment. Furthermore, the degradation of biological communities in the watershed is strongly associated with urban land use and its concomitant effects (MDE 2009b).

In order to quantify the impact of sediment on the aquatic life of non-tidal stream systems, a reference watershed TMDL approach was used and resulted in the establishment of a *sediment loading threshold* (Currey et al. 2006). This threshold is based on a detailed analysis of sediment loads from watersheds that are identified as supporting aquatic life (i.e., reference watersheds) based on Maryland's biocriteria (Roth et al. 1998, 2000; Stribling et al. 1998; MDE 2010b). This threshold is then used to determine a watershed specific sediment TMDL.

The computational framework chosen for the Seneca Creek watershed TMDL was the Chesapeake Bay Program Phase 5.2 (CBP P5.2) watershed model target *edge-of-field* (EOF) land use sediment loading rate calculations combined with a *sediment delivery ratio*. The *edge-of-stream* (EOS) sediment load is calculated per land use as a product of the land use area, land use target loading rate, and loss from the EOF to the main channel. The spatial domain of the CBP P5.2 watershed model segmentation aggregates to the MD 8-digit watersheds, which is consistent with the impairment listing.

EPA's regulations require TMDLs to take into account seasonality and critical conditions for stream flow, loading, and water quality parameters (CFR 2009b). The intent of this requirement is to ensure that the water quality of the waterbody is protected during times when it is most vulnerable. The biological monitoring data used to determine the reference watersheds reflect the impacts of stressors (i.e., sediment impacts to stream biota) over the course of time time (i.e., captures the impacts of all high and low flow events). Thus, critical conditions are inherently addressed. Seasonality is captured in two components. First, it is implicitly included in biological sampling as biological communities reflect the impacts of stressors over time, as described above. Second, the Maryland Biological Stream Survey (MBSS) dataset included benthic sampling in the spring and fish sampling in the summer.

All TMDLs need to be presented as a sum of waste load allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources generated within the assessment unit, accounting for natural background, tributary, and adjacent segment loads. Furthermore, all TMDLs must include a margin of safety (MOS) to account for any lack of knowledge and uncertainty concerning the relationship between loads and water quality (CFR 2009a,b). It is proposed that the estimated variability around the reference watershed group used in this analysis already accounts for such uncertainty, and therefore the MOS is implicitly included.

The Seneca Creek Total Baseline Sediment Load is 27,874.3 tons per year (ton/yr), which can be further subdivided into a nonpoint source baseline load (Nonpoint Source BL_{SC}) and two types of point source baseline loads: National Pollutant Discharge Elimination System (NPDES) regulated stormwater (NPDES Stormwater BL_{SC}) and regulated process water (Process Water BL_{SC}) (see Table ES-1).

Table ES-1: Seneca Creek Baseline Sediment Loads (ton/yr)

Total Baseline Load (ton/yr)	=	Nonpoint Source BL_{SC}	+	NPDES Stormwater BL_{SC}	+	Process Water BL_{SC}
27,874.3	=	17,332.6	+	9,527.1	+	1,014.6

The Seneca Creek Average Annual TMDL of Sediment/Total Suspended Solids (TSS) is 16,280.0 ton/yr. The Load Allocation (LA_{SC}) is 9,977.3 ton/yr, the NPDES Stormwater Waste Load Allocation (NPDES Stormwater WLA_{SC}) is 5,288.1 ton/yr, and the Process Water Waste Load Allocation (Process Water WLA_{SC}) is 1,014.6 ton/yr (see Table ES-2).

The Clopper Lake sediment TMDL of 129.0 ton/yr, which was developed by MDE to be protective of water quality standards within the impoundment and approved by the EPA in 2002, still applies as the target sediment loading capacity within the lake's drainage area, located in the southeast portion of the Seneca Creek watershed (MDE 2002). The attainment of water quality standards within the MD 8-digit Seneca Creek watershed and Clopper Lake impoundment can only be achieved by meeting the average annual TMDL of sediment/TSS specified for the MD 8-digit watershed within this report as well as the specific TMDL for the Clopper Lake drainage basin established by MDE in 2002. Furthermore, both the baseline sediment loading and TMDL for the impoundment are implicitly included within the Seneca Creek NPDES Stormwater BL_{SC}/Nonpoint Source BL_{SC} and NPDES Stormwater WLA_{SC}/LA_{SC}, respectively, due to the spatial resolution of the CBP P5.2 watershed model segmentation.

The Seneca Creek Average Annual TMDL of Sediment/TSS will ensure that the watershed sediment loads are at a level to support the Use I-P/III-P/IV-P designations for the Seneca Creek watershed, and more specifically, at a level to support aquatic life. The TMDL, however, will not completely resolve the impairment to biological communities within the watershed. Since the BSID watershed analysis identifies other stressors (i.e., chlorides, ammonia, and high pH) as impacting the biological conditions, this impairment remains to be fully addressed through the Integrated Report listing process and the TMDL development process, such that all impairing substances identified as impacting biological communities in the watershed are reduced to levels that will meet water quality standards, as established in future TMDLs for those substances (MDE 2009a,b).

Table ES-2: Seneca Creek Average Annual TMDL of Sediment/Total Suspended Solids (ton/yr)

TMDL (ton/yr)	=	LA_{SC}	+	NPDES Stormwater WLA_{SC}	+	Process Water WLA_{SC}	+	MOS
16,280.0	=	9,977.3	+	5,288.1	+	1,014.6	+	Implicit

Table ES-3: Seneca Creek Baseline Load, TMDL, and Total Reduction Percentage

Baseline Load (ton/yr)	TMDL (ton/yr)	Total Reduction (%)
27,874.3	16,280.0	41.6

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

Once the EPA has approved this TMDL, and it is known what measures must be taken to reduce pollution levels, implementation of best management practices (BMPs) is expected to take place. Relative to the required reduction in sediment loads from the regulated sector of the TMDL, specifically the NPDES Stormwater WLA as no reductions are required from the Process Water WLA, BMP implementation will primarily occur via the municipal separate storm sewer system (MS4) permitting process for medium and large municipalities. MDE intends 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 cost of implementation.

Maryland has several well-established programs to draw upon, including the Water Quality Improvement Act of 1998 (WQIA) and the Federal Nonpoint Source Management Program (§ 319 of the Clean Water Act). Several potential funding sources available for local governments for implementation are available, such as the Buffer Incentive Program (BIP), the State Water Quality Revolving Loan Fund, and the Stormwater Pollution Cost Share Program. Details of these programs and additional funding sources can be found at http://www.dnr.state.md.us/bay/services/summaries.html.

1.0 INTRODUCTION

This document, upon approval by the U.S. Environmental Protection Agency (EPA), establishes a Total Maximum Daily Load (TMDL) for sediment in the Seneca Creek watershed (basin number 02140208) (2010 *Integrated Report of Surface Water Quality in Maryland* Assessment Unit ID: MD-02140208). Section 303(d)(1)(C) of the federal Clean Water Act (CWA) and the EPA's implementing regulations direct each state to develop a TMDL for each impaired water quality limited segment (WQLS) on the State's Integrated Report, taking into account seasonal variations, critical conditions, and a protective margin of safety (MOS) to account for uncertainty (CFR 2009b). A TMDL reflects the total pollutant loading of the impairing substance a waterbody can receive and still meet water quality standards.

TMDLs are established to determine the pollutant load reductions needed to achieve and maintain water quality standards. A water quality standard is the combination of a designated use for a particular body of water and the water quality criteria designed to protect that use. Designated uses include activities such as swimming, drinking water supply, protection of aquatic life, and shellfish propagation and harvest. Water quality criteria consist of narrative statements and numeric values designed to protect the designated uses. Criteria may differ among waters with different designated uses.

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2.0 SETTING AND WATER QUALITY DESCRIPTION

2.1 General Setting

Location

Seneca Creek is a free flowing creek that originates near the city of Damascus in the northwest portion of Montgomery County, Maryland. The creek flows 27 miles in a southerly direction through the municipalities of Germantown and Gaithersburg, until it empties into the nontidal Potomac River near the town of Seneca. The watershed is located in the Middle Potomac River sub-basin of the Chesapeake Bay watershed. It is the largest watershed located entirely within Montgomery County, covering approximately 129 square miles (see Figure 1). Three large tributary systems flow into the creek's mainstem: Little Seneca Creek, Great Seneca Creek, and Dry Seneca Creek (MDE 2009b). There are no "high quality", or Tier II, stream segments (Benthic Index of Biotic Integrity (BIBI) and Fish Index of Biotic Integrity (FIBI) aquatic life assessment scores > 4 (scale 1 – 5)) located within the watershed requiring the implementation of Maryland's antidegradation policy (COMAR 2009g; MDE 2009c). Also, approximately 0.3% of the watershed is covered by water (i.e., streams, ponds, etc.). The total population in the Seneca Creek watershed is approximately 216,518 (US Census Bureau 2000).

Geology/Soils

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

The Seneca Creek watershed lies in the Chrome, Baile, Penn, and Waynesboro soil series. The Chrome series consists of moderately deep, well drained soils. The Baile series consists of very deep, poorly drained, moderately low to moderately high saturated hydraulic conductivity soils, generally found on upland depressions and footslopes. The Penn series consists of moderately deep, well drained soils, which were formed in residuum weathered from noncalcareous reddish shale, siltstone, and fine-grained sandstone of the Triassic age. The Waynesboro series consist of very deep, well drained, moderately permeable soils that formed in old alluvium or unconsolidated material of sandstone, shale, and limestone origin (USDA 1977).

Soil type for the Seneca Creek watershed is also categorized by the United States Department of Agriculture (USDA) Soil Conservation Service (SCS) into four hydrologic soil groups: Group A soils have high infiltration rates and are typically deep well-drained to excessively drained sands or gravels; Group B soils have moderate infiltration rates and consist of moderately deep to deep and moderately well to well drained soils, with moderately fine to moderately coarse textures; Group C soils have slow infiltration rates and a layer that impedes downward water movement and consist of moderately fine to fine textured soils; Group D soils have very slow infiltration rates and consist of clay soils with a permanently high water table that are shallow and often over nearly impervious material (USDA 1983b). The actual Seneca Creek watershed is comprised of primarily B type hydrologic soils with smaller amounts of and C and D type hydrologic soils (USDA 2006).

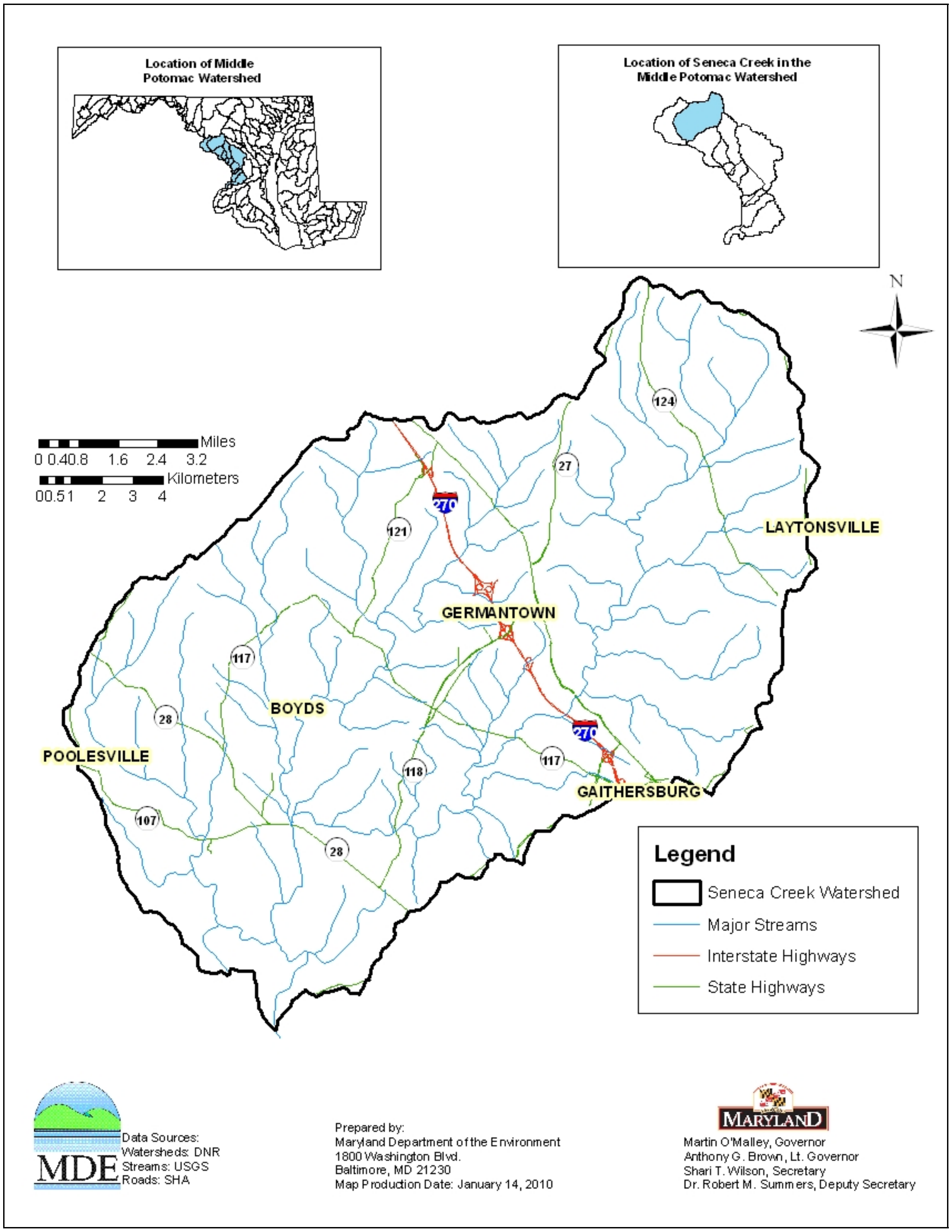

Figure 1: Location Map of the Seneca Creek Watershed in Montgomery County, Maryland

2.1.1. Land Use

Land Use Methodology

The land use framework used to develop this TMDL was originally developed for the Chesapeake Bay Program Phase 5.2 (CBP P5.2) watershed model.[1] The CBP P5.2 land use Geographic Information System (GIS) framework was based on two distinct layers of development. The first GIS layer was developed by the Regional Earth Science Applications Center (RESAC) at the University of Maryland and was based on 2001 satellite imagery (Landsat 7-Enhanced Thematic Mapper (ETM) and 5-Thematic Mapper (TM)) (Goetz et al. 2004). This layer did not provide the required level of accuracy that is especially important when developing agricultural land uses. In order to develop accurate agricultural land use calculations, the CBP P5.2 used county level U.S. Agricultural Census data as a second layer (USDA 1982, 1987, 1992, 1997, 2002).

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

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

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

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

Seneca Creek Watershed Land Use Distribution

The Seneca Creek watershed consists primarily of urban land use (38.5%) and forest land use (37.3%). There is also a considerable amount of crop (20.7%) and a small amount of pasture (3.5%). A detailed summary of the watershed land use areas is presented in Table 1, and a land use map is provided in Figure 2.

Table 1: Land Use Percentage Distribution for the Seneca Creek Watershed

General Land Use	Detailed Land Use	Area (Acres)	Percent	Grouped Percent of Total
Crop	Animal Feeding Operations	21.6	0.0	20.7
	Hay	4,696.0	5.7	
	High Till	1,883.2	2.3	
	Low Till	10,418.1	12.7	
	Nursery	9.4	0.0	
Extractive	Extractive	9.5	0.0	0.0
Forest	Forest	30,432.9	37.0	37.3
	Harvested Forest	307.4	0.4	
Pasture	Pasture	2,879.5	3.5	3.5
	Trampled Pasture	0.0	0.0	
Urban	Urban: Barren	349.9	0.4	38.5
	Urban: Impervious	6,190.3	7.5	
	Urban: Pervious	25,143.7	30.5	
Total		82,341.4	100.0	100.0

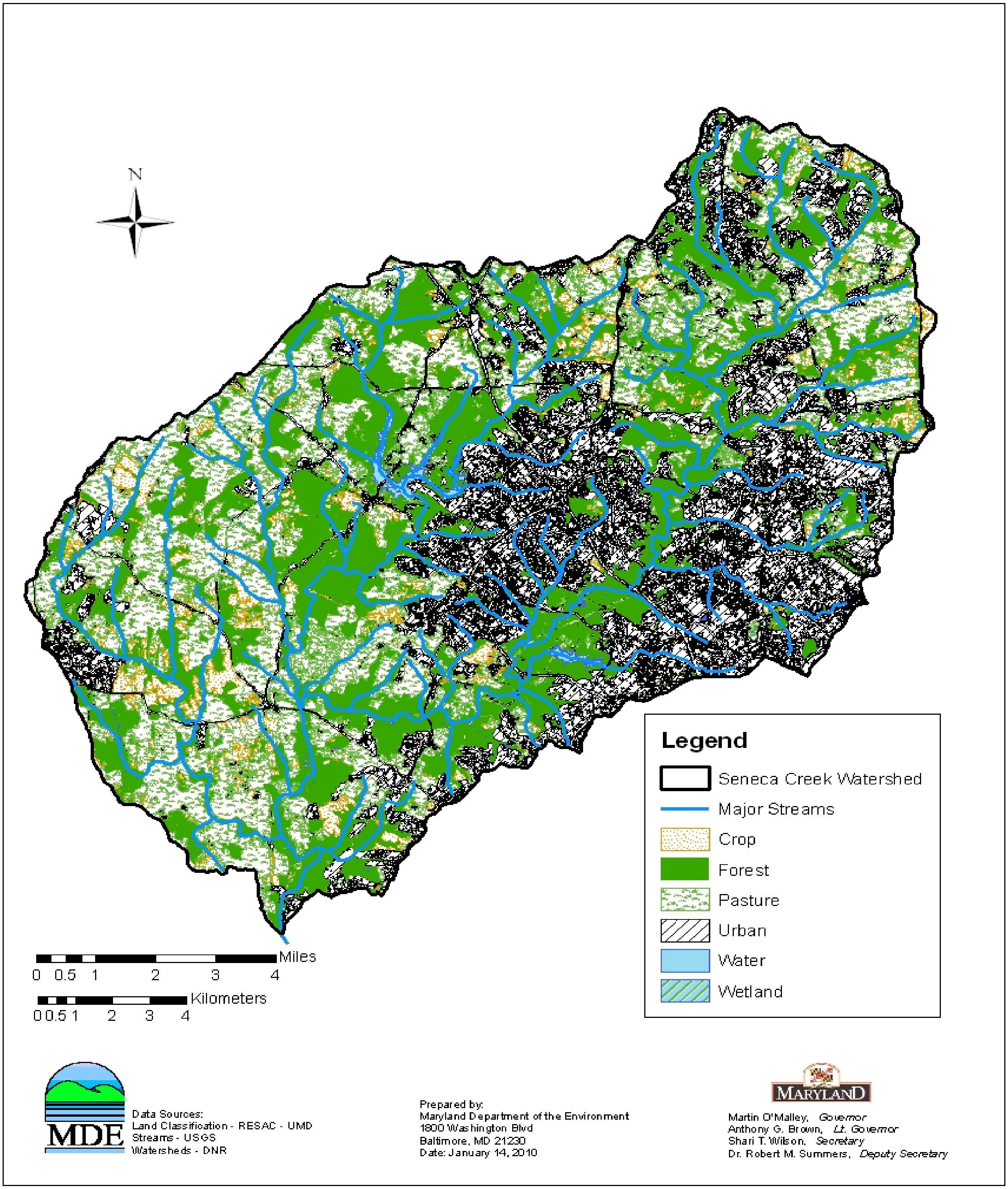

Figure 2: Land Use of the Seneca Creek Watershed

2.2 Source Assessment

The Seneca Creek Watershed Total Baseline Sediment Load can be subdivided into nonpoint and point source loads. This section summarizes the methods used to derive each of these distinct source categories.

2.2.1 Nonpoint Source Assessment

In this document, the nonpoint source loads account for sediment loads from unregulated stormwater runoff within the Seneca Creek watershed. This section provides the background and methods for determining the nonpoint source baseline loads generated within the Seneca Creek watershed (Nonpoint Source BL_{SC}).

General load estimation methodology

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

Edge-of-Field Target Erosion Rate Methodology

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

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

The average value of the 1982 and 1987 surveys was used as the basis for EOF target rates for pasture and cropland. The erosion rates from this period do not reflect best management practices (BMPs) or other soil conservation policies introduced in the wake of the effort to restore the Chesapeake Bay. To compensate for this, a BMP factor was included in the loading estimates using best available “draft” information from the CBP P5.2. For further details regarding EOF Erosion rates, please see Section 9.2.1 of the community watershed model documentation (US EPA 2009).

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

Table 2: Summary of EOF Erosion Rate Calculations

Land Use	**Data Source**	**Montgomery County (tons/acre/year)**
Forest	Phase 2 NRI	0.36
Harvested Forest[1]	Average Phase 2 NRI (x 10)	3
Nursery	Pasture NRI (x 9.5)	11.69
Pasture	Pasture NRI (1982-1987)	1.23
Trampled pasture[2]	Pasture NRI (x 9.5)	11.69
Animal Feeding Operations[2]	Pasture NRI (x 9.5)	11.69
Hay[2]	Crop NRI (1982-1987) (x 0.32)	2.8
High Till[2]	Crop NRI (1982-1987) (x 1.25)	10.96
Low Till[2]	Crop NRI (1982-1987) (x 0.75)	6.57
Pervious Urban	Intercept Regression Analysis	0.74
Extractive	Best professional judgment	10
Barren	Literature survey	12.5
Impervious	100% Impervious Regression Analysis	5.18

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

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

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

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

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

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

(2) *sediment delivery ratio*s for each land use were calculated (drainage area in Equation 2.1 was assumed to be equal to the area of a circle with radius equal to the mean distance between the land use and the river reach).

Edge-of-Stream Loads

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

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

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

Streambank Erosion

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

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

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

Using CBP P5.2 urban sediment EOF target values, MDE developed a formula for estimating the percent of the urban sediment load resultant from streambank erosion (i.e., that portion of the total urban sediment load attributed to stream bank erosion) based on the amount of impervious land within the total urban land use of a watershed. The assumption is that as impervious surfaces increase, the upland urban sources decrease, flow increases, and the change in sediment load results from increased streambank erosion. This formula recognizes that stream bank erosion can be a significant portion of both the urban sediment load and the total watershed sediment load. The formula is as follows:

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

where:
% E = Percent of urban sediment load resultant from streambank erosion

I = Percent impervious of urban land use acreage
L_I = Impervious urban land use EOF load
L_P = Pervious urban land use EOF load

The relationship demonstrated in equation 2.3 is expressed graphically in Figure 3.

While this formula only represents an empirical approximation, it is consistent with results from the Anacostia River Sediment TMDL. Using the equation, the Anacostia River watershed (31% of urban land use covered by impervious surfaces) would equate to approximately a 74% urban sediment load resultant from streambank erosion. This translates to approximately 64% of the total Anacostia River watershed sediment load resulting from streambank erosion, since total urban land use accounts for approximately 86% of the total watershed sediment load. This is slightly less, but still consistent with, the other methods used to estimate the percentage of the total watershed sediment load resultant from stream bank erosion within the Anacostia River Sediment TMDL.

Per Table 1, approximately 20% of the Seneca Creek watershed urban land use is covered by impervious surfaces. This would equate to approximately a 63% urban sediment load resultant from streambank erosion, or 22% of the total watershed sediment load.

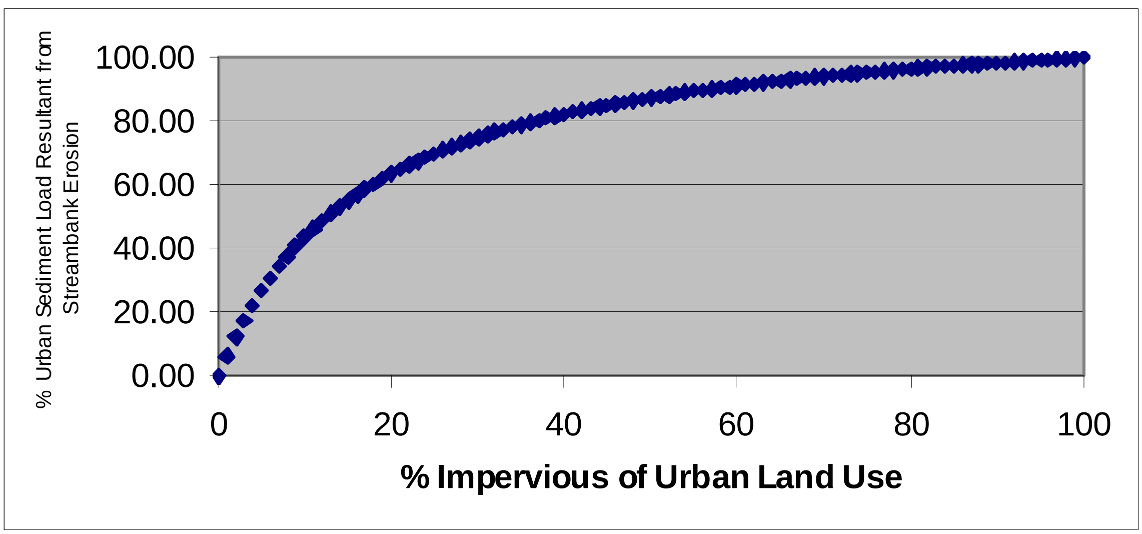

Figure 3: Percent Impervious of Urban Land Use vs. Percent of the Urban Sediment Load Resultant from Streambank Erosion (Based on Equation 2.3)

For this TMDL, the urban sediment load resultant from streambank erosion represents an aggregate load within the total urban impervious EOF loads as described in the report *Chesapeake Bay Phase V Community Watershed Model* (US EPA 2009) and is not explicitly reported.

2.2.2 Point Source Assessment

A list of 24 active permitted point sources that contribute to the sediment load in the Seneca Creek watershed was compiled using MDE's Environmental Permit Service

Center (EPSC) database. The types of permits identified include individual industrial, individual municipal, individual municipal separate storm sewer systems (MS4s), general industrial stormwater, and general MS4s. The permits can be grouped into two categories, process water and stormwater. The process water category includes those loads generated by continuous discharge sources whose permits have TSS limits. Other permits that do not meet these conditions are considered *de minimis* in terms of the total sediment load. The stormwater category includes all National Pollutant Discharge Elimination System (NPDES) regulated stormwater discharges.

The sediment loads for the four process water permits (Process Water BL_{SC}) are calculated based on their TSS limits (average monthly or weekly concentration values) and corresponding flow information. The 20 NPDES Phase I or Phase II stormwater permits identified throughout the Seneca Creek watershed are regulated based on BMPs and do not include TSS limits. In the absence of TSS limits, the NPDES regulated stormwater baseline load (NPDES Stormwater BL_{SC}) is calculated using Equation 2.2 and watershed specific urban land use factors. A detailed list of the permits appears in Appendix B.

2.2.3 Summary of Baseline Loads

Table 3 summarizes the Seneca Creek Baseline Sediment Load, reported in tons per year (ton/yr) and presented in terms of nonpoint and point source loadings. The baseline sediment loading within the Clopper Lake drainage basin (located in the southeast portion of the Seneca Creek watershed), for which a sediment TMDL was developed by MDE and approved by the EPA in 2002 (MDE 2002), is implicitly included within the Seneca Creek NPDES Stormwater BL_{SC} and Nonpoint Source BL_{SC}, due to the spatial resolution of the CBP P5.2 watershed model segmentation. Since the Clopper Lake drainage basin is far smaller than the smallest Seneca Creek watershed CBP P5.2 model segment, the finest scale at which sediment loading estimates are available, the loading cannot be extracted.

Table 3: Seneca Creek Baseline Sediment Loads (ton/yr)

Total Baseline Load (ton/yr)	=	**Nonpoint Source BL_{SC}**	+	**NPDES Stormwater BL_{SC}**	+	**Process Water BL_{SC}**
27,874.3	=	17,332.6	+	9,527.1	+	1,014.6

Table 4 presents a breakdown of the Seneca Creek Total Baseline Sediment Load, detailing loads per land use. The largest portion of the sediment load is from crop land (52.3%), followed closely by urban land (34.2%). The remainder of the sediment load is from forest (6.9%) and pasture (2.9%), with small amounts from other land uses.

Table 4: Detailed Baseline Sediment Budget Loads Within the Seneca Creek Watershed

General Land Use	Detailed Land Use	Load (Ton/Yr)	Percent	Grouped Percent of Total
Crop	Animal Feeding Operations	36.7	0.1	52.3
	Hay	1878.0	6.7	
	High Till	2864.2	10.3	
	Low Till	9788.7	35.1	
	Nursery	15.9	0.1	
Extractive	Extractive	16.9	0.1	0.1
Forest	Forest	1765.3	6.3	6.9
	Harvested Forest	149.3	0.5	
Pasture	Pasture	817.5	2.9	2.9
	Trampled Pasture	0.0	0.0	
Urban[1]	Urban: Barren	718.4	2.6	34.2
	Urban: Impervious	5596.8	20.1	
	Urban: Pervious	3211.8	11.5	
	Process Water	1014.6	3.640	3.6
	Total	**27,874.3**	**100.0**	**100.0**

Note: [1]The urban land use load represents the permitted stormwater load.

2.3 Water Quality Characterization

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

Currently in Maryland, there are no specific numeric criteria for suspended sediments. Therefore, to determine whether aquatic life is impacted by elevated sediment loads, MDE's BSID methodology was applied. The primary goal of the BSID analysis is to identify the most probable cause(s) for observed biological impairments throughout MD's 8-digit watersheds (MDE 2009a).

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

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

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

<u>Seneca Creek Watershed Monitoring Stations</u>

A total of 32 water quality monitoring stations were used to characterize the Seneca Creek Watershed in Maryland's 2010 Integrated Report. All 32 stations were biological/physical habitat monitoring stations from the MBSS program round one and two data collection. The BSID analysis used the 14 biological/physical habitat monitoring stations from the MBSS program round two data collection collected in 2001. All stations are presented in Figure 4 and listed in Table 5.

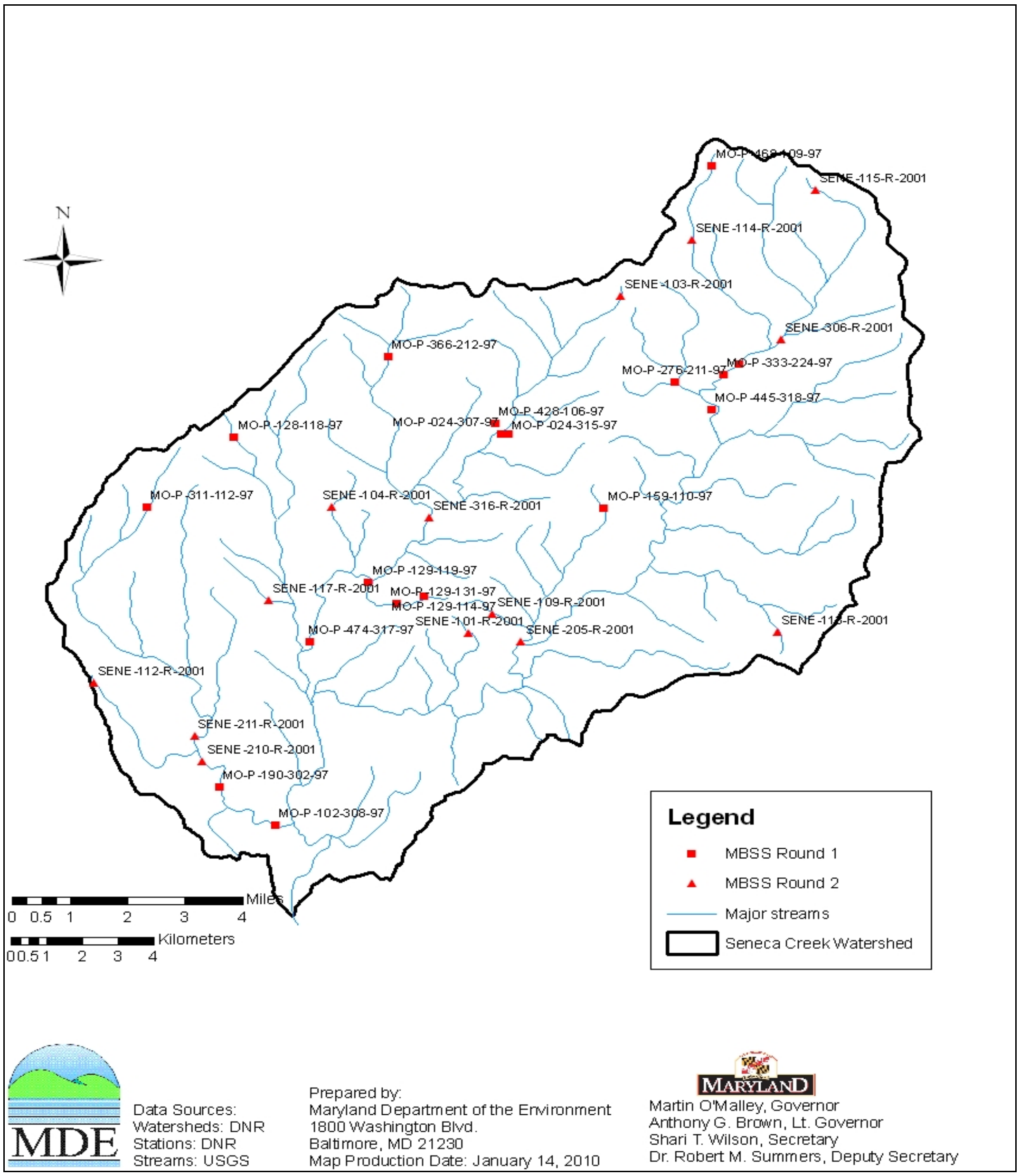

Figure 4: Monitoring Stations in the Seneca Creek Watershed

Table 5: Monitoring Stations in the Seneca Creek Watershed

Site Number	Sponsor	Site Type	Site Name	Latitude (dec degrees)	Longitude (dec degrees)
SENE-101-R-2001	MD DNR	MBSS, Round 2	GREAT SENECA CREEK UNNAMED TRIBUTARY 3	39.149	-77.285
SENE-103-R-2001	MD DNR	MBSS, Round 2	LITTLE SENECA CREEK	39.244	-77.236
SENE-104-R-2001	MD DNR	MBSS, Round 2	LITTLE SENECA CREEK UNNAMED TRIBUTARY 3	39.184	-77.329
SENE-109-R-2001	MD DNR	MBSS, Round 2	GUNNERS BRANCH UNNAMED TRIBUTARY 1	39.154	-77.277
SENE-112-R-2001	MD DNR	MBSS, Round 2	RUSSEL BRANCH	39.134	-77.406
SENE-113-R-2001	MD DNR	MBSS, Round 2	WHETSTONE RUN	39.149	-77.184
SENE-114-R-2001	MD DNR	MBSS, Round 2	MAGRUDER BRANCH	39.260	-77.212
SENE-115-R-2001	MD DNR	MBSS, Round 2	GREAT SENECA CREEK	39.274	-77.172
SENE-117-R-2001	MD DNR	MBSS, Round 2	BUCKLODGE BR UNNAMED TRIBUTARY 1	39.158	-77.349
SENE-205-R-2001	MD DNR	MBSS, Round 2	GREAT SENECA CREEK	39.146	-77.268
SENE-210-R-2001	MD DNR	MBSS, Round 2	DRY SENECA CREEK	39.112	-77.371
SENE-211-R-2001	MD DNR	MBSS, Round 2	DRY SENECA CREEK	39.119	-77.373
SENE-306-R-2001	MD DNR	MBSS, Round 2	GREAT SENECA CREEK	39.232	-77.184
SENE-316-R-2001	MD DNR	MBSS, Round 2	LITTLE SENECA CREEK	39.181	-77.298
MO-P-024-307-97	MD DNR	MBSS, Round 1	LITTLE SENECA CREEK	39.205	-77.274
MO-P-024-315-97	MD DNR	MBSS, Round 1	LITTLE SENECA CREEK	39.205	-77.272
MO-P-102-308-97	MD DNR	MBSS, Round 1	DRY SENECA CREEK	39.094	-77.347
MO-P-128-118-97	MD DNR	MBSS, Round 1	BUCKLODGE BRANCH	39.204	-77.361
MO-P-129-114-97	MD DNR	MBSS, Round 1	SENECA CR UNNAMED TRIBUTARY 2	39.159	-77.299
MO-P-129-119-97	MD DNR	MBSS, Round 1	SENECA CREEK UNNAMED TRIBUTARY 2	39.163	-77.317
MO-P-129-131-97	MD DNR	MBSS, Round 1	SENECA CREEK UNNAMED TRIBUTARY 2	39.157	-77.308
MO-P-159-110-97	MD DNR	MBSS, Round 1	GUNNERS BRANCH	39.184	-77.241
MO-P-190-302-97	MD DNR	MBSS, Round 1	DRY SENECA CREEK	39.105	-77.365
MO-P-276-211-97	MD DNR	MBSS, Round 1	WILD CAT BRANCH	39.22	-77.218
MO-P-311-112-97	MD DNR	MBSS, Round 1	DRY SENECA CREEK	39.184	-77.389
MO-P-333-207-97	MD DNR	MBSS, Round 1	GREAT SENECA CREEK	39.225	-77.197
MO-P-333-224-97	MD DNR	MBSS, Round 1	GREAT SENECA CREEK	39.222	-77.202
MO-P-366-212-97	MD DNR	MBSS, Round 1	TEN MILE CREEK	39.227	-77.311
MO-P-428-106-97	MD DNR	MBSS, Round 1	LITTLE SENECA CR UNNAMED TRIBUTARY 1	39.208	-77.276
MO-P-445-318-97	MD DNR	MBSS, Round 1	GREAT SENECA CREEK	39.212	-77.206
MO-P-468-109-97	MD DNR	MBSS, Round 1	MAGRUDER BRANCH	39.281	-77.206
MO-P-474-317-97	MD DNR	MBSS, Round 1	SENECA CREEK	39.146	-77.336

2.4 Water Quality Impairment

The Maryland water quality standards surface water use designation for the Seneca Creek mainstem and its tributaries is Use I-P (Water Contact Recreation, Protection of Aquatic Life, and Public Water Supply), except for 1) Little Seneca Creek and its tributaries, from the outlet of Little Seneca Lake to the stream's confluence with Bucklodge Branch, and Wildcat Branch and its tributaries, which are designated as Use III-P (Nontidal Coldwater and Public Water Supply), and 2) Little Seneca Creek and its tributaries upstream of Little Seneca Lake, which are designated as Use IV-P (Recreational Trout Waters and Public Water Supply) (COMAR 2009a,b,c,d,e,f). The water quality impairment of the Seneca Creek watershed addressed by this TMDL is caused by an elevated sediment load beyond a level that the watershed can sustain, thereby causing sediment related impacts that can not support aquatic life. Assessment of aquatic life is based on benthic and fish Index of Biotic Integrity (IBI) scores, as demonstrated via the BSID analysis for the watershed.

The Seneca Creek watershed is listed on Maryland's 2010 Integrated Report as impaired for impacts to biological communities. The biological assessment is based on the combined results of MBSS round one (1995-1997) and round two (2000-2004) data, which includes 32 stations. Nineteen of the 32 stations, or 59% of the stream miles in the watershed, are assessed as having BIBI and/or FIBI scores significantly lower than 3.0 (on a scale of 1 to 5) (MDE 2010b). As mentioned in Section 2.3, however, only MBSS round two data were used in the BSID analysis. See Figure 4 and Table 5 for station locations and information.

The results of the BSID analysis for the Seneca Creek watershed are presented in a report entitled *Watershed Report for Biological Impairment of the Seneca Creek Watershed in Montgomery County, Maryland Biological Stressor Identification Analysis Results and Interpretation*. The report states that the degradation of biological communities in the Seneca Creek watershed is strongly associated with urban land use and its concomitant effects (MDE 2009b).

The BSID analysis has determined that the biological impairment in the Seneca Creek watershed is due in part to flow/sediment related stressors. Specifically, the analysis confirmed that individual stressors within the sediment and habitat parameter groupings were contributing to the biological impairment in the watershed. Overall, sediment and flow stressors within the sediment and habitat parameter groupings were identified as having a statistically significant association with impaired biological communities at approximately 16% and 51%, respectively, of the sites with BIBI and/or FIBI scores significantly less than 3.0 throughout the watershed (MDE 2009b). Therefore, since sediment is identified as a stressor to the biological communities in the Seneca Creek watershed, the results confirm the 1996 sediment listing, and a TMDL is required.

3.0 TARGETED WATER QUALITY GOAL

The objective of the sediment TMDL established herein is to reduce sediment loads, and subsequent effects on aquatic life, in the Seneca Creek watershed to levels that support the Use I-P/III-P/IV-P designations (Water Contact Recreation, Protection of Aquatic Life, and Public Water Supply/Nontidal Coldwater and Public Water Supply/Recreational Trout Waters and Public Water Supply) (COMAR 2009a,b,c,d,e,f). Assessment of aquatic life is based on Maryland's biocriteria protocol, which evaluates both the amount and diversity of the benthic and fish community through the use of the IBI (Roth et al. 1998, 2000; Stribling et al. 1998; MDE 2010b).

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

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

4.0 TOTAL MAXIMUM DAILY LOADS AND SOURCE ALLOCATION

4.1 Overview

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

4.2 Analysis Framework

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

Watershed Model

The watershed model framework chosen for the Seneca Creek watershed TMDL was the CBP P5.2 long-term average annual watershed model EOS loading rates. The spatial domain of the CBP P5.2 watershed model segmentation aggregates to the MD 8-digit watersheds, which is consistent with the impairment listing. The EOS loading rates were used because actual time variable CBP P5.2 calibration and scenario runs were not available upon development of the nontidal sediment TMDL methodology (Currey et al. 2006). These target-loading rates have been used to calibrate the land use EOS loads within the CBP P5.2 model and thus should be consistent with future CBP modeling efforts.

The nonpoint source and NPDES stormwater baseline sediment loads generated within the Seneca Creek watershed are calculated as the sum of corresponding land use EOS loads within the watershed and represent a long-term average loading rate. Individual land use EOS loads are calculated as a product of the land use area, land use target loading rate, and loss from the EOF to the main channel. The loss from the EOF to the main channel is the *sediment delivery ratio* and is defined as the ratio of the sediment load reaching a basin outlet to the total erosion within the basin. A *sediment delivery ratio* is estimated for each land use type based on the proximity of the land use to the main channel. Thus, as the distance to the main channel increases, more sediment is stored within the watershed (i.e., *sediment delivery ratio* decreases). Details of the data sources for the unit loading rates can be found in Section 2.2 of this report.

The Seneca Creek watershed was evaluated using two TMDL segments, consisting of one CBP P5.2 model segment each (see Figure 5). TMDL Segment 1 (approximately 80% of the watershed area) represents the sediment loads transported by Little Seneca

Creek and Great Seneca Creek in the northwestern portion of the watershed. TMDL Segment 2 (approximately 20% of the watershed area) represents the sediment loads transported by Dry Seneca Creek and the Seneca Creek mainstem, including its discharge into the Potomac River, in the southwestern portion of the watershed.

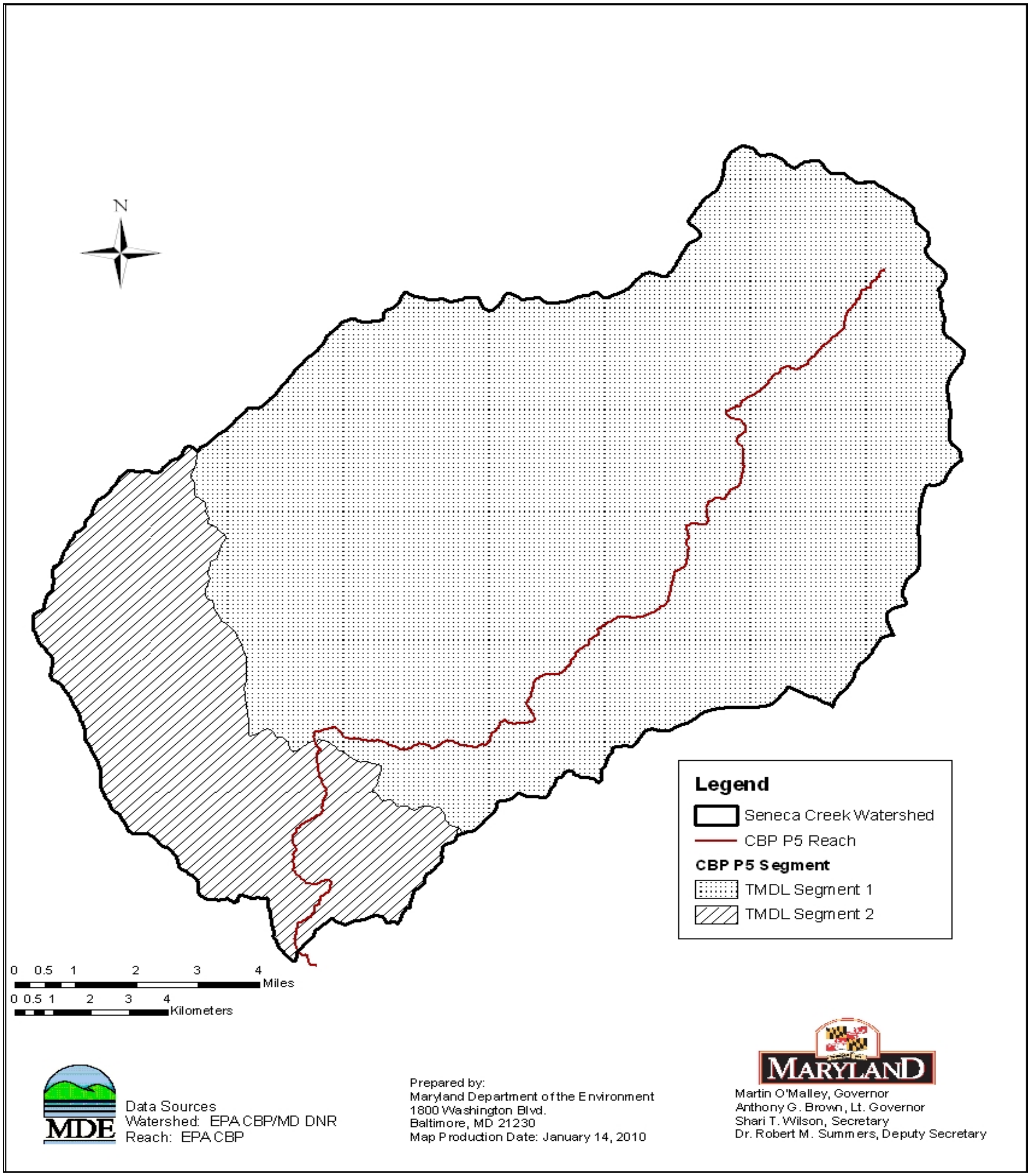

Figure 5: Seneca Creek Watershed TMDL Segmentation

Reference Watershed Approach

Currently in Maryland, there are no specific numeric criteria that quantify the impact of sediment on the aquatic life of non-tidal stream systems. Therefore, in order to quantify the impact of sediment on the aquatic life of non-tidal stream systems, a reference watershed TMDL approach was used and resulted in the establishment of a *sediment loading threshold* for watersheds within the Highland and Piedmont physiographic regions (Currey et al. 2006). Reference watersheds were determined based on Maryland's biocriteria methodology. The biocriteria methodology assesses biological impairment at the 8-digit watershed scale based on the percentage of MBSS monitoring stations, translated into watershed stream miles, that have BIBI and/or FIBI scores lower than the Minimum Allowable IBI Limit (MAL). The MAL is calculated based on the average annual allowable IBI value of 3.0 (on a scale of 1 to 5). It accounts for annual variability and helps to avoid classification errors (i.e., false positives) when assessing for biological impairments (Roth et al. 1998, 2000; Stribling et al. 1998; MDE 2010b).

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

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

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

where:

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

Nine reference watersheds were selected from the Highland/Piedmont region. Reference watershed *forest normalized sediment loads* were calculated using CBP P5.2 2000 land use in order to maintain consistency with MBSS sampling years. The median and 75th percentile of the reference watershed *forest normalized sediment loads* were calculated and found to be 3.3 and 4.2 respectively. These values are in close agreement with more complex methods used to determine the *sediment loading threshold* in previous nontidal sediment TMDLs. Therefore, the median value of 3.3 was established as the *sediment loading threshold* as an environmentally conservative approach to develop this TMDL (see Appendix A for more details).

The *forest normalized sediment loads* for the Seneca Creek watershed (estimated as 5.2 and 6.5 for TMDL Segments 1 and 2 respectively) were calculated using CBP P5.2 2005 landuse, to best represent current conditions. A comparison of the Seneca Creek watershed *forest normalized sediment loads* to the *forest normalized reference sediment load* (also referred to as the *sediment loading threshold*) demonstrates that both TMDL Segments exceed the *sediment loading threshold*, indicating that they are receiving loads above the maximum allowable load that they can sustain and still meet water quality standards.

4.3 Scenario Descriptions and Results

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

Baseline Conditions

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

The Seneca Creek watershed baseline sediment loads are estimated using the CBP P5.2 target EOS land use sediment loading rates with 2005 land use. Watershed loading calculations, based on the CBP P5.2 segmentation scheme, are often represented by multiple CBP P5.2 model segments within each TMDL segment. The sediment loads from these segments are combined to represent the baseline condition. The Seneca Creek watershed, however, consists of one CBP P5.2 model segment per TMDL Segment (see Figure 5). The point source sediment loads are estimated based on the existing permit information. Details of these loading source estimates can be found in Section 2.2 and Appendix B of this report.

TMDL Conditions

This scenario represents the future conditions of maximum allowable sediment loads that will be at a level to support aquatic life. In the TMDL calculation, the allowable load for the impaired watershed is calculated as the product of the *sediment loading threshold* (determined from watersheds with a healthy biological community) and the Seneca Creek TMDL Segment 1 and TMDL Segment 2 *all forested sediment loads* (see Section 4.2). The resulting load is considered the maximum allowable sediment load the watershed can sustain and support aquatic life.

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

The formula for estimating the TMDL is as follows:

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

where
TMDL = allowable load for impaired watershed (ton/yr)
Yn_{ref} = sediment loading threshold = forest normalized reference sediment load (3.3)
$y_{forest\,i}$ = all forested sediment load for CBP P5.2 model segment *i* (ton /yr)
i = CBP P5.2 model segment
n = number of CBP P5.2 model segments in watershed

The Seneca Creek watershed allowable sediment load is estimated using equation 4.2.

4.4 Critical Condition and Seasonality

EPA's regulations require TMDLs to take into account seasonality and critical conditions for stream flow, loading, and water quality parameters (CFR 2009b). The intent of this requirement is to ensure that the water quality of the waterbody is protected during times when it is most vulnerable. The biological monitoring data used to determine the reference watersheds reflect the impacts of stressors (i.e., sediment impacts to stream biota) over the course of time and time and therefore depict an average stream condition (i.e., captures all high and low flow events). Since the TMDL endpoint is based on the median of forest normalized loads from watersheds assessed as having good biological conditions (i.e., passing Maryland's biocriteria), by the nature of the biological data described above, it must inherently include the critical conditions of the reference watersheds. Therefore, since the TMDL reduces the watershed sediment load to a level compatible with that of the reference watersheds, critical conditions are inherently addressed.

Seasonality is captured in two components. First, it is implicitly included through the use of the biological monitoring data as biological communities reflect the impacts of stressors over time, as described above. Second, the MBSS dataset included benthic sampling in the spring (March 1 - April 30) and fish sampling in the summer (June 1 -

September 30). Benthic sampling in the spring allows for the most accurate assessment of the benthic population, and therefore provides an excellent means of assessing the anthropogenic effects of sediment impacts on the benthic community. Fish sampling is conducted in the summer when low flow conditions significantly limit the physical habitat of the fish community, and it is therefore most reflective of the effects of anthropogenic stressors as well.

4.5 TMDL Loading Caps

This section presents the Seneca Creek watershed average annual sediment TMDL. This load is considered the maximum allowable long-term average annual sediment load the watershed can sustain and support aquatic life.

The long-term average annual TMDL was calculated for TMDL Segment 1 and TMDL Segment 2 (see Figure 5) independently, based on Equation 4.2 and set at a load 3.3 times the all forested condition. In order to attain the TMDL loading cap calculated for the watershed, constant reductions were applied to the predominant controllable sources (i.e., significant contributors of sediment to the stream system), independent of jurisdiction. If only these predominant (generally the largest) sources are controlled, water quality standards can be achieved in the most effective, efficient, and equitable manner. Predominant sources typically include urban land, high till crops, low till crops, hay, and pasture, but additional sources could be controlled as well in order to ensure that the TMDL is attained. Urban land, high till crops, low till crops, hay, and pasture were identified as the predominant controllable sources in the watershed. Thus, constant reductions were applied to these sources. Additionally, all urban land in the Seneca Creek watershed is considered to represent regulated stormwater sources (i.e., all urban stormwater is regulated via a permit).

Relative to the estimated sediment load reductions applied to urban land, which are necessary to achieve the TMDL, the current Montgomery County Phase I MS4 permit requires the jurisdiction to retrofit 20% of its existing impervious area where there is failing, minimal, or no stormwater management (estimated to be areas developed prior to 2002) within a permit cycle (five years) (i.e., the jurisdiction needs to install/institute stormwater management practices to treat runoff from these existing impervious areas) (MDE 2010a). Theoretically, extending these permitting requirements to all urban stormwater sources (i.e., not solely those sources regulated via the Montgomery County Phase I MS4 permit) would require that all impervious areas developed prior to 2002 be retrofit at this pace. Additionally, MDE estimates that future stormwater retrofits will have, on average, a 65% TSS reduction efficiency (Claytor and Schueler 1997; Baldwin et al. 2007; Baish and Caliri 2009). By default, these retrofits will also provide treatment of any adjacent urban pervious runoff within the applicable drainage area.

The Seneca Creek Baseline Load and TMDL are presented in Table 6.

Table 6: Seneca Creek Baseline Load and TMDL

	Baseline Load (ton/yr)	TMDL (ton/yr)	Reduction (%)
TMDL Segment 1	21,302.9	12,984.4	39.0%
TMDL Segment 2	6,571.4	3,295.6	49.8%
Total	**27,874.3**	**16,280.0**	**41.6**

4.6 Load Allocations Between Point and Nonpoint Sources

Per EPA regulation, all TMDLs need to be presented as a sum of waste load allocations (WLAs) for point sources and load allocations (LAs) for nonpoint source loads generated within the assessment unit, accounting for natural background, tributary, and adjacent segment loads (CFR 2009a). Consequently, the Seneca Creek watershed TMDL allocations are presented in terms of WLAs (i.e., point source loads identified within the watershed) and LAs (i.e., the nonpoint source loads within the watershed). The State reserves the right to allocate the TMDL among different sources in any manner that protects aquatic life from sediment related impacts.

As described in section 4.5, reductions were applied equally to the predominant controllable sources, which were identified as urban land, high till crops, low till crops, hay, and pasture. Forest is the only non-controllable source, as it represents the most natural condition in the watershed, and no reductions were applied to permitted process load sources, since such controls would produce no discernable water quality benefit when nonpoint sources and regulated stormwater sources comprise 95.4% of the total watershed sediment load.

Based on the current Montgomery County Phase I MS4 permit requirements described in Section 4.5 and the theoretical extension of these requirements to all urban stormwater sources within the watershed, it is anticipated that the urban sediment load reductions necessary to achieve the TMDL will be achieved by retrofitting impervious areas within the watershed developed prior to 2002 (i.e., approximate areas with failing, minimal, or no stormwater management) (MDE 2010a). Also, it is expected that these future stormwater retrofits will have an estimated 65% TSS reduction efficiency (Claytor and Schueler 1997; Baldwin et al. 2007; Baish and Caliri 2009), and by default, they will provide treatment of any adjacent urban pervious runoff within the applicable drainage area.

Table 7 summarizes the TMDL results derived by applying equal percent reductions, within each TMDL Segment, to the predominant controllable sediment sources. Tables 8 and 9 summarize the TMDL results for TMDL Segments 1 and 2 individually. The TMDL results in an overall reduction of 41.6% for the Seneca Creek watershed. For more detailed information regarding the Seneca Creek Watershed TMDL nonpoint source LA, please see the technical memorandum to this document entitled "*Significant Sediment Nonpoint Sources in the Seneca Creek Watershed*". The reductions from the urban sector required to meet this TMDL would entail that at a 65% TSS reduction efficiency, approximately 96% of the urban area (impervious and pervious) within the watershed that was developed prior to 2002 would need to be retrofit, or an equivalent reduction in sediment loads from other types of stormwater retrofits is necessary (see Section 5.0 for a detailed description of the other types of stormwater retrofits).

Table 7: Seneca Creek TMDL Reductions by Source Category

Baseline Load Source Categories		Baseline Load (ton/yr)	TMDL Components	TMDL (ton/yr)	Reduction (%)
Nonpoint Source		17,332.6	LA	9,977.3	42.4
Point Source	Urban	9,527.1	WLA	5,288.1	44.5
	Process Water	1,014.6		1,014.6	0.0
TOTAL		**27,874.3**		**16,280.0**	**41.6**

Table 8: Seneca Creek TMDL Segment 1 Reductions by Source Category

Baseline Load Source Categories		Baseline Load (ton/yr)	TMDL Components	TMDL (ton/yr)	Reduction (%)
Nonpoint Source		11,211.0	LA	6,923.3	38.2
Point Source	Urban	9,145.7	WLA	5,114.9	44.1
	Process Water	946.2		946.2	0.0
TOTAL		**21,302.9**		**12,984.4**	**39.0**

Table 9: Seneca Creek TMDL Segment 2 Reductions by Source Category

Baseline Load Source Categories		Baseline Load (ton/yr)	TMDL Components	TMDL (ton/yr)	Reduction (%)
Nonpoint Source		6,121.6	LA	3,054.0	50.1
Point Source	Urban	381.4	WLA	173.19	54.6
	Process Water	68.4		68.4	0.0
TOTAL		**6,571.4**		**3,295.6**	**49.8**

The WLA of the Seneca Creek watershed is allocated to two permitted source categories, Process Water WLA and Stormwater WLA. The categories are described below.

<u>Process Water WLA</u>

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

Process Water permits with specific TSS limits include:

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

There are four process water sources with explicit TSS limits in the Seneca Creek watershed, which include one industrial and three municipal discharges. The total estimated TSS load from all of the process water sources is based on current permit limits and is equal to 1,014.6 ton/yr. As mentioned above, no reductions were applied to this source, since such controls would produce no discernable water quality benefit when nonpoint sources and regulated stormwater sources comprise 96.4% of the total watershed sediment load. For a detailed list of the four process water sources including information on their permit limits, please see Appendix B. For information regarding the allocations to individual process water point sources, please see the technical memoranda to this document entitled "*Significant Sediment Point Sources in the Seneca Creek Watershed*".

Stormwater WLA

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

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

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

The Seneca Creek NPDES stormwater WLA is based on reductions applied to the sediment load from the urban land use in the watershed and may include legacy or other sediment sources. Some of these sources may also be subject to controls from other management programs. The Seneca Creek NPDES stormwater WLA requires an overall reduction of 44.5% (see Table 7).

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

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

4.7 Margin of Safety

All TMDLs must include a MOS to account for any lack of knowledge and uncertainty concerning the relationship between loads and water quality (CFR 2009b). The MOS shall also account for any rounding errors generated in the various calculations used in the development of the TMDL. It is proposed that the estimated variability around the reference watershed group used in this analysis already accounts for such uncertainty. Analysis of the reference group *forest normalized sediment loads* indicates that approximately 75% of the reference watersheds have a value of less than 4.2. Also, 50% of the reference watersheds have a value less than 3.3. Based on this analysis the *forest normalized reference sediment load* (also referred to as the *sediment loading threshold*) was set at the median value of 3.3 (Currey et al. 2006). This is considered an environmentally conservative estimate, since 50% of the reference watersheds have a load above this value (3.3), which when compared to the 75% value (4.2), results in an implicit MOS of approximately 18%.

4.8 Summary of Total Maximum Daily Loads

The average annual Seneca Creek watershed TMDL is summarized in Table 10. The TMDL is the sum of the LA, NPDES Stormwater WLA, Process Water WLA, and MOS. Additionally, the Clopper Lake sediment TMDL of 129.0 ton/yr, which was developed by MDE to be protective of water quality standards within the impoundment and approved by the EPA in 2002, still applies as the target sediment loading capacity within the lake's drainage area, located within the southeast portion of TMDL Segment 1 (MDE 2002). The attainment of water quality standards within the MD 8-digit Seneca Creek watershed and Clopper Lake impoundment can only be achieved by meeting the average annual TMDL of sediment/TSS specified for the MD 8-digit watershed within this report as well as the specific TMDL for the Clopper Lake drainage basin established by MDE in 2002. The Maximum Daily Load (MDL) is summarized in Table 11 (See Appendix C for more details).

Table 10: Seneca Creek Watershed Average Annual TMDL of Sediment/TSS (ton/yr)

	TMDL (ton/yr)	=	LA_{SC}	+	NPDES Stormwater WLA_{SC}	+	Process Water WLA_{SC}	+	MOS
TMDL Segment 1	12,984.4		6,923.3		5,114.9		946.2		Implicit
TMDL Segment 2	3,295.6	=	3,054.0	+	173.2	+	68.4	+	Implicit
Total	16,280.0		9,977.3		5,288.1		1,014.6		Implicit

Table 11: Seneca Creek Watershed Maximum Daily Loads of Sediment/TSS (ton/day)

	MDL (ton/day)	=	LA_{SC}	+	NPDES Stormwater WLA_{SC}	+	Process Water WLA_{SC}	+	MOS
TMDL Segment 1	453.4		256.2		189.3		8.0		Implicit
TMDL Segment 2	120.0	=	113.0	+	6.4	+	0.6	+	Implicit
Total	573.4		369.2		195.7		8.6		Implicit

5.0 ASSURANCE OF IMPLEMENTATION

This section provides the basis for reasonable assurances that the sediment TMDL will be achieved and maintained. Section 303(d) of the CWA and current EPA regulations require reasonable assurance that the TMDL load and WLAs can and will be implemented (CFR 2009b). Maryland has several well-established programs to draw upon, including the Water Quality Improvement Act of 1998 (WQIA) and the Federal Nonpoint Source Management Program (§ 319 of the Clean Water Act).

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

Potential BMPs for reducing sediment loads and resulting impacts can be grouped into two general categories. The first is directed toward agricultural lands and the second is directed toward urban (developed) lands.

In agricultural areas, comprehensive soil conservation plans can be developed that meet criteria of the NRCS Field Office Technical Guide (USDA 1983a). Soil conservation plans help control erosion by modifying cultural practices or structural practices. Cultural practices may change from year to year and include changes to crop rotations, tillage practices, or use of cover crops. Structural practices are long-term measures that include, but are not limited to, the installation of grass waterways (in areas with concentrated flow), terraces, diversions, sediment basins, or drop structures. The reduction percentage attributed to cultural practices is determined based on changes in land use, while structural practices have a reduction percentage up to 25%. In addition, livestock can be controlled via stream fencing and rotational grazing. Sediment reduction efficiencies of methods applicable to pasture land use range from 40% to 75% (US EPA 2004). Lastly, riparian buffers can reduce the effect of agricultural sediment sources through trapping and filtering, and reforestation, whether adjacent to part of the watershed stream system or in a watershed’s interior, can decrease agricultural sediment sources as well.

Sediment from urban areas can be reduced by stormwater retrofits that address both water quality and flow control. Examples of these retrofits include the modification of existing stormwater structural practices, the construction of new stormwater BMPs in prior development where there is none, a reduction in impervious surfaces, street sweeping, inlet cleaning, increases in the urban tree canopy, stream restoration, and any other management practice that effectively addresses water quality and flow control (i.e., riparian buffers for urban areas and watershed reforestation adjacent to the watershed stream system or within a watershed’s interior). A significant portion of the sediment loading required from the urban area within the Seneca Creek watershed is attributed to streambank erosion (see section 2.2.1). Therefore, flow controls must be implemented to reduce sheer stress and limit bank erosion in order to address this portion of the urban sediment load. Additionally, impervious surface reduction results in a change in hydrology that could also reduce streambank erosion. In terms of upland urban sediment loads, stormwater retrofit reductions range from as low as 10% for dry detention to approximately 80% for wet ponds, wetlands, infiltration practices, and filtering practices (US EPA 2003). It is anticipated that the implementation of the TMDL will include the array of urban BMPs and practices outlined above. Implementation of the required urban sediment load reductions is expected to occur primarily via the Phase I MS4 permitting process for medium and large municipalities, specifically, in this watershed, the current Montgomery County Phase I MS4 permit, which requires the jurisdiction to retrofit 20% of its existing impervious area within a permit cycle, or five years, and develop an implementation plan to meet its assigned regulated stormwater allocation (please see the technical memorandum to this document entitled "*Significant Sediment Point Sources in the Seneca Creek Watershed*") (MDE 2010a). The Montgomery County Phase I MS4 jurisdiction should work with the other regulated stormwater entities in the watershed (see Appendix B, Table B-4) during the implementation process to achieve the necessary reductions.

It has been estimated that the average TSS removal efficiencies for urban BMPs installed between the years of 1985-2002 and post 2002, which are reflective of the stormwater management regulations in place during these time periods, is 50% and 80%, respectively (Claytor and Schueler 1997; Baldwin et al. 2007; Baish and Caliri 2009). Based on these average TSS reduction efficiencies, BMP specific reduction efficiencies as estimated by CBP, and best professional judgment, MDE estimates that future stormwater retrofits, which are expected to be implemented as part of the 20% retrofit requirement to existing impervious land every five years for the Montgomery County Phase I MS4 jurisdiction (MDE 2010a), will have approximately a 65% reduction efficiency for TSS, which is subject to change over time. Additionally, any new development in the watershed will be subject to Maryland's Stormwater Management Act of 2007 and will be required to use environmental site design (ESD) to the maximum extent practicable.

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

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APPENDIX A – Watershed Characterization Data

Table A-1: Reference Watersheds

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

Notes: [1]Based on the percentage of MBSS stations with BIBI and/or FIBI scores significantly lower than 3.0 within the MD 8-digit watershed (MDE 2010b).
[2]The percent stream miles with BIBI and/or FIBI scores significantly lower than 3.0 threshold to determine if an 8-digit watershed is impaired for impacts to biological communities is based on a comparison to reference conditions (MDE 2010b).
[3]Forest normalized sediment loads based on Maryland watershed area only (consistent with MBSS random monitoring data).

APPENDIX B – MDE Permit Information

Table B-1: Permit Summary

Permit #	NPDES	Facility	City	County	Type	TMDL[1]
05DP2776	MD0064955	CONCRETE GENERAL, INC.	GAITHERSBURG	MONTGOMERY	WMA1	Process Water
01DP0781	MD0023001	POOLESVILLE WWTP[1]	POOLESVILLE	MONTGOMERY	WMA2	Process Water
04DP0156	MD0021491	WSSC - SENECA WWTP	GERMANTOWN	MONTGOMERY	WMA2M	Process Water
03DP0162	MD0020982	WSSC - DAMASCUS WWTP	GAITHERSBURG	MONTGOMERY	WMA2M	Process Water
02SW0391		M-NCPPC - BLACK HILL PARK MAINTENANCE YARD	BOYDS	MONTGOMERY	WMA5SW	Stormwater WLA
02SW0014		DRS - SIGNAL SOLUTIONS, INC.	GAITHERSBURG	MONTGOMERY	WMA5SW	Stormwater WLA
02SW0268		MONTGOMERY COUNTY - POOLESVILLE DEPOT	POOLESVILLE	MONTGOMERY	WMA5SW	Stormwater WLA
02SW0269		MONTGOMERY COUNTY - DAMASCUS DEPOT	DAMASCUS	MONTGOMERY	WMA5SW	Stormwater WLA
02SW0290		MONTGOMERY COLLEGE - GERMANTOWN	GERMANTOWN	MONTGOMERY	WMA5SW	Stormwater WLA
02SW1440		WASTE MANAGEMENT OF MARYLAND - GAITHERSBURG	GAITHERSBURG	MONTGOMERY	WMA5SW	Stormwater WLA
02SW1250		GAITHERSBURG PUBLIC WORKS FACILITY	GAITHERSBURG	MONTGOMERY	WMA5SW	Stormwater WLA
02SW0120		WSSC - SENECA WASTEWATER TREATMENT PLANT	GERMANTOWN	MONTGOMERY	WMA5SW	Stormwater WLA
02SW1221		WSSC - DAMASCUS WASTEWATER TREATMENT PLANT	GAITHERSBURG	MONTGOMERY	WMA5SW	Stormwater WLA

02SW1737		WSSC - GAITHERSBURG GARAGE	GAITHERSBURG	MONTGOMERY	WMA5SW	Stormwater WLA
02SW1322		SHA - GAITHERSBURG SHOP	GAITHERSBURG	MONTGOMERY	WMA5SW	Stormwater WLA
02SW0525		MONTGOMERY COUNTY SCHOOLS - CLARKSBURG	CLARKSBURG	MONTGOMERY	WMA5SW	Stormwater WLA
02SW1790		POOLESVILLE WWTP	POOLESVILLE	MONTGOMERY	WMA5SW	Stormwater WLA
02SW1903		M-NCPPC - SOUTH GERMANTOWN RECREATIONAL PARK	BOYDS	MONTGOMERY	WMA5SW	Stormwater WLA
02SW1904		M-NCPPC - BLACK HILL REGIONAL PARK YARD 2	BOYDS	MONTGOMERY	WMA5SW	Stormwater WLA
02SW2035		SENECA CREEK STATE PARK	GAITHERSBURG	MONTGOMERY	WMA5SW	Stormwater WLA
03-IM-5500-026	MDR05550	CITY OF GAITHERSBURG MS4	GAITHERSBURG	MONTGOMERY	WMA6G	Stormwater WLA
01DP3320	MD0068349	MONTGOMERY COUNTY MS4	COUNTY WIDE	MONTGOMERY	WMA6	Stormwater WLA
99DP3313	MD0068276	STATE HIGHWAY ADMINSTRATION MS4	STATE-WIDE	ALL PHASE I	WMA6	Stormwater WLA
		MDE GENERAL PERMIT TO CONSTRUCT	ALL	ALL		Stormwater WLA

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

Table B-2: Individual Industrial Permit Data

Facility Name	NPDES #	MDE Permit #	Flow (MGD)[1]	Permit Avg. Quarterly Conc. (mg/l)[2]	Permit Daily Max. Conc. (mg/l)
CONCRETE GENERAL, INC.	MD0064955	05DP2776	0.0009	30	45

Notes: [1]MGD = Millions of Gallons per Day.
[2]mg/l = Milligrams per liter.

Table B-3: Individual Municipal Permit Data

Facility Name	NPDES #	MDE Permit #	Flow (MGD)	Permit Avg. Monthly Conc. (mg/l)	Permit Avg. Weekly Conc. (mg/l)
POOLESVILLE WWTP	MD0023001	01DP0781	0.75	30	45
WSSC - SENECA WWTP	MD0021491	04DP0156	20	30	45
WSSC - DAMASCUS WWTP	MD0020982	03DP0162	1.5	30	45

Table B-4: Stormwater Permits[1]

MDE Permit #	Facility	NPDES Group
02SW0391	M-NCPPC - BLACK HILL PARK MAINTENANCE YARD	Phase I
02SW0014	DRS - SIGNAL SOLUTIONS, INC.	Phase I
02SW0268	MONTGOMERY COUNTY - POOLESVILLE DEPOT	Phase I
02SW0269	MONTGOMERY COUNTY - DAMASCUS DEPOT	Phase I
02SW0290	MONTGOMERY COLLEGE - GERMANTOWN	Phase I
02SW1440	WASTE MANAGEMENT OF MARYLAND - GAITHERSBURG	Phase I
02SW1250	GAITHERSBURG PUBLIC WORKS FACILITY	Phase I
02SW0120	WSSC - SENECA WASTEWATER TREATMENT PLANT	Phase I
02SW1221	WSSC - DAMASCUS WASTEWATER TREATMENT PLANT	Phase I
02SW1737	WSSC - GAITHERSBURG GARAGE	Phase I
02SW1322	SHA - GAITHERSBURG SHOP	Phase I
02SW0525	MONTGOMERY COUNTY SCHOOLS - CLARKSBURG	Phase I
02SW1790	POOLESVILLE WWTP	Phase I
02SW1903	M-NCPPC - SOUTH GERMANTOWN RECREATIONAL PARK	Phase I
02SW1904	M-NCPPC - BLACK HILL REGIONAL PARK YARD 2	Phase I
02SW2035	SENECA CREEK STATE PARK	Phase I
03-IM-5500-026	CITY OF GAITHERSBURG MS4	Phase II
01DP3320	MONTGOMERY COUNTY MS4	Phase I
99DP3313	STATE HIGHWAY ADMINSTRATION MS4	Phase I
	MDE GENERAL PERMIT TO CONSTRUCT	Phase I/II

Notes: [1] Although not listed in this table, some individual process water permits incorporate stormwater requirements and are accounted for within the NPDES stormwater WLA (specifically the "Other" Regulated Stormwater Allocation in the Technical Memorandum *Significant Sediment Point Sources in the Seneca Creek Watershed* accompanying this TMDL report) as well additional Phase II permitted MS4s, such as military bases, hospitals, etc.

APPENDIX C – Technical Approach Used to Generate Maximum Daily Loads

Summary

This appendix documents the technical approach used to define MDLs of sediment consistent with the average annual TMDL in the Seneca Creek watershed, which is considered the maximum allowable load the watershed can sustain and support aquatic life. The approach builds upon the modeling analysis that was conducted to determine the sediment loadings and can be summarized as follows.

- The approach defines MDLs for each of the source categories.
- The approach builds upon the TMDL modeling analysis that was conducted to ensure that average annual loading targets are at a level that support aquatic life.
- The approach converts daily time-series loadings into TMDL values in a manner that is consistent with available EPA guidance on generating daily loads for TMDLs (US EPA 2007).
- The approach considers a daily load level of a resolution based on the specific data that exists for each source category.

Introduction

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

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

Basis for approach

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

- **Average Annual TMDL:** The basis of the average annual sediment TMDL is that cumulative high sediment loading rates have negative impacts on the biological community. Thus, the average annual sediment load was calculated so as to ensure the support of aquatic life.
- **CBP P5.2 Watershed Model Sediment Loads:** There are two spatial calibration points for sediment within the CBP P5.2 watershed model framework. First, EOS loads are calibrated to long term EOS target loads. These target loads are the loads used to determine an average annual TMDL, as actual CBP P5.2 calibration and scenario runs were not available upon development of the nontidal sediment TMDL methodology (Currey et al. 2006). Since the EOS target loads applied in the TMDL remained relatively unchanged during the final calibration stages of

the CBP P5.2 model, they are consistent with the final CBP P5.2 sediment loading estimates. The CBP P5.2 model river segments were calibrated to daily monitoring information for watersheds with a flow greater than 100 cubic feet per second (cfs), or an approximate area of 100 square miles.

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

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

Options considered

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

This section describes the range of options that were considered when developing methods to calculate Seneca Creek MDLs.

<u>Level of Resolution</u>

The level of resolution pertains to the amount of detail used in specifying the MDL. The draft EPA guidance document on daily loads provides three categories of options for level of resolution, all of which are potentially applicable for the Seneca Creek watershed:

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

<u>Probability Level</u>

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

1. Water quality criteria consist of components describing acceptable magnitude, duration, and frequency. The frequency component addresses how often

conditions can allowably surpass the combined magnitude and duration components.

2. Pollutant loads, especially from wet weather sources, typically exhibit a large degree of variability over time. It is rarely practical to specify a "never to be exceeded value" for a daily load, as essentially any loading value has some finite probability of being exceeded.

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

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

Selected Approach

The approach selected for defining a Seneca Creek MDL was based upon the specific data that exists for each source category. The approach consists of unique methods for each of the following categories of sources:

- Approach for Nonpoint Sources and Stormwater Point Sources within the Seneca Creek watershed
- Approach for Process Water Point Sources within the Seneca Creek watershed

<u>Approach for Nonpoint Sources and Stormwater Point Sources within the Seneca Creek watershed</u>

The level of resolution selected for the Seneca Creek MDL was a representative daily load, expressed as a single daily load for each loading source. This approach was chosen based upon the specific data that exists for nonpoint sources and stormwater point sources within the Seneca Creek watershed. Currently, the best available data is the CBP P5.2 model daily time series calibrated to long-term average annual loads (per landuse). The CBP reach simulation results are calibrated to daily monitoring information for watershed segments with a flow typically greater than 100 cfs, but these model calibration runs were not available upon development of the average annual nontidal sediment TMDL methodology (Currey et al. 2006). Therefore, to be consistent with the average annual TMDL, it was concluded that it would not be appropriate to apply the absolute values of the reach simulation model, daily time series results to calculate the MDL. Thus, the annual loads were used instead. However, it was assumed that the distribution of the daily values was correct, in order to calculate a normalized statistical parameter to estimate the MDLs.

The MDL was estimated based on three factors: a specified probability level, the average annual sediment TMDL, and the coefficient of variation (CV) of the CBP P5.2 Seneca Creek reach simulation daily loads. The probability level (or exceedance frequency) is based upon guidance from EPA (US EPA 1991) where examples suggest that when converting from a long-term average to a daily value, the z-score corresponding to the 99th percentile of the log-normal probability distribution should be used. The average annual sediment TMDL is estimated from the CBP P5.2 EOS target loads. The calculation of the CV is described below.

The CBP P5.2 Seneca Creek reach simulation consisted of a daily time series beginning in 1985 and extending to the year 2005. The CV was estimated by first converting the daily sediment load values to a log distribution and then verifying that the results approximated the normal distribution (see Figure C-1). Next, the CV was calculated using the arithmetic mean and standard deviation results from the log transformation. The log-transformed values were used to reduce the possible influence of outliers. The resulting CV of 5.9 was calculated using the following equation:

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

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

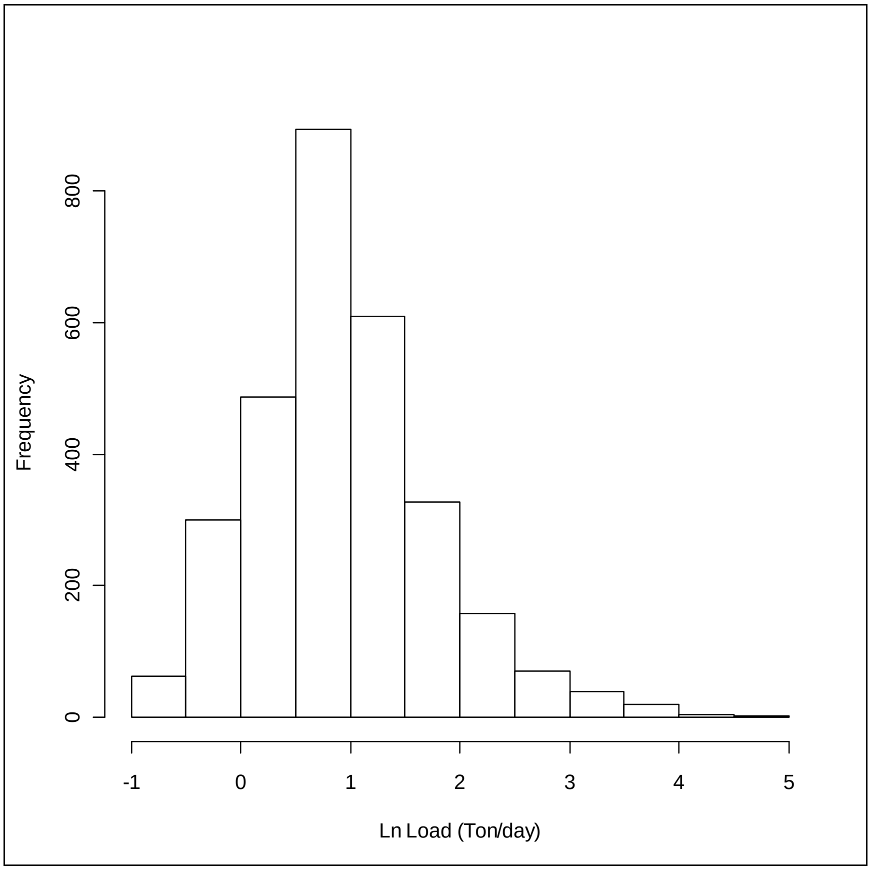

Figure C-1: Histogram of CBP River Segment Daily Simulation Results for the Seneca Creek Watershed

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

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

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

Using a z-score associated with the 99^{th} percent probability, a CV of 5.9, and consistent units, the resulting dimensionless conversion factor from long term average annual loads to a MDL is 13.6. The average annual Seneca Creek TMDL of sediment/TSS is reported in ton/year, and the conversion from ton/year to a MDL in ton/day is 0.037 (e.g. 13.6/365).

<u>Approach for Process Water Point Sources within the Seneca Creek watershed</u>

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

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

Results of approach

This section lists the results of the selected approach to define the Seneca Creek MDLs.

- Calculation Approach for Nonpoint Sources and Stormwater Point Sources within the Seneca Creek watershed

LA_{SC} (Ton/day) = Average Annual TMDL LA_{SC} (ton/yr) * 0.037

Stormwater WLA_{SC} (Ton/day) = Average Annual TMDL Stormwater WLA_{SC} (ton/yr) * 0.037

- Calculation Approach for Process Water Point Sources within the Seneca Creek watershed
    - For permits with a daily maximum limit:

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

-
    - For permits without a daily maximum limit:

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

Table C-1: Seneca Creek Maximum Daily Loads of Sediment/TSS (ton/day)

	MDL (ton/day)		LA_{SC}		NPDES Stormwater WLA_{SC}		Process Water WLA_{SC}		MOS
TMDL Segment 1	453.4		256.2		189.3		8.0		Implicit
TMDL Segment 2	120.0	=	113.0	+	6.4	+	0.6	+	Implicit
Total	573.4		369.2		195.7		8.6		Implicit