Total Maximum Daily Load of Sediment in the Baltimore Harbor Watershed, Baltimore City, Baltimore County, and Anne Arundel County, Maryland

FINAL

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List of Abbreviations

AFB	Air Force Base
AFO	Animal Feeding Operations
ANC	Acid Neutralizing Capacity
BIBI	Benthic Index of Biotic Integrity
BIP	Buffer Incentive Program
BMP	Best Management Practices
BSID	Biological Stressor Identification
CAFOs	Concentrated Animal Feeding Operations
CBLCD	Chesapeake Bay Land-Cover Dataset
CB3MH	Chesapeake Bay Mesohaline
CBP	Chesapeake Bay Program
CBP P4.3	Chesapeake Bay Program Model Phase 4.3
CBP P5.3.2	Chesapeake Bay Program Model Phase 5.3.2
CBT	Chesapeake Bay Trust
CCAP	Coastal Change Analysis Program
CFR	Code of Federal Regulations
cfs	Cubic Feet per Second
CHSTF	Baltimore Harbor Tidal Fresh
COMAR	Code of Maryland Regulations
CV	Coefficient of Variation
CWA	Clean Water Act
DI	Diversity Index
DO	Dissolved oxygen
EOF	Edge-of-Field
EOS	Edge-of-Stream
EPT	*Ephemeroptera*, *Plecoptera*, and *Trichoptera*
ESD	Environmental Site Design
FIBI	Fish Index of Biologic Integrity
GIS	Geographic Information System
HBI	Hilsenhoff Biotic Index
HSPF	Hydrological Simulation Program Fortran
IBI	Index of Biotic Integrity
LA	Load Allocation
m	Meter
m^3/yr	Meters cubed per year
MACS	Maryland Agricultural Water Quality Cost-Share Program
MAL	Minimum Allowable IBI Limit
MBSS	Maryland Biological Stream Survey
MDA	Maryland Department of Agriculture
MDDNR	Maryland Department of Natural Resources
MDE	Maryland Department of the Environment
MDL	Maximum Daily Load

MDP	Maryland Department of Planning
MGD	Millions of Gallons per Day
mg/l	Milligrams per liter
MGS	Maryland Geological Survey
MOS	Margin of Safety
PCLC	Multi-Resolution Land Characteristics
MS4	Municipal Separate Storm Sewer System
NLCD	National Land-Cover Dataset
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPS	Non-point source
NRCS	Natural Resource Conservation Service
NRI	Natural Resources Inventory
PATMH	Patapsco mesohaline
PSU	Primary Sampling Unit
SCS	Soil Conservation Service
SDF	Sediment Delivery Factor
SHA	State Highway Administration
TMDL	Total Maximum Daily Load
ton/acre/yr	Tons per acre per year
ton/day	Tons per day
ton/yr	Tons per year
TSD	Technical Support Document
TSS	Total Suspended Solids
USDA	United States Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USGS	United States Geological Survey
WIP	Watershed Implementation Plan
WLA	Waste Load Allocation
WQA	Water Quality Analysis
WQLS	Water Quality Limited Segment
WRF	Water Reclamation Facility
WWTP	Waste Water Treatment Plant

EXECUTIVE SUMMARY

Section 303(d) of the federal Clean Water Act (CWA) and the U.S. Environmental Protection Agency's (USEPA) 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 2012b). This document, upon approval by USEPA, establishes a Total Maximum Daily Load (TMDL) for sediment/total suspended solids (TSS) in the Maryland 8-Digit Baltimore Harbor watershed (2018 *Integrated Report of Surface Water Quality in Maryland* Assessment Unit ID: MD-02130903). In this TMDL report, the terms total suspended solids (TSS) and sediment may be used interchangeably.

The Baltimore Harbor watershed is associated with three assessment units in Maryland's Integrated Report: a non-tidal 8-digit watershed (02130903) and two estuary portions [Chesapeake Bay Segments Upper Chesapeake Bay Mesohaline (CB3MH) and Patapsco Mesohaline (PATMH)]. Sediment TMDLs for the CB3MH and PATMH were established as part of the Chesapeake Bay TMDLs in 2010. Background information on the tidal portions of the watershed are presented for informational purposes only.

The Maryland Department of the Environment (MDE) identified the waters of the Baltimore Harbor watershed on the State's 2018 Integrated Report as impaired by multiple pollutants in both tidal and non-tidal waters (MDE 2018). A full list of the impairment listings appears in Table 1 of this TMDL document. A data solicitation for sediment was conducted by MDE in November 2018, and all readily available data has been considered.

The Maryland Surface Water Use Designation in the Code of Maryland Regulations (COMAR) for the Baltimore Harbor watershed's non-tidal tributaries are designated as Use Class I - *water contact recreation, and protection of non-tidal warmwater aquatic life.* Tidal tributaries are designated Use Class II - *support of estuarine and marine aquatic life and shellfish harvesting* (COMAR 2020 a, b, c).

The Baltimore Harbor watershed was originally listed for biological impairment of its non-tidal waters on the 2002 Integrated Report. The listing was based on the biological assessment methodology, which uses aquatic health scores, consisting of the Benthic Index of Biotic Integrity (BIBI) and Fish Index of Biotic Integrity (FIBI). These indices indicated that the biological metrics for the watershed exhibit a significant negative deviation from reference conditions (MDE 2014b).

In order to determine what stressor or stressors are impacting non-tidal aquatic life, MDE's *Biological Stressor Identification* (BSID) methodology was applied. The BSID analysis for the Baltimore Harbor watershed identified sediment, instream habitat, riparian habitat, inorganic chemistry and nutrient chemistry parameter groups. The sediment parameter group shows a significant association with moderate to poor and poor epifaunal substrate. The instream habitat parameter group shows a significant association with channelization present, concrete/gabion present, marginal to poor and poor instream habitat structure, marginal to poor riffle/run quality, and poor velocity/depth diversity. The riparian habitat parameter group shows a significant association with no riparian buffer. The inorganic chemistry parameter group shows a significant association with high conductivity, chlorides, and sulfates. The nutrient chemistry parameter group shows a significant association with low dissolved oxygen (DO) (<5 mg/L and <6 mg/L) and low DO saturation. Further details of this analysis are presented in the 2014 document entitled, *Watershed Report for Biological Impairment of the Baltimore Harbor Watershed in Baltimore City, Baltimore and Anne Arundel Counties, Maryland Biological Stressor Identification Analysis Results and Interpretation* (MDE 2014c).

As a result of the BSID analysis, the MD 8-digit Baltimore Harbor watershed was listed on the 2014 Integrated Report as impaired by TSS, thus requiring a TMDL. The objective of this TMDL is to ensure that watershed sediment loads are at a level that supports the Use Class I (*water contact recreation, and protection of non-tidal warmwater aquatic life)* designations for the non-tidal Baltimore Harbor watershed. The TMDL will address impacts to aquatic life in the non-tidal Baltimore Harbor watershed (1st through 4th order streams) caused by elevated sediment loads.

The CWA requires TMDLs to be protective of all the designated uses applicable to a particular waterbody. The primary focus of this TMDL is the designated use of protection of aquatic life because the Integrated Report listing was based on a biological assessment of the watershed. The biological assessment revealed the current levels of TSS and other pollutants prevent the watershed from achieving its designated use of supporting aquatic life. The required reductions within the TMDL are expected to protect all designated uses of the watershed from sediment impacts, including water contact recreation. Aquatic life is more sensitive to sediment impacts than recreation because of continuous exposure that can affect respiration and propagation. Recreation, on the other hand, is sporadic and sediment is unlikely to pose a human health risk due to dermal contact or minimal ingestion that would occur during recreation. Additionally, EPA's *Framework for Developing Suspended and Bedded Sediments (SABS) Water Quality Criteria* states:

> *… where multiple designated uses (such as aquatic life and irrigation) overlap in a waterbody or on a specific segment or portion of the waterbody, SABS criteria established to protect the aquatic life use most likely will be stringent enough to protect all other uses except perhaps drinking water uses.* (USEPA 2006)

Currently in Maryland, there are no specific numeric criteria that quantify the impact of sediment on the aquatic life of stream systems. In order to quantify this impact, a reference watershed TMDL approach was used, which resulted in the establishment of a *sediment loading threshold* (MDE 2006a). 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 biological assessment methodology (Roth et al. 1998, 2000; Stribling et al. 1998; MDE 2014b). This threshold is then used to determine a watershed specific sediment TMDL endpoint. The resulting loads are considered the maximum allowable loads the waterbody can receive without causing any sediment related impacts to aquatic health.

In order to use a reference watershed approach, sediment loads are estimated using a watershed model. For this analysis, the Chesapeake Bay Program Phase 5.3.2 (CBP P5.3.2) watershed model was chosen and specifically, the *edge-of-stream* (EOS) land-use sediment loads were used. The CBP P5.3.2 model was appropriate for this TMDL because the spatial domain of the model segmentation aggregates to the MD 8-digit watershed scale, which is consistent with the impairment listing.

USEPA's regulations require TMDLs to take into account seasonality and critical conditions for stream flow, loading, and water quality parameters (CFR 2012b). The intent of this requirement is to ensure that the water quality of the waterbody is protected during times when it is most vulnerable. The biological monitoring data used to determine the reference watersheds reflect the impacts of stressors (i.e., sediment impacts to stream biota) over the course of time (i.e., captures the impacts of both high and low flow events). Thus, critical conditions are inherently addressed. Seasonality is captured in several 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, which serves as the primary dataset for calculating the biological metrics of the watershed (i.e., BIBI and FIBI scores), included benthic sampling in the spring and fish sampling in the summer. Moreover, the sediment loading rates used in the TMDL were determined using the CBP P5.3.2 model, which is a continuous simulation model with a simulation period 1991-2000, based on the Hydrological Simulation Program Fortran (HSPF) model, thereby addressing annual changes in hydrology and capturing wet, average, and dry years. It should also be noted that the biological impact of sediment generally occurs over time and therefore use of a long term modeling approach also contributes to capturing critical conditions.

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 2012a,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. Because the sediment loading threshold was conservatively based on the median (50^{th} percentile) sediment loading rates from reference watersheds, Maryland has adopted an implicit MOS for sediment TMDLs.

The Baltimore Harbor watershed total baseline sediment load is 6,982 tons per year (ton/yr). The Baltimore Harbor watershed baseline load is further subdivided into a nonpoint source baseline load (Nonpoint Source BL_{BH}) and two types of point source baseline loads: National Pollutant Discharge Elimination System (NPDES) regulated stormwater (NPDES Stormwater BL_{BH}) and NPDES regulated wastewater (Wastewater BL_{BH}) (see Table ES-1).

Table ES-1: Baltimore Harbor Watershed Baseline Sediment Loads (ton/yr)

Total Baseline Load	=	Nonpoint Source BL_{BH}	+	NPDES Stormwater BL_{BH}	+	Wastewater BL_{BH}
6,982	=	177	+	6,804	+	1

The Baltimore Harbor Watershed average annual TMDL of TSS is 3,247 ton/yr (a 53% reduction from the baseline load). The Baltimore Harbor TSS TMDL is further subdivided into point and nonpoint source allocations and is comprised of a load allocation (LA_{BH}) of 177 ton/yr, an NPDES Stormwater Waste Load Allocation (NPDES Stormwater WLA_{BH}) of 3,069 ton/yr, and a Wastewater Load Allocation (Wastewater WLA_{BH}) of 1 ton/yr (see Table ES-2). Sediment loads from both the Cox Creek Water Reclamation Facility (WRF) and Patapsco Wastewater Treatment Plant (WWTP) are not included in this analysis because they discharge into the tidal portion of the watershed, which is not included in this TMDL. Sediment loads from these facilities were addressed in the 2010 Chesapeake Bay TMDL for sediment in the PATMH segment.

Table ES-2: Baltimore Harbor Watershed Average Annual TMDL of Sediment (ton/yr)

TMDL	=	LA_{BH}		NPDES Stormwater WLA_{BH}	+	Wastewater WLA_{BH}	+	MOS
3,247	=	177	+	3,069	+	1	+	Implicit

Table ES-3: Baltimore Harbor Watershed Baseline Load, TMDL, and Total Reduction Percentage

Baseline Load (ton/yr)	TMDL (ton/yr)	Total Reduction (%)
6,982	3,247	53

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 B and presented in Table B-1.

This TMDL will ensure that watershed sediment loads are at a level to support the Use Class I designation for the Baltimore Harbor watershed, and more specifically, at a level to support aquatic life. The TMDL will not completely resolve the impairment to biological communities within the watershed since the BSID watershed analysis identifies other possible stressors impacting the biological conditions (e.g. chlorides and high conductivity).

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. Section 303(d) of the Clean Water Act and current EPA regulations require reasonable assurance that the TMDL load and wasteload allocations can and will be implemented. Implementation of the Baltimore Harbor sediment TMDL is expected to occur in parallel with implementation efforts for the 2010 Chesapeake Bay TMDL for nutrients and sediment. Reductions of sediment, nitrogen, and phosphorus loads will be required to meet the Chesapeake Bay TMDL established by EPA (US EPA 2010a). These reductions are necessary to meet water quality standards to protect the designated uses of the Chesapeake Bay and its tidal tributaries, independent of any additional nutrient reductions that may be required to meet existing water quality standards designed to protect aquatic life in local non-tidal waterbodies.

MDE recommends that the first stage of implementation of the Baltimore Harbor sediment TMDL shall be the achievement of the sediment reductions needed within the Baltimore Harbor watershed in order to meet target loads consistent with the Chesapeake Bay TMDL, which is expected to be fully implemented in Maryland by 2025. Once the Bay TMDL nutrient target loads for the Baltimore Harbor watershed have been met, MDE may revisit the status of nutrient impacts on aquatic life in Baltimore Harbor, based on any additional monitoring data available.

In addition, MDE published the Final Determinations to issue Stormwater Permits to Baltimore City (November 2021), Baltimore County (November 2021), Anne Arundel County (November 2021), and the Maryland Department of Transportation State Highway Administration (November 2019). (MDE 2021a, 2021b, 2021c, 2019a) The permits state, "*By regulation at 40 CFR §122.44, BMPs and programs implemented pursuant to this permit must be consistent with applicable WLAs developed under [US]EPA approved TMDLs*". For TMDLs approved after this permit, implementation plans are due within one year of USEPA approval of the TMDL. Many of the practices which are described in the permittees' stormwater WLA implementation plans may also be used by the permittees as retrofits for meeting their impervious area restoration requirements (impervious surface retrofit per five-year permit cycle).

While this TMDL establishes a sediment loading target for the watershed, watershed managers and other stakeholders should always remain cognizant that the endpoint of this TMDL, and hence the definition of its successful implementation, is based on in-stream biological health. Load reductions are critical to tracking this effort, since the TMDL target is defined as the point where sediment loads match those seen in reference watersheds, but the watershed cannot be delisted or classified as meeting water quality standards until it is demonstrated that the biological health of the stream system is no longer impaired by sediment. In planning any implementation efforts related to this TMDL, careful consideration should be given both to the sediment load reductions, and to their direct potential impacts on biological communities.

Many practices in the implementation plans that reduce sediment concurrently address other stressors identified in the BSID report. Since biological improvements will likely only be seen when multiple structural and pollutant stressors are addressed, watershed managers developing plans to address sediment should consider the effect of restoration projects on other stressors. Where possible, preference should be given to designs that address multiple stressors.

1.0 INTRODUCTION

Section 303(d) of the federal Clean Water Act (CWA) and the U.S. Environmental Protection Agency's (USEPA) 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 2012b). This document, upon approval by the USEPA, establishes a Total Maximum Daily Load (TMDL) for sediment in the Maryland 8-Digit Baltimore Harbor watershed (2018 *Integrated Report of Surface Water Quality in Maryland* Assessment Unit ID: MD-02130903). In this TMDL report, the terms total suspended solids (TSS) and sediment may be used interchangeably.

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

The Baltimore Harbor watershed is associated with three assessment units in Maryland's Integrated Report: a non-tidal 8-digit watershed (02130903) and two estuary portions [Chesapeake Bay Segments Upper Chesapeake Bay Mesohaline (CB3MH) and Patapsco Mesohaline (PATMH)]. Sediment TMDLs for the CB3MH and PATMH were established as part of the Chesapeake Bay TMDLs in 2010. Background information on the tidal portions of the watershed are presented for informational purposes only.

The Maryland Department of the Environment (MDE) identified the waters of the Baltimore Harbor watershed and associated assessment units on the State's 2018 Integrated Report as impaired by multiple pollutants (MDE 2018). Table 1 identifies the impairment listings associated with this watershed.

A data solicitation for sediment was conducted by MDE in November 2018 and all readily available data have been considered.

Table 1: Baltimore Harbor Integrated Report Listings

Watershed	Sub-basin	Waterbody	Designated Use Class	Designated Use Class Subcategory	Year Listed	Identified Pollutant	Listing Category
Baltimore Harbor 02130903		Non-tidal (1st through 4th order streams)	I	Aquatic Life and Wildlife	2014	Chloride	5
						Sulfate	5
						TSS	5
						Habitat alterations	4c
						Lack of Riparian Buffer	4c
		Tidal subsegment	II	Fishing	1998	Chlordane	4a
	Mainstem				1998	PCBs in fish tissue	
	Stansbury Pond	Impoundment	II	Fishing	2012	PCBs in fish tissue	5
CB3MH		Chesapeake Bay segment	I	Aquatic Life and Wildlife	2006	Unknown	5
			II	Open-Water Fish and Shellfish Subcategory	1996	TN	4a
				Open-Water Fish and Shellfish Subcategory		TP	4a
				Seasonal Deep-Channel Refuge Use		TN	4a
				Seasonal Deep-Channel Refuge Use		TP	4a
				Seasonal Deep-Water Fish and Shellfish Subcategory		TN	4a
				Seasonal Deep-Water Fish and Shellfish Subcategory		TP	4a
				Seasonal Shallow-Water Submerged Aquatic Vegetation Subcategory	2008	TSS	4a
				Seasonal Migratory Fish Spawning and Nursery Subcategory	2012	TN	4a
				Seasonal Migratory Fish Spawning and Nursery Subcategory	2012	TP	4a
PATMH		Chesapeake Bay segment	I	Aquatic Life and Wildlife	2004	Cause unknown	5
			II	Open-Water Fish and Shellfish Subcategory	1996	TN	4a
				Open-Water Fish and Shellfish Subcategory		TP	
				Seasonal Deep-Channel Refuge Use		TN	
				Seasonal Deep-Channel Refuge Use		TP	

Watershed	Sub-basin	Waterbody	Designated Use Class	Designated Use Class Subcategory	Year Listed	Identified Pollutant	Listing Category
PATMH		Tidal subsegment	II	Seasonal Deep-Water Fish and Shellfish Subcategory	1996	TN	4a
				Seasonal Deep-Water Fish and Shellfish Subcategory		TP	
				Seasonal Migratory Fish Spawning and Nursery Subcategory		TN	
				Seasonal Migratory Fish Spawning and Nursery Subcategory		TP	
				Seasonal Shallow-Water Submerged Aquatic Vegetation Subcategory		TSS	
	Bear Creek		I	Aquatic Life and Wildlife	1998	PCBs	4a
	Bear Creek				1998	Zinc in sediment	5
	Bear Creek					Chromium in sediment	2
	Curtis Bay Creek				1998	PCBs	4a
	Curtis Bay Creek				1998	Zinc in sediment	5
	Erachem-001					Copper	2
	Erachem-001					Nickel	2
	Furnace Creek			Water contact sports	1998	Enterococcus	4a
	Marley Creek				1998	Enterococcus	4a
	Middle Branch-Northwest Harbor				2010	Enterococcus	5
	Middle Branch-Northwest Harbor-Littoral				2008	Trash	4a
	Middle Harbor			Aquatic Life and Wildlife	1998	Zinc in sediment	5
	Millenium-002					Nickel	2
	Northwest Branch				2014	Chromium in sediment	2
	Northwest Branch				1998	Lead in sediment	5
	Northwest Branch				1998	Zinc in sediment	5
	Rock Creek			Water contact sports	2004	Fecal coliform	2

Watershed	Sub-basin	Tidal/Non-tidal	Designated Use Class	Designated Use Class Subcategory	Year Listed	Identified Pollutant	Listing Category
PATMH	Sparrows Point – 001	Tidal subsegment	I	Aquatic Life and Wildlife	1996	Copper	4b
						Cyanide	
						Nickel	
	Sparrows Point-014					Copper	2
						Cyanide	
						Nickel	
	Sparrows Point-021					Copper	
						Cyanide	
						Nickel	

- Category 2 indicates the waterbody is meeting water quality standards for the identified substance
- Category 4a indicates a TMDL has been completed and approved by EPA, but are still impaired
- Category 4b indicates a TMDL is not needed because other pollution control requirements are expected to result in the attainment of an applicable WQSs in a reasonable period of time
- Category 4c indicates the cause of the impairment is pollution and not a pollutant
- Category 5 indicates that the waterbody is impaired and a TMDL or water quality analysis (WQA) is needed.

The Maryland Surface Water Use Designation in the Code of Maryland Regulations (COMAR) for the Baltimore Harbor watershed's non-tidal tributaries are designated as Use Class I - *water contact recreation, and protection of non-tidal warmwater aquatic life.* Tidal tributaries are designated Use Class II - *support of estuarine and marine aquatic life and shellfish harvesting* (COMAR 2020 a, b, c).

The Baltimore Harbor watershed was originally listed for biological impairment on the 2002 Integrated Report. The listing was based on the biological assessment methodology, which uses aquatic health scores, consisting of the Benthic Index of Biotic Integrity (BIBI) and Fish Index of Biotic Integrity (FIBI). These indices indicated that the biological metrics for the watershed exhibit a significant negative deviation from reference conditions (MDE 2006a).

In order to determine what stressor or stressors are impacting aquatic life, MDE's *Biological Stressor Identification* (BSID) methodology was applied. The BSID analysis for the Baltimore Harbor watershed identified sediment, instream habitat, riparian habitat, inorganic chemistry and nutrient chemistry parameter groups. The sediment parameter group shows a significant association with moderate to poor and poor epifaunal substrate. The instream habitat parameter group shows a significant association with channelization present, concrete/gabion present, marginal to poor and poor instream habitat structure, marginal to poor riffle/run quality, and poor velocity/depth diversity. The riparian habitat parameter group shows a significant association with no riparian buffer. The inorganic chemistry parameter group shows a significant association with high conductivity, chlorides, and sulfates. The nutrient chemistry parameter group shows a significant association with low DO (<5 mg/L and <6 mg/L) and low DO saturation. Further details of this analysis are presented in the 2014 document entitled, *Watershed Report for Biological Impairment of the Baltimore Harbor Watershed in Baltimore City, Baltimore and Anne Arundel Counties, Maryland Biological Stressor Identification Analysis Results and Interpretation* (MDE 2014).

The objective of this TMDL is to ensure that watershed sediment loads are at a level that supports the Use Class I designation for the Baltimore Harbor watershed (1st through 4th order streams). The TMDL will address water clarity problems and associated impacts to aquatic life in the Baltimore Harbor watershed caused by high sediment and TSS concentrations.

The CWA requires TMDLs to be protective of all the designated uses applicable to a particular waterbody. The primary focus of this TMDL is the designated use of protection of aquatic life because the Integrated Report listing was based on a biological assessment of the watershed. The biological assessment revealed the current levels of TSS and other pollutants prevent the watershed from achieving its designated use of supporting aquatic life. However, the required reductions are expected to protect all designated uses of the watershed, including water contact recreation. It is understood that aquatic life is more sensitive to sediment impacts than recreation because aquatic life impacts result from continuous exposure than can affect respiration and propagation. Recreation, on the other hand, is sporadic and sediment is unlikely to pose a human health risk due to dermal contact or minimal ingestion that would occur during recreation. Additionally, EPA's *Framework for Developing Suspended and Bedded Sediments (SABS) Water Quality Criteria* states:

> *… where multiple designated uses (such as aquatic life and irrigation) overlap in a waterbody or on a specific segment or portion of the waterbody, SABS criteria established to protect the aquatic life use most likely will be stringent enough to protect all other uses except perhaps drinking water uses.* (USEPA 2006).

2.0 SETTING AND WATER QUALITY DESCRIPTION

2.1 General Setting

Location

The Baltimore Harbor watershed is located within Baltimore City, Baltimore County, and Anne Arundel County, Maryland. The Baltimore Harbor Watershed is located immediately south east of Baltimore City and includes Old Road Bay and other small tributaries to the Patapsco River and Chesapeake Bay. Smaller tributaries feeding the Harbor are the Gwynns Falls (upper Middle Branch of the Harbor), Jones Falls (Northwest Branch of Baltimore Harbor), Bear Creek, Furnace Creek, Marley Creek, Rock Creek, Stony Creek, and Curtis Creek (see Figure 1). The Harbor is a tidal estuary located on the western shore of the Chesapeake Bay, just south of Back River. Baltimore Harbor lies in the Patapsco watershed and it is estimated that 60 percent of the total freshwater entering Baltimore Harbor comes from the Patapsco River (QLME, 1973).

The watershed is located predominately on the western shore of the Coastal Plain region, one of three distinct eco-regions identified in the Maryland Department of Natural Resources Maryland Biological Stream Survey (MDDNR MBSS) Index of Biological Integrity (IBI) metrics (Southerland et al. 2005a) (see Figure 2). A location map of the Baltimore Harbor watershed is provided in Figure 1. The northern tip extends into the Piedmont region.

According to the Chesapeake Bay Program's Phase 5.3.2 watershed model, the total drainage area of the Maryland 8-digit watershed is approximately 55,176 acres, not including water/wetlands. Approximately 386 acres of the watershed area is covered by water.

There are no "high quality," or Tier II, stream segments located within the Baltimore Harbor watershed. Tier II segments are designated using MBSS data, and both the FIBI and BIBI values must be greater than 4.00 (on a scale of 1 – 5). Tier II segments require the implementation of Maryland's anti-degradation policy, which is designed to prevent degradation of high quality waters. The policy requires a review of all permitted activities upstream of Tier II stream segments. (COMAR 2020d; MDE 2011).

Geology/Soils

The watershed lies within two physiographic provinces, the Piedmont and the Coastal Plain, whose division runs through the northern tip of the watershed. The northern portion of the watershed is in the Piedmont Plateau province, characterized by steep stream valleys and well-drained loamy soils underlain by Precambrian crystalline rocks. The Piedmont portion of the watershed is higher and more rugged than that of the coastal plain due to the greater resistance to erosion, and streambeds tend to be rocky, with relatively steep gradients. The remainder of the basin lies within the Coastal Plain province, a wedge-shaped mass of primarily unconsolidated sediments of the Lower Cretaceous, Upper Cretaceous and Pleistocene ages covered by sandy soils. The Coastal Plain portion of the watershed is characterized by lower relief, and is drained by slowly meandering streams with shallow channels and gentle slopes (MGS 2012).

Soils typically found in the Baltimore Harbor watershed are the Beltsville, Evesboro, Westbrook, and Othello series. The Beltsville series consist of very deep, moderately well drained soils on uplands. Saturated hydraulic conductivity is moderately low or low in the fragipan. The Evesboro series consist of very deep excessively drained on coastal plain uplands. Saturated hydraulic conductivity is high in the subsoil and high to very high in the substratum. The Westbrook series consist of very deep, very poorly drained soils formed in organic deposits over loamy mineral material. They are in tidal marshes subject to inundation by salt water twice daily. Saturated hydraulic conductivity is moderately high to very high in the organic layers and low to high in the underlying mineral sediments. The Othello series consist of very deep, poorly drained soils, with saturated hydraulic conductivity being moderately high (USDA 2006).

The United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) classifies soils into 4 hydrologic soil groups: Group A soils have high infiltration rates and are typically deep well drained/excessively drained sands or gravels; Group B soils have moderate infiltration rates and consist of soils that are moderately deep to deep and moderately well to well drained soils, with moderately fine/coarse textures; Group C soils have slow infiltration rates with a layer that impedes downward water movement, and they primarily have moderately fine-to-fine textures; Group D soils have very slow infiltration rates consisting of clay soils with a permanently high water table that are often shallow over nearly impervious material. The Baltimore Harbor watershed is comprised primarily of Group A soils (35%) and Group D soils (30%), with smaller portions of the watershed consisting of Group C soils (21%) and Group D soils (14%) (USDA 2006).

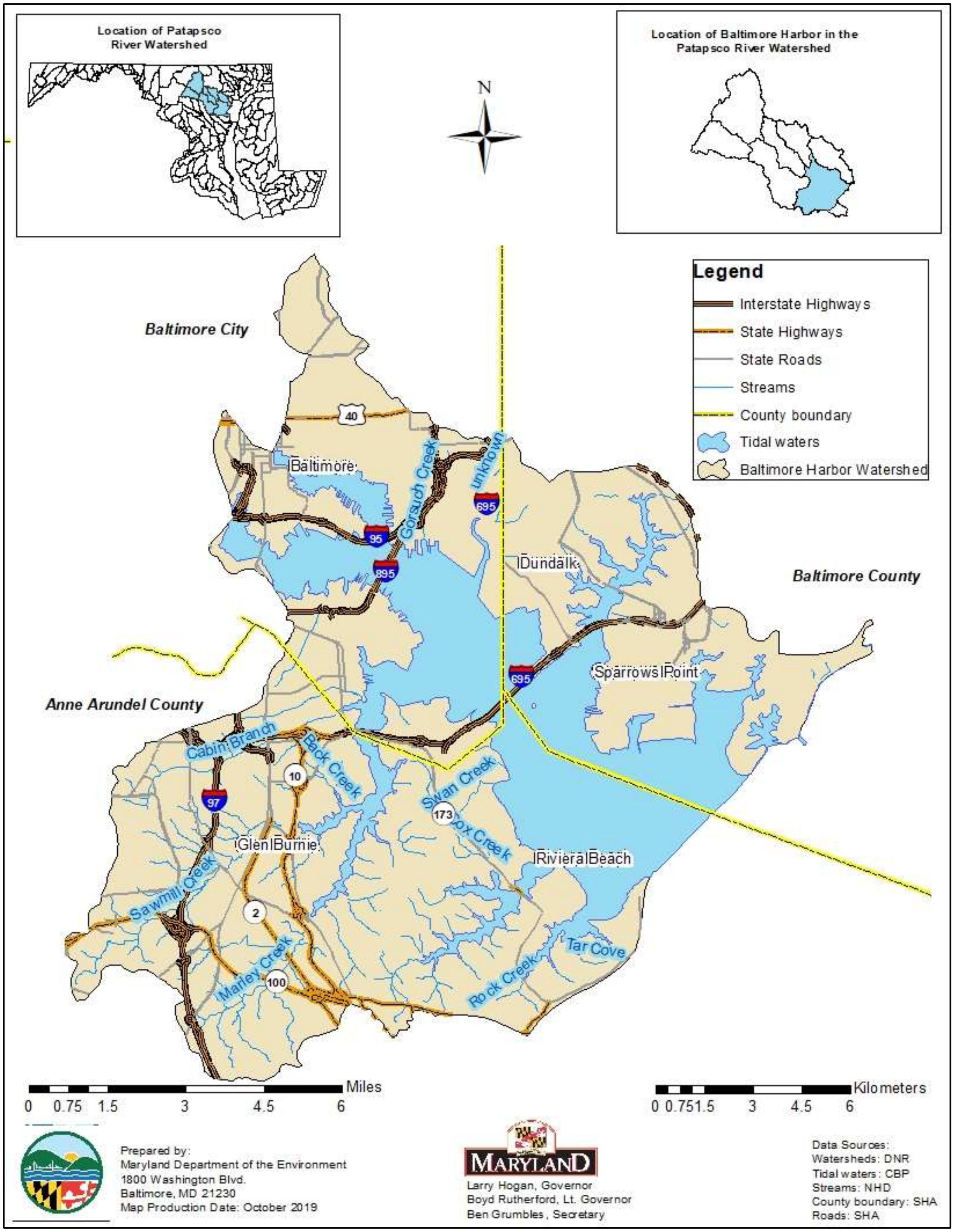

Figure 1: Location Map of the Baltimore Harbor Watershed in Baltimore City, Baltimore County, and Anne Arundel County, Maryland

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 5.3.2 (CBP P5.3.2) Watershed Model. The CBP P5.3.2 land-use was based on two distinct stages of development.

The first stage consisted of the development of the Chesapeake Bay Watershed Land-Cover Data (CBLCD) series of Geographic Information System (GIS) datasets. These datasets provide a 30-meter resolution raster representation of land-cover in the Chesapeake Bay watershed, based on sixteen Anderson Level two land-cover classes. The CBLCD basemap, representing 2001 conditions, was primarily derived from the Multi-Resolution Land Characteristics (PCLC) Consortium's National Land-Cover Data (NLCD) and the National Oceanic and Atmospheric Administration's (NOAA) Coastal Change Analysis Program's (CCAP) Land-Cover Data. By applying Cross Correlation Analysis to Landsat 5 Thematic Mapper and Landsat 7 Enhanced Thematic Mapper satellite imagery, CBLCD datasets for 1984, 1992, and 2006 from the baseline 2001 dataset. The watershed model documentation, *Chesapeake Bay Phase 5.3 Community Watershed Model* (USEPA 2010b), describes the development of the CBLCD series in more detail. USGS and NOAA also developed an impervious cover dataset from Landsat satellite imagery for the CBLCD basemap, which was used to estimate the percent impervious cover associated with CBLCD developed land-cover classifications.

The second stage consisted of using ancillary information for: 1) the creation of a modified 2006 CBLCD raster dataset, and 2) the subsequent development of the CBP P5.3.2 land-use framework in tabular format. Estimates of the urban footprint in the 2006 CBLCD were extensively modified using supplemental datasets. Navteq street data (secondary and primary roads) and institutional delineations were overlaid with the 2006 CBLCD land-cover and used to reclassify underlying pixels. Certain areas adjacent to the secondary road network were also reclassified based on assumptions developed by USGS researchers, in order to capture residential development (*i.e.*, subdivisions not being picked up by the satellite in the CBLCD). In addition to spatially modifying the 2006 CBLCD, the following datasets were used to supplement the developed land cover data in the final CBP P5.3.2 land-use framework: US Census housing unit data, Maryland Department of Planning (MDP) Property View data, and estimates of impervious coefficients for rural residential properties (determined via a sampling of these properties using aerial photography). This additional information was used to estimate the extent of impervious area in roadways and residential lots. Acres of construction and extractive land-uses were determined independently using a method developed by USGS (Claggett, Irani, and Thompson 2012). Finally, in order to develop accurate agricultural land-use acreages, the CBP P5.3.2 incorporated county level US Agricultural Census data (USDA 1982, 1987, 1992, 1997, 2002). The watershed model documentation, *Chesapeake Bay Phase 5.3 Community Watershed Model* (USEPA 2010b), describes these modifications in more detail.

The result of these modifications is that CBP P5.3.2 land-use does not exist in a single GIS coverage; instead, it is only available in a tabular format. The CBP P5.3.2 watershed model is comprised of 30 land-uses. The land-uses are divided into 13 classes with distinct sediment erosion rates. Table 2 lists the CBP P5.3.2 generalized land-uses, detailed land-uses, which are classified by their sediment erosion rates, and the acres of each land-use in the Baltimore Harbor watershed. The land-use acreage used to inform this TMDL is based on the CBP P5.3.2 2009 Progress Scenario.

Baltimore Harbor Watershed Land-Use Distribution

The land-use distribution of the Baltimore Harbor watershed consists primarily of urban lands (85%) and forest (14%). A detailed summary of the watershed land-use areas is presented in Table 2, and a land-use map is provided in Figure 2.

Table 2: Land-Use Percentage Distribution for the Baltimore Harbor Watershed

General Land Use	Detailed Land-Use	Area (Acres)	Percent (%)
Forest	Forest	7,657	14%
	Harvested Forest	76	0.1%
AFOs	Animal Feeding Operations	0	0.0%
CAFOs	Concentrated Animal Feeding Operations	0	0.0%
Pasture	Pasture	61	0.1%
Crop	Crop	206	0.4%
Nursery	Nursery	1	0.0%
Regulated Urban	Construction	366	0.7%
	Developed	46,406	84%
	Extractive	17	0.0%
Water	Water	386	0.7%
Total		**55,176**	**100%**

Note: Individual values may not add to total load due to rounding.

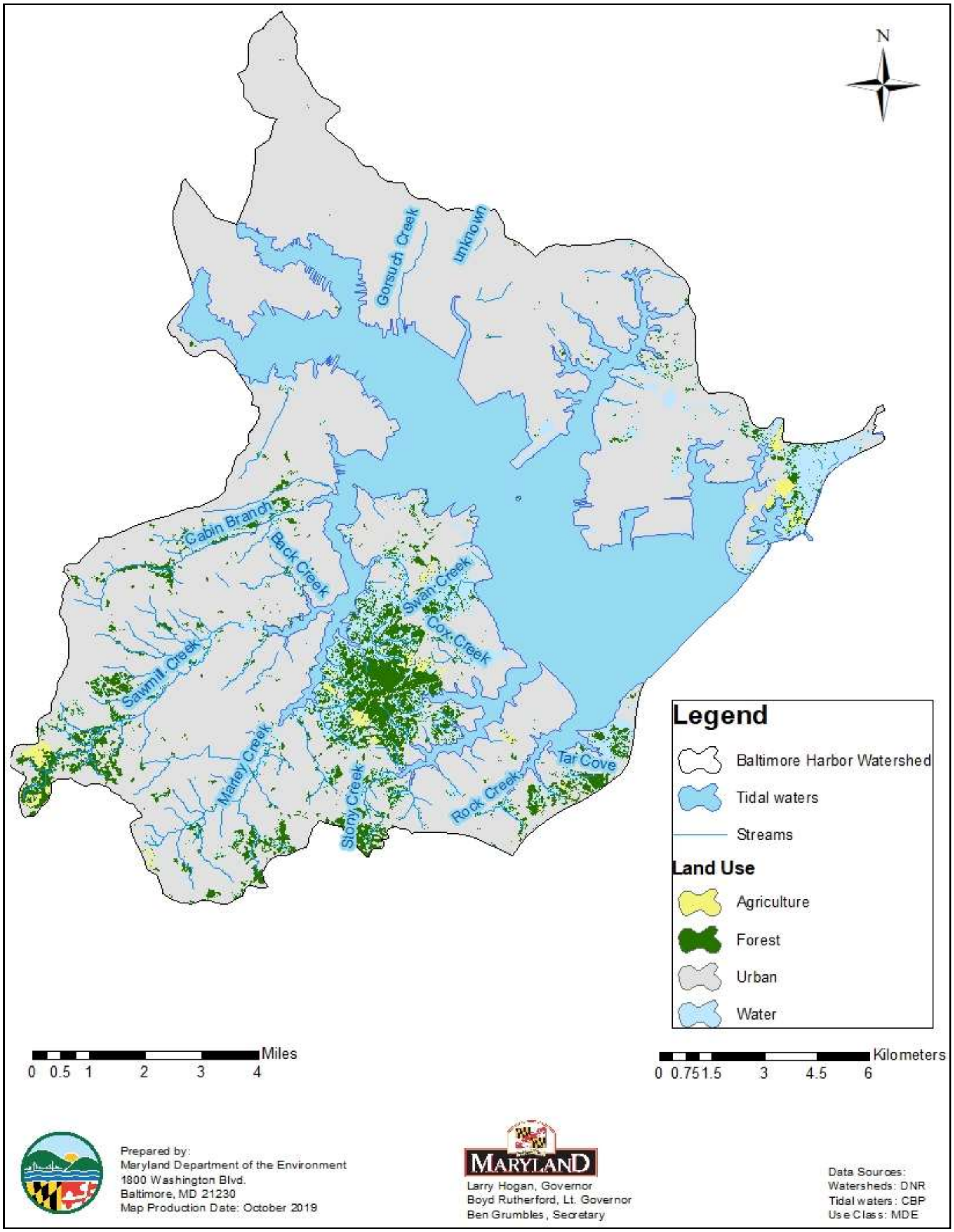

Figure 2: Land-use of the Baltimore Harbor Watershed

2.2 Source Assessment

The Baltimore Harbor Watershed Baseline Sediment load consists of nonpoint source loads, and point source loads which can be further divided into National Pollutant Discharge Elimination System (NPDES) Stormwater loads, and Wastewater 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 all sediment loads not covered under a NPDES permit within the Baltimore Harbor watershed. In general, these are rainfall driven land-use based loads from agricultural and forested lands. This section provides the background and methods for determining the nonpoint source baseline loads generated within the Baltimore Harbor watershed (Nonpoint Source $BL_{\mathbf{BH}}$).

General Load Estimation Methodology

Nonpoint source sediment loads generated within the Baltimore Harbor watershed are estimated based on the *edge-of-stream (EOS)* loads from the CBP P5.3.2 watershed model 2009 Progress Scenario. Within the CBP P5.3.2 watershed model, EOS sediment loads are calculated 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 factor (SDF)* (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 documented in the report entitled *Chesapeake Bay Phase 5 Community Watershed Model* (USEPA 2010b). A summary of the methodology is presented in the following sections.

Edge-of-Field Target Erosion Rate Methodology

Edge-of-field erosion can be defined as erosion or sediment loss from any particular land surface. EOF target erosion rates are the values used in the calibration of the Chesapeake Bay Program (CBP) model, based on literature values. EOF target erosion rates for agricultural land-uses and forested land-use were based on erosion rates determined by the Natural Resource Inventory (NRI). The NRI is a statistical survey of land-use and natural resource conditions conducted by the NRCS (USDA 2006). The 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 the NRI; however, for the purpose of the Chesapeake Bay Program Phase 4.3 (CBP P4.3) watershed model, the NRI calculated average annual erosion rates for forested land-use on a watershed basis. These rates were used as targets in the CBP P5.3.2 model.

The average value of the 1982 and 1987 surveys was used as the basis for EOF target rates for pasture and cropland. Rates for urban pervious, urban impervious, extractive, and barren land were based on a combination of best professional judgment, literature analysis, and regression analysis. The EOF erosion rates 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, BMPs are applied to the modeled EOS loads in the CBP P5.3.2 2009 Progress Scenario. BMP data, representing BMPs in place in 2009, was collected by the Chesapeake Bay Program (CBP), and TSS reduction efficiencies have been estimated by CBP for specific types of BMPs based on peer reviewed studies, data collected by local jurisdictions, and an analysis of available literature values. For further details regarding EOF erosion rates, please see Section 9.2.1 of the *Chesapeake Bay Phase 5 Community Watershed Model* (USEPA 2010b). Table 3 lists EOF erosion rates specific to Baltimore City, Baltimore County, and Anne Arundel County, where the Baltimore Harbor watershed is located.

Table 3: Baltimore City, Baltimore County, and Anne Arundel County, Target EOF TSS Loading Rates (ton/acre/yr) by Land-Use

Land-use	**Data Source**	**Baltimore City Target EOF TSS Loading rate (ton/acre/yr)**	**Baltimore County Target EOF TSS Loading rate (ton/acre/yr)**	**Anne Arundel County Target EOF TSS Loading rate (ton/acre/yr)**
Forest	NRI (1987)	0.47	0.46	0.29
Harvested Forest	Literature values	3	3	3
Nursery	Equivalent to conventional till	2.57	12.26	10.06
Pasture	NRI average (1982-1987)	0.27	1.29	0.47
Animal Feeding Operations	NRI pasture average (1982-1987) multiplied by 9	2.57	12.26	4.2
Hay	Adjusted NRI average (1982-1987)	0.8	3.18	2.58
Conventional Till	Adjusted NRI average (1982 – 1987)	3.14	12.42	10.06
Conservation Till	Adjusted NRI average (1982 – 1987)	1.89	7.45	6.04
Pervious Urban	Regression Analysis	0.74	0.74	0.74
Extractive	Literature values/best professional judgment	10	10	10
Barren (Construction)	Literature values	23	23	23
Impervious Urban	Regression Analysis	5.18	5.18	5.18

Edge-of-Stream Sediment Loads

EOS sediment loads are the loads that enter the modeled river reaches. Modeled river reaches are those with discharges of 100 cubic feet per second (cfs) or greater. (Exceptions were made for some river reaches that had useful monitoring data but were less than 100 cfs.) EOS sediment 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 influence of the sum of these processes is represented in the estimated SDF.

The formula for the EOS load calculation within the CBP P5.3.2 watershed model is as follows:

$$\sum_{i}^{n} EOS = Acres_i * EOF_i * SDF_i \qquad \text{(Equation 2.1)}$$

where:
n = number of land-use classifications
i = land-use classification
EOS = Edge of stream load, tons per year (ton/yr)
Acres = acreage for land-use i
EOF = Edge-of-field erosion rate for land-use i, ton/acre/yr
SDF = sediment delivery factor for land-use i

2.2.2 Point Source Assessment

A list of active permitted point sources that contribute to the sediment load in the Baltimore Harbor watershed was compiled using best available resources. The types of permits identified were individual industrial, Phase I and II Municipal Separate Storm Sewer System (MS4) permits, general industrial stormwater permits, and the general permit for stormwater discharges from construction sites. The permits can be grouped into two categories: wastewater and stormwater. The wastewater category includes those loads generated by continuous discharge sources whose permits have TSS limits. Wastewater permits that do not meet these conditions are considered *de minimis* in terms of the total sediment load. The stormwater category includes all NPDES regulated stormwater discharges.

The baseline sediment loads for the wastewater permits (Wastewater BL_{BH}) are calculated based on their permitted TSS limits (average monthly or weekly concentration values) and corresponding flow information. The stormwater permits identified throughout the Baltimore Harbor watershed do not include numeric TSS limits. In the absence of TSS limits, the NPDES regulated stormwater baseline load (NPDES Stormwater BL_{BH}) is calculated using the CBP P5.3.2 Progress Scenario urban land-use EOS loads (as per Equation 2.1) similar to the approach for nonpoint source (NPS) loads outlined in Section 2.1. The technical memorandum to this document entitled *Point*

Sources of Sediment in the Baltimore Harbor Watershed provides detailed information regarding the calculation of the Baltimore Harbor watershed NPDES Stormwater BL_{BH}.

2.2.3 Summary of Baseline Loads

Table 4 summarizes the Baltimore Harbor Baseline Sediment Load, reported in tons per year (ton/yr) and presented in terms of Nonpoint source, NPDES Stormwater, and Wastewater Baseline Loads

Table 4: Baltimore Harbor Watershed Baseline Sediment Loads (ton/yr)

Total Baseline Load	=	Nonpoint Source BL_{BH}	+	NPDES Stormwater BL_{BH}	+	Wastewater BL_{BH}
6,982	=	177	+	6,804	+	1

Table 5 presents a breakdown of Baltimore Harbor Watershed Total Baseline Sediment Load, detailing loads per land-use or other source category.

Table 5: Detailed Baseline Sediment Loads Within the Baltimore Harbor Watershed

General Land Use	Detailed Land-Use	Tons	Percent (%)
Forest	Forest	115	1.6%
	Harvested Forest	8	0.1%
AFOs	Animal Feeding Operations	0.2	0.0%
Pasture	Pasture	2	0.0%
Crop	Crop	51	0.7%
Nursery	Nursery	1	0.0%
Regulated Urban	Construction	350	5.0%
	Developed	6,443	92.3%
	Extractive	11	0.2%
Wastewater Point Sources	Industrial Point Sources	1	0.0%
	Municipal Point Sources	0	0.0%
Total		**6,982**	**100.0%**

Note: Individual values may not add to total load due to rounding.

2.3 Water Quality Characterization

The Baltimore Harbor watershed was originally listed for impacts to biological communities in the 2002 Integrated Report. To refine the listing for impacts to biological communities, Maryland conducted a stressor identification analysis. Details of this analysis are presented below and in the document entitled, *Watershed Report for Biological Impairment of the Baltimore Harbor Watershed in Baltimore City, Baltimore and Anne Arundel Counties, Maryland Biological Stressor Identification Analysis Results and Interpretation* (MDE 2014c).

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 as probable or unlikely causes of the poor biological conditions within a given 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 includes MDDNR MBSS Round 2 and Round 3 data (collected between 2000-2009) because it provides a broad spectrum of paired data variables, which allow for a more comprehensive stressor analysis. MDDNR-MBSS Round 1 can also be used if there is limited Round 2 and 3 data. The MBSS is a robust statewide probability-based sampling survey for assessing the biological conditions of 1st through 4th order streams (Klauda et al. 1998; Roth et al. 2005). It uses a fixed length (75 meter) 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 stressor as contributing to the biological impairment is based on the results of the individual stressor associations within the sediment parameter grouping, which reveal the effects of sediment related impacts on stream biota (MDE 2009a).

Baltimore Harbor Watershed Monitoring Stations

A total of 28 water quality monitoring stations were used to characterize the Baltimore Harbor watershed for the purpose of this TMDL. The biological assessment was based on the combined results of MBSS Round 1, Round 2 data and Round 3 data, which includes 28 stations. The BSID analysis used stations from MBSS Round 2 and Round 3, which includes 20 stations. All stations are listed in Table 6 and presented in Figure 3.

Table 6: Monitoring Stations in the Baltimore Harbor Watershed

Site Number	Sponsor	Site Type	Location	Latitude (decimal degrees)	Longitude (decimal degrees)
AA-N-020-124-96	DNR	MBSS Round 1	Sloop Cove, unnamed tributary 1	39.1474	-76.5620
AA-N-104-114-95	DNR	MBSS Round 1	Marley Creek, unnamed tributary 1	39.1301	-76.6332
AA-N-126-306-95	DNR	MBSS Round 1	Sawmill Creek	39.1813	-76.6201
AA-N-172-209-95	DNR	MBSS Round 1	Sawmill Creek	39.1587	-76.6496
AA-N-186-115-96	DNR	MBSS Round 1	Sawmill Creek, unnamed tributary 2	39.1819	-76.6225
AA-N-244-203-95	DNR	MBSS Round 1	Sawmill Creek, unnamed tributary 1	39.1789	-76.6262
AA-N-262-101-96	DNR	MBSS Round 1	Marley Creek, unnamed tributary 1	39.1477	-76.6116
AA-N-323-225-96	DNR	MBSS Round 1	Sawmill Creek	39.1582	-76.6518
BALT-103-R-2001	DNR	MBSS Round 2	Cabin Branch Curtis Creek	39.2031	-76.6212
BALT-103-R-2004	DNR	MBSS Round 2	Cabin Branch Curtis Creek	39.2032	-76.6211
BALT-104-R-2001	DNR	MBSS Round 2	Marley Creek	39.1214	-76.6303
BALT-106-R-2001	DNR	MBSS Round 2	Marley Creek, unnamed tributary 3	39.1449	-76.6135
BALT-106-R-2004	DNR	MBSS Round 2	Marley Creek	39.1243	-76.6325
BALT-108-R-2001	DNR	MBSS Round 2	Northwest Harbor, unnamed tributary 1	39.2819	-76.5494
BALT-108-R-2004	DNR	MBSS Round 2	Cabin Branch Curtis Creek	39.2108	-76.5980
BALT-110-R-2001	DNR	MBSS Round 2	Marley Creek, unnamed tributary 4	39.1449	-76.5854
BALT-112-R-2004	DNR	MBSS Round 2	Marley Creek	39.1227	-76.6320
BALT-113-R-2001	DNR	MBSS Round 2	Marley Creek, unnamed tributary 2	39.1334	-76.6102
BALT-116-R-2004	DNR	MBSS Round 2	Curtis Creek, unnamed tributary 1	39.2122	-76.6126
BALT-117-R-2004	DNR	MBSS Round 2	Marley Creek	39.1214	-76.6307
BALT-118-R-2004	DNR	MBSS Round 2	Sawmill Creek	39.1425	-76.6763
BALT-119-R-2004	DNR	MBSS Round 2	Sawmill Creek, unnamed tributary 3	39.1640	-76.6612
BALT-202-R-2001	DNR	MBSS Round 2	Sawmill Creek	39.1694	-76.6303
BALT-207-R-2001	DNR	MBSS Round 2	Marley Creek	39.1378	-76.6114
BALT-214-R-2001	DNR	MBSS Round 2	Marley Creek	39.1370	-76.6131
BALT-214-R-2004	DNR	MBSS Round 2	Sawmill Creek	39.1582	-76.6488
BALT-102-R-2009	DNR	MBSS Round 3	Cabin Branch Creek	39.2054	-76.6125
BALT-204-R-2009	DNR	MBSS Round 3	Marley Creek	39.1449	-76.6066

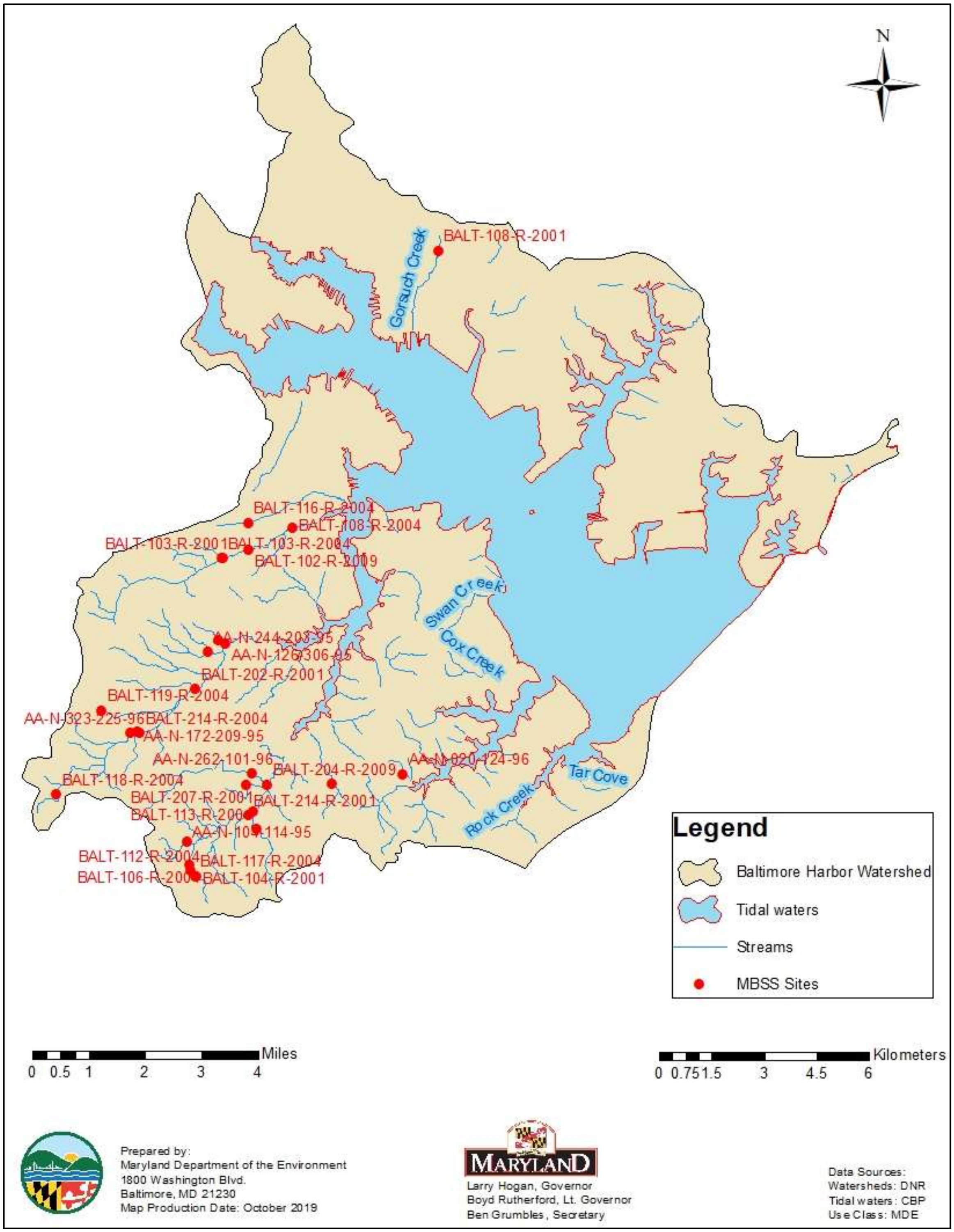

Figure 3: Monitoring Stations in the Baltimore Harbor Watershed

2.4 Water Quality Impairment

The Maryland Surface Water Use Designation in the COMAR for the Baltimore Harbor watershed's non-tidal streams are Use Class I - *water contact recreation, and protection of non-tidal warmwater aquatic life.* All of the tidal waters are designated Use Class II - *support of estuarine and marine aquatic life and shellfish harvesting* (COMAR 2020 a, b, c). This TMDL only addresses the non-tidal portion of the watershed, 1st through 4th order streams. A map of the Designated Use Classes is provided in Figure 4.

The water quality impairment of the Baltimore Harbor watershed addressed by this TMDL is caused, in part, by an elevated sediment load beyond a level that the watershed can sustain; thereby causing sediment related impacts to aquatic life. Assessment of aquatic life is based on Benthic Index of Biological Integrity and Fish Index of Biological Integrity (BIBI and FIBI) scores, as demonstrated via the BSID analysis for the watershed.

The non-tidal portion of the Baltimore Harbor watershed was originally listed on Maryland's 2002 Integrated Report as impaired for impacts to biological communities. The biological assessment was based on the combined results of MBSS Round 1 (1995-1997), Round 2 (2000-2004), and Round 3 (2007-2009) data, which included 28 stations. Approximately 71% of the stream miles in the watershed, were assessed as having BIBI and/or FIBI scores significantly lower than 3.0 (on a scale of 1 to 5) (MDE 2006a). See Figure 3 and Table 6 for station locations and information.

The results of the BSID analysis for the Baltimore Harbor watershed are presented in a report entitled *Watershed Report for Biological Impairment of the Baltimore Harbor Watershed in Baltimore City, Baltimore and Anne Arundel Counties, Maryland Biological Stressor Identification Analysis Results and Interpretation*. The report states that the degradation of biological communities in the Baltimore Harbor watershed is strongly associated with impervious/urban and anthropogenic impacts, inorganics (chlorides/sulfates), sediment and instream habitat stressors, channelization, and inadequate riparian buffer. (MDE 2014c).

The BSID analysis determined that the biological impairment in the non-tidal Baltimore Harbor watershed is due in part to stressors within the sediment parameter grouping. Overall, stressors within the sediment parameter grouping were identified as having a statistically significant association with impaired biological communities at approximately 59% of the sites with BIBI and/or FIBI scores significantly less than 3.0 throughout the watershed (MDE 2014c). Therefore, since sediment is identified as a stressor to the biological communities in the Baltimore Harbor watershed, the watershed was listed as impaired by sediment in the 2014 Integrated Report, and a TMDL is required.

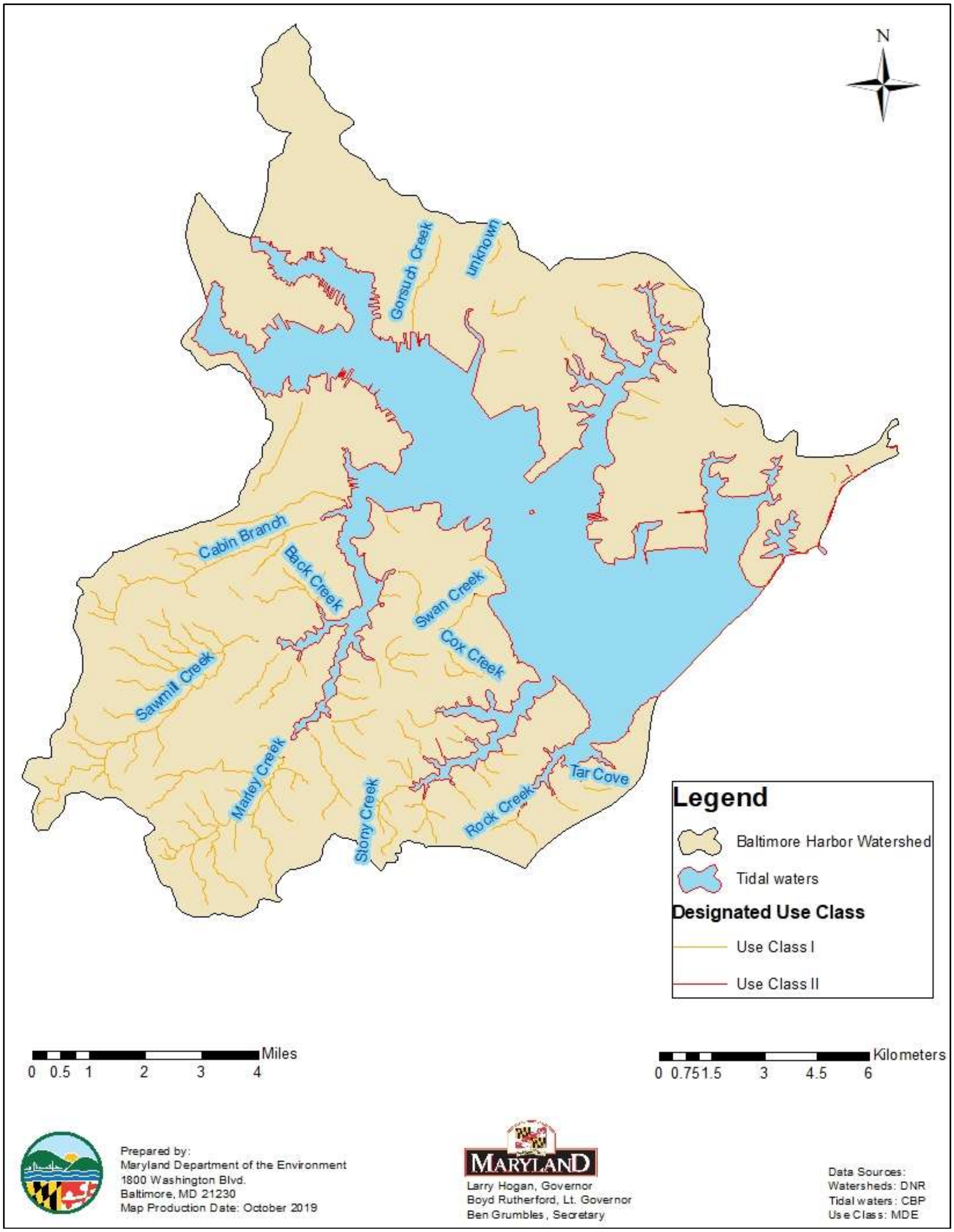

Figure 4: Designated Use Classes of the Baltimore Harbor Watershed in Baltimore City, Baltimore County, and Anne Arundel County, Maryland

3.0 TARGETED WATER QUALITY GOAL

The objective of the sediment TMDL established herein is to reduce sediment loads, and their detrimental effects on aquatic life in the Baltimore Harbor watershed, to levels that support the Use Class I designations for the watershed. Excessive sediment has been identified by the USEPA as the leading cause of impairment of our nation's waters, and as contributing to the decline of populations of aquatic life in North America (USEPA 2006). Sediment in streams may reduce visibility, preventing fish from seeing their prey, and may clog gills and filter feeding mechanisms of fish and benthic (bottom-dwelling) organisms. Excessive deposition of sediment on streambeds may bury eggs or larvae of fish and benthic macroinvertebrates, or degrade habitat by clogging the interstitial spaces between sand and gravel particles. Excessive sediment can also create hazards for recreation due to low visibility and the possibility of unseen objects.

The CWA requires TMDLs to be protective of all the designated uses applicable to a particular waterbody. The primary focus of this TMDL is the designated use of protection of aquatic life because the Integrated Report listing was based on a biological assessment of the watershed. The biological assessment revealed the current levels of TSS and other pollutants prevent the watershed from achieving its designated use of supporting aquatic life. The required reductions within the TMDL are expected to protect all designated uses of the watershed from sediment impacts, including water contact recreation. Aquatic life is more sensitive to sediment impacts than recreation because of continuous exposure that can affect respiration and propagation. Recreation, on the other hand, is sporadic and sediment is unlikely to pose a human health risk due to dermal contact or minimal ingestion that would occur during recreation. Additionally, EPA's *Framework for Developing Suspended and Bedded Sediments (SABS) Water Quality Criteria* states:

> *… where multiple designated uses (such as aquatic life and irrigation) overlap in a waterbody or on a specific segment or portion of the waterbody, SABS criteria established to protect the aquatic life use <u>most likely</u> will be stringent enough to protect all other uses except perhaps drinking water uses.* (USEPA 2006)

Reductions in sediment loads are expected to result from decreased watershed 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 decrease in fine sediment (fines), and improved stream habitat diversity, all of which will result in improved water quality.

The TMDL will not completely resolve the impairment to biological communities within the watershed, since the BSID watershed analysis also identifies additional possible stressors impacting the biological conditions (e.g. chlorides). This impairment to aquatic life will only be fully addressed when all substances identified as impairing biological communities in the watershed are reduced to levels that will meet water quality standards. (MDE 2009a, 2014c).

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 Baltimore Harbor watershed.

4.2 Analysis Framework

Since there are no specific numeric criteria in Maryland that quantify the impact of sediment on the aquatic life of stream systems, a reference watershed approach was used to establish the TMDL. In order to use a reference watershed approach, sediment loads were estimated using a watershed model. For this analysis, the CBP P5.3.2 model was used to calculate the sediment loads used in the reference watershed approach.

Watershed Model

The CBP P5.3.2 watershed model was chosen to estimate the sediment loads for the Baltimore Harbor watershed TMDL and the loads were expressed as EOS sediment loads. The spatial domain of the CBP P5.3.2 watershed model segmentation aggregates to the MD 8-digit watersheds, which is with the scale of the impairment listing. The nonpoint source baseline sediment loads generated within the Baltimore Harbor watershed are based on the EOS loads from the CBP P5.3.2 watershed model 2009 Progress Scenario. CBP P5.3.2 Progress Scenario EOS loads are calculated as the sum of individual land-use EOS loads within the watershed and represent a long-term average loading rate. Individual land-use EOS loads are calculated within the CBP P5.3.2 watershed model as a product of the land-use area, land-use target EOF loading rate, and loss from the EOF to the main channel. BMP data and reduction efficiencies are then subsequently applied to produce the final EOS loads. The loss from the EOF to the main channel is the *sediment delivery factor* and is defined as the ratio of the sediment load reaching a basin outlet to the total erosion within the basin. A *sediment delivery factor* 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 factor* decreases). Details of the data sources for the unit loading rates can be found in Section 2.2 of this report.

Reference Watershed Approach

In order to quantify the impact of sediment on the aquatic life of stream systems, a reference watershed TMDL approach was used. Reference watersheds are those watersheds that are identified as supporting aquatic life, based on Maryland's biological assessment methodology. The biological assessment methodology assesses biological impairment at the 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 represents the threshold under which a watershed is listed as impaired for biology and is calculated based on the average annual allowable IBI value of 3.0 (on a scale of 1 to 5), the coefficient of variation of annual sentinel site results, and an assumed normal distribution. 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 2014b). For a full description of the selection of reference watersheds, please see *A Methodology for Addressing Sediment Impairments in Maryland's Watersheds* (MDE 2006a).

Comparison of sediment loads from impaired watersheds to loads from reference watersheds requires that the watersheds be similar in physical and hydrological characteristics. For the establishment of this specific TMDL, watersheds were selected from the non-tidal western shore Coastal Plain region since the Baltimore Harbor watershed is within this geologic province (see Section 2.1). See Appendix A for the list of reference watersheds. The same methodology as described in MDE 2006a for the selection of the Highland and Piedmont reference watersheds was used to select the western shore Coastal Plain reference watersheds. Furthermore, all subsequent methodologies used to establish the TMDL end point, based on these reference watersheds, are exactly the same as those described in MDE 2006a.

To further reduce the effect of the variability within the western shore Coastal Plain 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* (y_{for}). The y_{for} is a modeled simulation of what the sediment load would be if the watershed were in its natural all forested state, instead of its current mixed land use. It is calculated using the CBP P5.3.2 model. The *forest normalized sediment load* for this TMDL is calculated as the baseline 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)

Seven reference watersheds were identified in the western shore of the Coastal Plain physiographic region. Reference watershed *forest normalized sediment loads* were calculated using CBP P5.3.2 watershed model 2009 Progress Scenario EOS loads. The median and 75th percentile of the reference watershed *forest normalized sediment loads* were calculated and found to be 3.9 and 4.5 respectively[1]. The median value of 3.9 was used as an environmentally conservative approach for establishing the sediment loading threshold for the TMDL (see Appendix A for more details).

The *forest normalized sediment load* for the Baltimore Harbor watershed, estimated as 8.4, was calculated using CBP P5.3.2 2009 Progress Scenario EOS loads, as follows:

$$Y_n = \frac{y_{ws}}{y_{for}} = \frac{6{,}982\ ton/yr}{832\ ton/yr} = 8.4 \qquad \text{(Calculation 4.1)}$$

A comparison of the Baltimore Harbor watershed *forest normalized sediment loads* to the *sediment loading threshold* demonstrates that the watershed exceeds the *sediment loading threshold*, indicating that it is receiving loads above the maximum allowable load that it can sustain and still meet water quality standards.

4.3 Scenario Descriptions and Results

The following analyses compare baseline conditions in the watershed (under which water quality problems exist) with potential 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. Baseline loads are calculated for nonpoint and point source loads. Point source loads can be subdivided into two categories, wastewater and stormwater.

The Baltimore Harbor watershed baseline nonpoint source sediment loads are estimated using the land-use and EOS sediment loading rates from the CBP P5.3.2 2009 Progress Scenario. The 2009 Progress Scenario was chosen because it is used as the baseline year in the Chesapeake Bay TMDL. The 2009 Progress Scenario represents 2009 land-use and BMP implementation simulated using precipitation and other meteorological inputs from the period 1990-2000 to represent variable hydrological conditions, thereby addressing

[1] The 75th percentile value of reference condition streams was recommended by EPA to be used in establishing numerical criteria (MDE 2006a). The median was found, for the sediment reference watersheds, to be approximately equivalent to other more complex statistical analyses and was used for ease of calculation (MDE 2009b). Both of these values ensure that the selected threshold will represent the reference group values, with the median being more conservative (lower).

annual changes in hydrology and capturing wet, average and dry years. The period 1991-2000 is the hydrological simulation period for the Chesapeake Bay TMDL.

In general, wastewater point source baseline sediment loads are estimated based on the existing permit information. There is one wastewater point source with TSS limits in the non-tidal Baltimore Harbor watershed. Sediment loads from both the Cox Creek Water Reclamation Facility (WRF) and Patapsco Wastewater Treatment Plant (WWTP) are not included in this analysis because they discharge into the tidal portion of the watershed, which is not included in this TMDL. Sediment loads from these facilities were addressed in the 2010 Chesapeake Bay TMDL for sediment in the PATMH segment.

The stormwater point source baseline sediment loads are also based on CBP 5.3.2 loading rates, specifically those for urban land use. Details of these loading source estimates can be found in Section 2.2 and the technical memorandum to this document entitled *Point Sources of Sediment in the Baltimore Harbor Watershed*.

<u>TMDL Conditions</u>

The TMDL scenario simulates conditions under which sediment loads have been reduced to levels that 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 Baltimore Harbor watershed *all forested sediment load* (see Section 4.2). The resulting load is considered the maximum allowable load the watershed can sustain and support aquatic life.

The TMDL loading and associated reductions are averaged at the watershed scale; however, 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:

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

Where:

TMDL = allowable load for impaired watershed (ton/yr)

Yn_{ref} = sediment loading threshold

y_{for_i} = all forested sediment load for CBP P5.3.2 model segment *i* (ton/yr)

i = CBP P5.3.2 model segment

n = number of CBP P5.3.2 model segments in watershed

4.4 Critical Condition and Seasonality

USEPA's regulations require TMDLs to take into account seasonality and critical conditions for stream flow, loading, and water quality parameters (CFR 2012b). The intent of this requirement is to ensure that the water quality of the waterbody is protected during times when it is most vulnerable. The biological monitoring data used to determine the reference watersheds reflect the impacts of stressors (i.e., sediment impacts to stream biota) over the course of time and therefore depict an average stream condition (i.e., captures all high and low flow events). Since the TMDL endpoint is based on the median of forest normalized loads from watersheds assessed as having good biological conditions (i.e., passing Maryland's biological assessment), 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. Moreover, the sediment loading rates used in the TMDL were determined using the CBP P5.3.2 model, which is a continuous simulation model with a simulation period 1991-2000, based on Hydrological Simulation Program Fortran (HSPF) model, thereby addressing annual changes in hydrology and capturing wet, average, and dry years. It should also be noted that the biological impact of sediment generally occurs over time and therefore use of a long term modeling approach also contributes to capturing critical conditions.

Seasonality is captured in two components. First, it is implicitly included through the use of the biological monitoring data as this data reflects 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 Baltimore Harbor watershed average annual sediment TMDL. This load is considered the maximum allowable long-term average annual load the watershed can sustain and support aquatic life.

The long-term average annual TMDL was calculated for the Baltimore Harbor watershed based on Equation 4.2 and set at a load 3.9 times the all forested condition of the watershed. In order to attain the TMDL loading cap calculated for the watershed, reductions were applied to the predominant sediment sources (i.e., significant contributors of sediment to the stream system), independent of jurisdiction. Sediment reductions are also required in the Baltimore Harbor watershed to meet the sediment allocations assigned under the 2010 Chesapeake Bay TMDL for sediment in the PATMH and CB3MH Water Quality Segments. To ensure consistency with the Bay TMDL, and therefore efficiency in the reduction of sediment loads, reductions will be applied to the same sediment sources identified in Maryland's Watershed Implementation Plans (WIPs) for the Bay TMDL, as applicable in the watershed. These include: (1) regulated developed land; (2) conventional till crops, conservation till crops, hay, and pasture; (3) harvested forest; (4) unregulated animal feeding operations and concentrated animal feeding operations (CAFOs); and (5) industrial wastewater sources and municipal wastewater treatment plants. Forest land is not assigned reductions because it is considered the most natural condition in the watershed.

The Baltimore Harbor Watershed Baseline Load and TMDL are presented in Table 7.

Table 7: Baltimore Harbor Watershed Baseline Load and TMDL

Baseline Load (ton/yr)	TMDL (ton/yr)	Total Reduction (%)
6,982	3,247	53

4.6 Load Allocations Between Nonpoint and Point Sources

Per USEPA regulation, all TMDLs need to be presented as a sum of Wasteload 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 2012a). The State reserves the right to allocate the TMDL among different sources in any manner that protects aquatic life from sediment related impacts.

Load Allocation

Individual LAs for each nonpoint land-use sector were calculated using the allocation methodology in the MD Phase I Watershed Implementation Plan (WIP), which was designed to be equitable, effective, and consistent with water quality standards (MDE 2010). The allocations were calculated by applying equal reductions to the *reducible* loads of all sectors. The *reducible* load is defined as the difference between the No Action (NA) scenario and the "Everything, Everyone, Everywhere" (E3) scenario. The NA scenario represents current land-uses without any sediment controls applied, while the E3 scenario represents the application of all possible BMPs and control technologies to current land-use. For more detailed information regarding the calculation of the LA, please see *Maryland's Phase I Watershed Implementation Plan for the Chesapeake Bay Total Maximum Daily Load.*

In the Baltimore Harbor watershed, urban land was identified as the only land use requiring reductions. All other land uses contributed less than 1% of the total load and were not reduced as they would produce no discernible reductions. Forest is not assigned reductions, as it represents the most natural condition in the watershed. Sediment loads from regulated urban lands under National Pollutant Discharge Elimination System (NPDES) permits are considered point source loads that must be included in the WLA portion of a TMDL (USEPA 2002).

In this document, the LA for the Baltimore Harbor watershed is expressed as one aggregate value for all nonpoint sources. For more detailed information regarding the Baltimore Harbor watershed TMDL nonpoint source LA, please see the technical memorandum to this document entitled *Nonpoint Sources of Sediment in the Baltimore Harbor Watershed.*

A summary of the baseline and load allocation for nonpoint sources is presented in Table 8. The percent reduction shown in Table 8 does not represent the reduction applied to reducible loads, but the required reduction between the allocation and the baseline load.

Wasteload Allocation
The WLA of the Baltimore Harbor watershed is allocated to two permitted source categories, the Wastewater WLA and the Stormwater WLA. The categories are described below.

Wastewater WLA
Wastewater permits with specific TSS limits and corresponding flow information are assigned a WLA. In this case, detailed information is available to accurately estimate the WLA. If specific TSS limits are not explicitly stated in the wastewater permit, then TSS loads are expected to be *de minimis*. If loads are *de minimis,* they pose little risk to the aquatic environment.

Wastewater permits with specific TSS limits can include:

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

There is one wastewater source with explicit TSS limits in the Baltimore Harbor watershed that contributes to the watershed sediment load. Sediment loads from both the Cox Creek Water Reclamation Facility (WRF) and Patapsco Wastewater Treatment Plant (WWTP) are not included in this analysis because they discharge into the tidal portion of the watershed, which is not included in this TMDL. Sediment loads from these facilities were addressed in the 2010 Chesapeake Bay TMDL for sediment in the PATMH segment.

Stormwater WLA
Per USEPA 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" (USEPA 2002). Phase I and II permits can include the following types of discharges:

- Small, medium, and large municipal separate storm sewer systems (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
- Mineral mining facilities that do not have TSS limits

USEPA currently recommends that WLAs for NPDES regulated stormwater discharges be expressed as different WLAs for different identifiable categories (e.g., separate WLAs for MS4 and industrial stormwater discharges). These categories should be defined as narrowly as available information allows (e.g., for municipalities, separate WLAs for each municipality and for industrial sources, separate WLAs for different types of industrial stormwater sources or dischargers). In general, states are encouraged to disaggregate the WLA to facilitate implementation. USEPA recognizes that available data and information are usually not detailed enough to determine WLAs for NPDES regulated stormwater discharges on an outfall-specific basis (USEPA 2014).

The Baltimore Harbor NPDES Stormwater WLA is based on reductions applied to the sediment load from the portion of the urban land-use in the watershed associated with NPDES regulated stormwater permits. The NPDES stormwater WLA is calculated in the same manner as the load allocation, described above. Some of these sources may also be subject to controls from other management programs. The Baltimore Harbor NPDES Stormwater WLA requires an overall reduction of 55% (see Table 8).

Table 8: Baltimore Harbor Watershed TMDL Reductions by Source Category

<table>
<tr><th></th><th colspan="2">Baseline Load Source Categories</th><th>Baseline Load (ton/yr)</th><th>TMDL Components</th><th>TMDL (ton/yr)</th><th>Reduction (%)</th></tr>
<tr><td rowspan="3">Baltimore Harbor Watershed contribution</td><td colspan="2">Nonpoint Source</td><td>177</td><td>LA</td><td>177</td><td>0</td></tr>
<tr><td rowspan="2">Point Source</td><td>Regulated Stormwater</td><td>6,804</td><td rowspan="2">WLA</td><td>3,069</td><td>55</td></tr>
<tr><td>Wastewater</td><td>1</td><td>1</td><td>0</td></tr>
<tr><td colspan="3">Total</td><td>6,982</td><td></td><td>3,247</td><td>53</td></tr>
</table>

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

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.

4.7 Margin of Safety

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 2012b). The MOS shall also account for any rounding errors generated in the various calculations used in the development of the TMDL. This TMDL was developed using an environmentally conservative approach that implicitly incorporates an MOS.

Specifically, as was described in Section 4.2, the reference watershed forest normalized EOS loads were chosen in a conservative manner. Analysis of the reference group *forest normalized sediment loads* indicates that the 75th percentile of the reference watersheds is a value of 4.5 and that the median value is 3.9. For this analysis, the *sediment loading threshold* was set at the median value of 3.9 (MDE 2006a). Use of the median as the threshold creates an environmentally conservative estimate, and results in an implicit MOS.

4.8 Summary of Total Maximum Daily Loads

The average annual Baltimore Harbor watershed TMDL is summarized in Table 9. The TMDL is the sum of the LA, NPDES Stormwater WLA, Wastewater WLA, and MOS. The LAs include nonpoint source loads generated within the Baltimore Harbor watershed. The attainment of water quality standards within the Baltimore Harbor watershed can only be achieved by meeting the average annual TMDL of TSS specified for the watershed within this report. The Maximum Daily Load (MDL) is summarized in Table 10 (See Appendix B for more details).

Table 9: Baltimore Harbor Watershed Average Annual TMDL of TSS (ton/yr)

TMDL	**=**	**LA_{BH}**		**NPDES Stormwater WLA_{BH}**	**+**	**Wastewater WLA_{BH}**	**+**	**MOS**
3,247	=	177	+	3,069	+	1	+	Implicit

Table 10: Baltimore Harbor Watershed Maximum Daily Load of TSS (ton/day)

MDL (ton/day)	**=**	**LA_{BH}**	**+**	**NPDES Stormwater WLA_{BH}**	**+**	**Wastewater WLA_{BH}**	**+**	**MOS**
15	=	1	+	14	+	0	+	Implicit

5.0 ASSURANCE OF IMPLEMENTATION

Section 303(d) of the CWA and current USEPA regulations require reasonable assurance that the sediment TMDL can and will be implemented (CFR 2012b). This section provides the basis for reasonable assurance that the sediment TMDL in the Baltimore Harbor watershed will be achieved and maintained.

While this TMDL establishes a sediment loading target for the watershed, watershed managers and other stakeholders should always remain cognizant that the endpoint of this TMDL, and hence the definition of its successful implementation, is based on in-stream biological health. Load reductions are critical to tracking this effort, since the TMDL target is defined as the point where sediment loads match those seen in reference watersheds, but the watershed cannot be delisted or classified as meeting water quality standards until it is demonstrated that the biological health of the stream system is no longer impaired by sediment. In planning any implementation efforts related to this TMDL, careful consideration should be given both to the sediment load reductions, and to the direct potential impacts on biological communities.

The Baltimore Harbor sediment TMDL is expected to be implemented in parallel with implementation efforts for the 2010 Chesapeake Bay TMDL for nutrients and sediment.. This implementation process should be designed to achieve both the sediment reductions needed within the Baltimore Harbor watershed and to meet target loads consistent with the Chesapeake Bay TMDL, established by EPA in 2010 (US EPA 2010a) and scheduled for full implementation by 2025. The Bay TMDL requires reductions of nitrogen, phosphorus and sediment loads throughout the Bay watershed to meet water quality standards that protect the designated uses in the Bay and its tidal tributaries. The sediment reductions for the Bay TMDL are independent of those needed to implement any TMDLs developed to address sediment-related impairments in Maryland's non-tidal waterbodies, however, their reduction goals and strategies do overlap. For example, the implementation planning framework, developed by the Bay watershed jurisdictions in partnership with EPA, provides a staged approach to achieving Bay TMDL sediment reduction goals that is also applicable to implementation of sediment TMDLs in local non-tidal watersheds. In short, sediment reductions required to meet the Chesapeake Bay TMDL will also support the restoration and protection of local water quality.

<u>Phase I MS4 Permit Implementation Plans</u>

MDE published the Final Determinations to issue Stormwater Permits to Baltimore City (November 2021), Baltimore County (November 2021), Anne Arundel County (November 2021), and the Maryland Department of Transportation State Highway Administration (November 2019) (MDE 2021a, 2021b, 2021c, 2019a). The permits state, "*By regulation at 40 CFR §122.44, BMPs and programs implemented pursuant to this permit must be consistent with applicable WLAs developed under [US]EPA approved TMDLs*".

Section IV.E. of the permit details requirements for *Restoration Plans and Total Maximum Daily Loads*. Within one year of permit issuance, the permittee is required to submit an implementation plan for each stormwater WLA approved by the USEPA prior to the effective date of the permit. For TMDLs approved after the permit, implementation plans are due within one year of the USEPA approval of the TMDL. Implementation plans should include the following: a detailed implementation schedule, the final date for meeting applicable WLAs, a detailed cost estimate for all elements of the plan, a system that evaluates and tracks implementation through monitoring or modeling to document progress towards meeting established benchmarks, deadlines, and stormwater WLAs, and a public participation program. An annual TMDL assessment report shall also be submitted to MDE. Many of the practices which are described in the permittees' stormwater WLA implementation plans may also be used by the permittees as retrofits for meeting their impervious area restoration requirements.

Stormwater retrofits can address both water quality and quantity. Examples of these retrofits include the reduction of impervious surfaces, modification of existing or installation of new stormwater structural practices, increased urban tree canopy, and stream restoration projects. Based on estimates by CBP, stormwater retrofit reductions range from as low as 10% for dry detention, to approximately 80% for wet ponds, wetlands, infiltration practices, and filtering practices (USEPA 2003).

For more information on the MS4 permits, please see Maryland's NPDES Municipal Separate Storm Sewer System (MS4) Permits.

General Permit for Discharges from Small MS4s

MDE published the Final Determination to Issue the General Permit for Discharges from Small Municipal Separate Storm Sewer Systems (MS4s) in April 2018. The permit states that MS4 owners and operators must meet the following requirement:

> *Attain applicable wasteload allocations (WLAs) for each established or approved Total Maximum Daily Load (TMDL) for each receiving water body, consistent with Title 33 of the U.S. Code (USC) 1342(p)(3)(B)(iii); 40 CFR § 122.44(k)(2)…*

Section V of the permit details requirements for *Chesapeake Bay Restoration and Meeting Total Maximum Daily Loads*. The general permit will require small MS4s to commence restoration efforts of existing developed lands that have little or no stormwater management. The five-year permit term requires permittees to develop planning strategies and work toward implementing water quality improvement projects. Restoration planning strategies and implementation schedules required under the general permit are consistent with addressing the water quality goals of the Chesapeake Bay TMDL by 2025. The general permit requires permittees to perform watershed assessments, identify water quality improvement opportunities, secure appropriate funding, and develop an implementation schedule to show the adequate impervious area restoration will be achieved to meet the 2025 deadlines in the Chesapeake Bay TMDL.

Stormwater retrofits can address both water quality and quantity. Examples of these retrofits include the reduction of impervious surfaces, modification of existing or installation of new stormwater structural practices, increased urban tree canopy, and stream restoration projects. Based on estimates by CBP, stormwater retrofit reductions range from as low as 10% for dry detention, to approximately 80% for wet ponds, wetlands, infiltration practices, and filtering practices (USEPA 2003).

For more information on the MS4 permits, please see Maryland's NPDES Municipal Separate Storm Sewer System (MS4) Permits.

General Permit For Discharges of Stormwater Associated With Industrial Activity (12-SW-A) and General Discharge Permit For Discharges from Mineral Quarries, Borrow Pits, and Concrete and Asphalt Plants (15-MM)

MDE published the Final Determination to Issue the General Permit for Discharges of Stormwater Associated With Industrial Activity in December 2018. MDE published the Final Determination to Issue the General Permit for Discharges from Mineral Quarries, Borrow Pits, and Concrete and Asphalt Plant in May 2017.

Both permits contain the following requirements, which insure consideration of TMDLs:

- *Provide to the Department data to support a showing that the discharge is not expected to cause or contribute to an exceedance of a water quality standard, and retain such data onsite with your SWPPP. To do this, you must provide data and other technical information to the Department sufficient to demonstrate:*
    - *i.) For discharges to waters without a EPA approved or established TMDL, that the discharge of the pollutant for which the water is impaired will meet in-stream water quality criteria at the point of discharge to the waterbody; or*
    - *ii.) For discharges to waters with an EPA approved or established TMDL, that there are sufficient remaining wasteload allocations in an EPA approved or established TMDL to allow your discharge and that existing dischargers to the waterbody are subject to compliance schedules designed to bring the waterbody into attainment with water quality standards.*

- *If you discharge to an impaired water, the Department will inform you if any additional monitoring, limits or controls are necessary for your discharge to be consistent with the assumptions of any available wasteload allocation in an EPA Approve*

For more information on this general permit, please see:
https://mde.maryland.gov/programs/Permits/WaterManagementPermits/Pages/stormwater.aspx

https://mde.maryland.gov/programs/Permits/WaterManagementPermits/Pages/amines.aspx

General Permit for Discharges of Stormwater Associated With Construction Activity

MDE issued the General Permit for Stormwater Associated with Construction Activity, MDRC (General Permit), referred to as the 14-GP, which took effect on January 1, 2015. At this time, the permit is administratively extended until the Department issues a renewed permit. The permit states the following requirements, which insure consideration of TMDLs:

> *Part V. CONSISTENCY WITH TOTAL MAXIMUM DAILY LOADS*
> *If the discharge covered by this permit enters a water with an established or approved Total Maximum Daily Load (TMDL), including the Chesapeake Bay TMDL and the Maryland Watershed Implementation Plan, the permittee must implement measures to ensure that the discharge of pollutants from the site is consistent with the assumptions and meets the requirements of the approved TMDL, including any specific wasteload allocation that has been established that would apply to the discharge.*

For more information on this general permit, please see:
https://mde.maryland.gov/programs/Water/wwp/Pages/gp_construction.aspx

2010 Chesapeake Bay TMDLs
Implementation of the TMDL for sediment in the Baltimore Harbor watershed is expected to occur in parallel with implementation efforts for the 2010 Chesapeake Bay TMDLs for nutrients and sediment in the PATMH and CB3MH Water Quality Segments. While the objectives of the two efforts differ, with the 2010 Bay TMDLs focused on tidal water quality and this TMDL targeting biological integrity in streams, many of the sediment reductions achieved through implementation activities should result in progress toward both goals.

The strategies for implementing the 2010 Bay TMDLs are described in Maryland's Phase I WIP (MDE 2010), Phase II WIP (MDE 2012), and Phase III WIP (MDE 2019b). The WIPs are the centerpieces of the State's "reasonable assurance" of implementation for the 2010 Bay TMDLs, and the strategies encompass a host of BMPs, pollution controls and other actions for all source sectors that cumulatively will result in meeting the State's 2025 targets, as verified by the Chesapeake Bay Water Quality Sediment Transport Model. In particular, the implementation of practices to reduce sediment loadings from the agricultural and urban stormwater sectors should result in decreased loads in the Baltimore Harbor watershed's streams.

Maryland Funding Programs
In response to the WIPs and the increased responsibility for local governments to achieve nutrient and sediment reduction goals, Maryland has continued to increase funding in the Chesapeake and Atlantic Coastal Bays Trust Fund. '*Historical and Projected Chesapeake*

Bay Restoration Spending: A Report to the Maryland General Assembly pursuant to the 2018 Joint Chairman's Report' about Section 40 of Maryland's Operating Budget. Even though the annual restoration funds for the four agencies [MDDNR, MDA, MDE, MDP] varies from year to year, the total restoration funds for the first three years of the its evaluated time period (FY00 – FY02) was $882,327,165, while the total for a more recent three year period (FY15 – FY17) was $2,657,862,414, an increase of 201.2 percent. This increase was driven in part by the creation and subsequent funding increases in the two primary Bay restoration Special Funds: The Bay Restoration Fund and the Chesapeake and Atlantic Coastal Bays 2010 Trust Fund (MDE et al. 2018). For more information on Maryland's implementation and funding strategies to achieve nutrient and sediment reductions throughout the State's portion of the Chesapeake Bay watershed, please see Maryland's Phase III Watershed Implementation Plan.

Some other examples of programs that can provide funding for local governments and agricultural sources include the Federal Nonpoint Source Management Program (§ 319 of the Clean Water Act), the Buffer Incentive Program (BIP), the State Water Quality Revolving Loan Fund and the Maryland Agricultural Water Quality Cost-Share Program.

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

Additional Biological Stressors

As has been stated previously in this report, the biological impairment in this watershed is due to multiple stressors (e.g. chlorides), not just sediment. While reducing TSS will bring about a water quality impact in terms of clarity, achieving a positive impact in stream biological communities might require several stressors to be addressed. These stressors were described in the Baltimore Harbor BSID report.

Many of the implementation actions to address sediment could concurrently address the other stressors identified in the BSID report. Since biological improvements will likely only be seen when multiple structural and pollutant stressors are addressed, watershed managers developing plans to address sediment should consider the effect of restoration projects on other stressors. Where possible, preference should be given to designs that address multiple stressors.

REFERENCES

CFR (Code of Federal Regulations). 2012a. *40 CFR* 130.2(i). https://www.gpo.gov/fdsys/pkg/CFR-2011-title40-vol22/pdf/CFR-2011-title40-vol22-sec130-2.pdf

___________. 2012b. *40 CFR 130.7*. https://www.gpo.gov/fdsys/pkg/CFR-2011-title40-vol22/pdf/CFR-2011-title40-vol22-sec130-7.pdf

Claggett, P., F. M. Irani, and R. L. Thompson. 2012. *Estimating the Extent of Impervious Surfaces and Turf Grass across Large Regions*. Annapolis, MD: United States Geological Survey, Chesapeake Bay Program Office.

Cochran, W. G. 1977. *Sampling Techniques*. New York: John Wiley and Sons.

COMAR (Code of Maryland Regulations). 2020a. *26.08.02.02 B*; 26.08.02.02-1. http://www.dsd.state.md.us/comar/comarhtml/26/26.08.02.02.htm (Accessed January 2020).

___________. 2020b. *26.08.02.08 K*. http://www.dsd.state.md.us/comar/comarhtml/26/26.08.02.08.htm (Accessed January 2020).

___________. 2020c. *26.08.02.07 A*. http://www.dsd.state.md.us/comar/comarhtml/26/26.08.02.07.htm (Accessed January 2020).

___________. 2020d. *26.08.02.04*. http://www.dsd.state.md.us/comar/comarhtml/26/26.08.02.04.htm (Accessed January 2020).

Klauda, R., P. Kazyak, S. Stranko, M. Southerland, N. Roth, and J. Chaillou. 1998. The Maryland Biological Stream Survey: A State Agency Program to Assess the Impact of Anthropogenic Stresses on Stream Habitat Quality and Biota. *Environmental Monitoring and Assessment* 51: 299-316.

MDE (Maryland Department of the Environment). 2006a. *A Methodology for Addressing Sediment Impairments in Maryland's Watersheds*. Baltimore, MD: Maryland Department of the Environment. Also Available at http://www.mde.state.md.us/assets/document/Sediment%20TMDL%20Method%20Report_20070728.pdf

_________. 2006b. Total Maximum Daily Loads of Fecal Bacteria for the Non-Tidal Baltimore Harbor Basin in Baltimore City, Baltimore County, and Anne Arundel

County, Maryland. Baltimore, MD: Maryland Department of the Environment. Available at http://www.mde.state.md.us/programs/Water/TMDL/ApprovedFinalTMDLs/Pages/Programs/WaterPrograms/TMDL/approvedfinaltmdl/tmdl_final_piscataway_creek_fc.aspx (Accessed April, 2015).

___________. 2009a. *Maryland Biological Stressor Identification Process*. Baltimore, MD: Maryland Department of the Environment. Also Available at: http://www.mde.state.md.us/programs/Water/TMDL/Documents/BSID_Reports/BSID_Methodology_Final_2009.pdf

__________. 2009b. *Updates to A Methodology for Addressing Sediment Impairments in Maryland's Watersheds for Sediment Total Maximum Daily Loads (TMDLs) developed starting in Fiscal Year (FY) 2009.* Baltimore, MD: Maryland Department of the Environment. Also Available at: http://www.mde.state.md.us/programs/Water/TMDL/ApprovedFinalTMDLs/Documents/www.mde.state.md.us/assets/document/Methodology_Sed-NT_Addendum_20090505.pdf

__________. 2010. *Maryland's Phase I Watershed Implementation Plan for the Chesapeake Bay Total Maximum Daily Load*. Baltimore, MD: Maryland Department of the Environment. Also available at http://www.mde.marylnad.gov/programs/Water/TMDL/TMDLImplementation/Pages/Final_Bay_WIP_2010.aspx.

___________. 2011. *Maryland Tier II Dataset.* Baltimore, MD: Maryland Department of the Environment.

___________. 2012. *Maryland's Phase II Watershed Implementation Plan for the Chesapeake Bay Total Maximum Daily Load*. Baltimore, MD: Maryland Department of the Environment. Also available at http://www.mde.state.md.us/programs/Water/TMDL/TMDLImplementation/Pages/FINAL_PhaseII_WIPDocument_Main.aspx.

___________. 2014a. *2014 Integrated Report of Surface Water Quality in Maryland*. Baltimore, MD: Maryland Department of the Environment. Also available at: http://www.mde.state.md.us/programs/Water/TMDL/Integrated303dReports/Pages/2014IR.aspx

___________. 2014b. *Biological Assessment Methodology for Wadeable Streams*. Baltimore, MD: Maryland Department of the Environment. Also Available at: http://www.mde.state.md.us/programs/Water/TMDL/Integrated303dReports/Documents/Assessment_Methodologies/Biological_Listing_Methodology-wadeablestreams_2014_Final%20(New%20links).pdf

___________. 2014c. *Watershed Report for Biological Impairment of the Baltimore Harbor Watershed in Baltimore City, Baltimore and Anne Arundel Counties, Maryland Biological Stressor Identification Analysis Results and Interpretation*. Baltimore, MD: Maryland Department of the Environment. Also available at: https://mde.maryland.gov/programs/Water/TMDL/Baltimore_Harbor_02130903/Baltimore_Harbor_BSID_Report_032814.pdf

___________. 2018. *2018 Integrated Report of Surface Water Quality in Maryland*. Baltimore, MD: Maryland Department of the Environment. Also available at: http://www.mde.maryland.gov/programs/Water/TMDL/Integrated303dReports/Pages/2018IR.aspx

___________. 2019a. *Municipal Separate Storm Sewer System Discharge Permit for the Maryland Department of Transportation State Highway Administration.* Baltimore, MD: Maryland Department of the Environment.
Also Available at:
https://mde.maryland.gov/programs/Water/StormwaterManagementProgram/Documents/Modified%20Permit%20for%20MDOT%20SHA.pdf

___________. 2019b. *Maryland's Phase II Watershed Implementation Plan for the Chesapeake Bay Total Maximum Daily Load*. Baltimore, MD: Maryland Department of the Environment. Also available at: https://mde.maryland.gov/programs/Water/TMDL/TMDLImplementation/Pages/Phase3WIP.aspx

___________. 2021a. *Municipal Separate Storm Sewer System Discharge Permit for Baltimore City.* Baltimore, MD: Maryland Department of the Environment. Also Available at:
http://www.mde.maryland.gov/programs/water/StormwaterManagementProgram/Pages/storm_gen_permit.aspx

___________. 2021b. *Municipal Separate Storm Sewer System Discharge Permit for Anne Arundel County.* Baltimore, MD: Maryland Department of the Environment.
Also Available at:
http://www.mde.maryland.gov/programs/water/StormwaterManagementProgram/Pages/storm_gen_permit.aspx

___________. 2021c. *Municipal Separate Storm Sewer System Discharge Permit for Baltimore County.* Baltimore, MD: Maryland Department of the Environment.
Also Available at:
http://www.mde.maryland.gov/programs/water/StormwaterManagementProgram/Pages/storm_gen_permit.aspx

MDE, MDDNR, MDA (Maryland Department of Agriculture), MDP (Maryland Department of Planning), DBM (Maryland Department of Budget and Management). 2018. *Historical and Projected Chesapeake Bay Restoration Spending*: *A Report to the Maryland General Assembly pursuant to the 2015 Joint Chairman's Report.*

MGS (Maryland Geological Survey). 2012. *A Brief Description of the Geology of Maryland*. http://www.mgs.md.gov/esic/brochures/mdgeology.html

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

QLME (Quirk, Lawler and Matusky Engineers). 1973. Water Quality of Baltimore Harbor. Prepared for the Maryland Environmental Service. Quirk, Lawyer and Matusky Engineers, Tappan, NY.

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

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

Roth, N. E., M. T. Southerland, J. C. Chaillou, G. M. Rogers, and J. H. Volstad. 2005. Maryland Biological Stream Survey 2000-2004: Volume IV: Ecological Assessment of Watersheds Sampled in 2003. Columbia, MD: Versar, Inc. with Maryland Department of Natural Resources, Monitoring and Assessment Division.

Southerland, M. T., G. M. Rogers, R. J. Kline, R. P. Morgan, D. M. Boward, P. F. Kazyak, R. J. Klauda and S. A. Stranko. 2005. New biological indicators to better assess the condition of Maryland Streams. Columbia, MD: Versar, Inc. with Maryland Department of Natural Resources, Monitoring and Assessment Division. CBWP-MANTA-EA-05-13. Available at http://www.dnr.state.md.us/streams/pubs/ea-05-13_new_ibi.pdf

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

US Census Bureau. 2010. *2010 Census*. Prince George's, DC: US Census Bureau.

USDA (United States Department of Agriculture). 1982. *1982 Census of Agriculture*. Prince George's, DC: United States Department of Agriculture.

____________. 1983. Sediment Sources, Yields, and Delivery Ratios. In *National Engineering Handbook, Section 3, Sedimentation*. Prince George's, DC: United States Department of Agriculture, Natural Resources Conservation Service.

____________. 1987. *1987 Census of Agriculture*. Prince George's, DC: United States Department of Agriculture.

____________. 1992. *1992 Census of Agriculture*. Prince George's, DC: United States Department of Agriculture.

____________. 1997. *1997 Census of Agriculture*. Prince George's, DC: United States Department of Agriculture.

____________. 2002. *2002 Census of Agriculture*. Prince George's, DC: United States Department of Agriculture.

____________. 2006. *State Soil Geographic (STATSGO) Database for Maryland*. Prince George's, DC: United States Department of Agriculture, Natural Resources Conservation Service. Also available at http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm.

USEPA (U.S. Environmental Protection Agency). 2002. *Establishing Total Maximum Daily Load (TMDL) Wasteload Allocations (WLAs) for Storm Water Sources and NPDES Permit Requirements Based on Those WLAs*. Prince George's, DC: U.S. Environmental Protection Agency.

___________. 2003. Stormwater Best Management Practice Categories and Pollutant Removal Efficiencies. Annapolis, MD: U.S. Environmental Protection Agency with Chesapeake Bay Program.

___________. 2004. *Agricultural BMP Descriptions as Defined for the Chesapeake Bay Program Watershed Model*. Annapolis, MD: U.S. Environmental Protection Agency with Chesapeake Bay Program.

___________. 2006. Framework for Developing Suspended and Bedded Sediments (SABS) Water Quality Criteria. USEPA Science Advisory Board Consultation, EPA Office of Water, Office of Science and Technology, May 2006.

___________. 2007. Options for the Expression of Daily Loads in TMDLs. Washington, DC: U.S. Environmental Protection Agency, Office of Wetlands, Oceans & Watersheds. Also available at www.epa.gov/owow/tmdl/draft_daily_loads_tech.pdf.

___________. 2010a. *Chesapeake Bay Total Maximum Daily Load for Nitrogen, Phosphorus, and Sediment*. Annapolis, MD: U.S. Environmental Protection Agency, Chesapeake Bay Program Office. Also available at: https://www.epa.gov/chesapeake-bay-tmdl/chesapeake-bay-tmdl-document

___________. 2010b. *Chesapeake Bay Phase 5.3 Community Watershed Model*. Annapolis, MD: U.S. Environmental Protection Agency, Chesapeake Bay Program Office. Also available at: http://www.chesapeakebay.net/what/programs/modeling/phase_5.3_watershed_model

___________. 2014. *Revisions to the November 22, 2002 Memorandum "Establishing Total Maximum Daily Load (TMDL) Wasteload Allocations (WLAs) for Storm Water Sources and NPDES Permit Requirements Based on Those LAs".* Prince George's, DC: U.S. Environmental Protection Agency.

APPENDIX A – Watershed Characterization Data

Table A-1: Reference Watersheds in the Western Coastal Plain Physiographic Region

MD 8-Name	MD 8-digit	Percent Stream Mile BIBI/FIBI < 3.0 (%)[1,2]	Forest Normalized Sediment Load[3]
Potomac River - Middle Tidal	02140102	14.3	2.46
Breton Bay	02140104	16.7	3.81
St. Clements Bay	02140105	16.7	4.30
Wicomico River	02140106	20.0	4.80
Gilbert Swamp	02140107	17.6	4.72
Zekiah Swamp	02140108	14.3	3.91
Nanjemoy Creek	02140110	17.6	2.88
Median			**3.9**
75th percentile			**4.5**

Notes:
[1] Percent stream mile is based on the percentage of MBSS stations with BIBI and/or FIBI scores significantly lower than 3.0 within the watershed (MDE 2014b).
[2] The threshold to determine if an 8-digit watershed is impaired for impacts to biological communities (IBI<3.0), is based on a comparison to reference conditions (MDE 2014b).
[3] Forest normalized sediment loads based on Maryland watershed area only (consistent with MBSS random monitoring data).

APPENDIX B – Technical Approach Used to Generate Maximum Daily Loads

Summary

This appendix documents the technical approach used to define maximum daily loads (MDLs) of sediment consistent with the average annual TMDL in the Baltimore Harbor 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 USEPA guidance on generating daily loads for TMDLs (USEPA 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 P5.3.2 Watershed Model Sediment Loads:** As described in Section 2.2, the nonpoint source sediment loads from the Baltimore Harbor watershed are based on EOS loads from the CBP P5.3.2 watershed model. The CBP P5.3.2 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 USEPA 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 (USEPA 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 USEPA guidance and available information.

Options considered

The draft USEPA 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 (USEPA 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 Baltimore Harbor watershed MDLs.

<u>Level of Resolution</u>

The level of resolution pertains to the amount of detail used in specifying the MDL. The draft USEPA guidance document on daily loads provides three categories of options for level of resolution, all of which are potentially applicable for the Baltimore Harbor 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. **Variable daily load:** This option allows the MDL to vary as function of a particular characteristic that affects loading or waterbody response, such as flow or season.

<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 (USEPA 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 maximum daily load 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 maximum daily load is a value that will be exceeded with a pre-defined probability:** In this option, a "reasonable" upper bound percentile is selected for the 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.
3. **The maximum daily load 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.

Selected Approach

The approach selected for defining an Baltimore Harbor Watershed 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 Baltimore Harbor watershed
- Approach for Wastewater Point Sources within the Baltimore Harbor watershed

Approach for Nonpoint Sources and Stormwater Point Sources within the Baltimore Harbor Watershed

The level of resolution selected for the Baltimore Harbor 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 Baltimore Harbor watershed. Currently, the best available data is the CBP P5.3.2 model daily time series calibrated to long-term average annual loads (per land-use). The CBP reach simulation results are calibrated to daily monitoring information for watershed segments with a flow typically greater than 100 cfs.

The probability level selected for the Baltimore Harbor MDL was a pre-defined exceedance probability. Based on the USEPA guidance, "in the case where a long term daily load dataset is available, in which multiple years of data and a variety of environmental conditions are represented, it is preferable to select a maximum daily load as a percentile of the load distribution. A sufficiently long-term dataset allows for minimizing error associated with the fact that the daily load dataset might not exactly match a normal or lognormal distribution" (USEPA 2007). The exact percentile value to be used should be determined by the TMDL developer, based on site specific characteristics.

This CBP P5.3.2 model output provides a time series of daily TSS loads from the Baltimore Harbor watershed, covering a 20-year period from 1985 to 2005. Because this is a long-term time series, it captures a broad range of meteorological and hydrological conditions and also minimizes the effect of potential statistical variances. As with the calculation of the TMDL value, environmentally conservative principles are also used in the MDL calculation. A 95th percentile flow was selected for the MDL, meaning that there is a 5% probability that daily loads will exceed this value. This percentile was chosen rather the 99th (which is also considered acceptable based on USEPA), in order to avoid the influence of extreme weather events and statistical outliers. Since the model daily time series represents the current (baseline) condition, the reduction percentage applied to each sector of the TMDL, was applied directly to the 95th percentile values to calculate the final MDL value.

$$MDL = 95th\ percentile\ of\ daily\ load\ series\ values * Reduction\ \%\ from\ TMDL \quad \text{(Eq B-1)}$$

Where:
MDL = Maximum Daily Load, ton/day
Daily load series values = CBP 5.3.2 output
TMDL = Long term average annual load, ton/yr

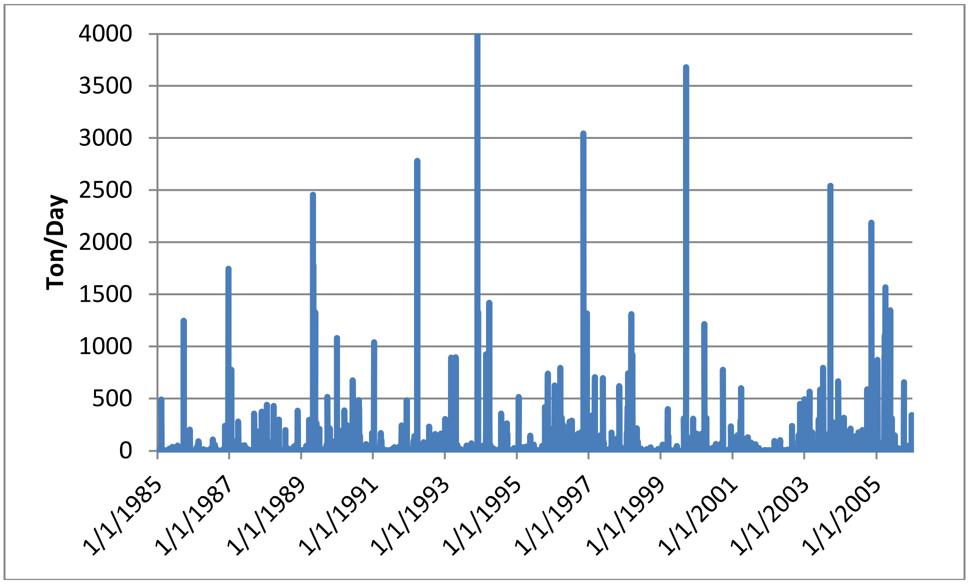

Figure B-1: Daily Time Series of CBP River Segment Daily Simulation Results for the Baltimore Harbor Watershed

<u>Approach for Wastewater Point Sources within the Baltimore Harbor 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 and a conversion factor of 0.0042 to obtain an MDL in ton/day. 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 (USEPA 1991). The long-term average annual TMDL was converted to maximum daily limits using Table 5-2 of the TSD assuming a coefficient of variation of 0.6 and a 99^{th} percentile probability. This results in a dimensionless multiplication factor of 3.11. The average annual Baltimore Harbor 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 Baltimore Harbor MDLs. The final results are presented in Table B-1.

- Calculation Approach for Nonpoint Sources and Stormwater Point Sources within the Baltimore Harbor Watershed

The MDL for Nonpoint Sources and Stormwater Point Sources within the Baltimore Harbor Watershed is based upon the 95^{th} percentile value of the CBP P5.3.2 model daily load time series, reduced by the same percentage as the corresponding TMDL value. The 95^{th} percentile load of the daily times series is 32 tons/day and with a TMDL reduction of 53%, it results in a total watershed MDL of 15 tons/day. The total MDL is subdivided in accordance with the same ratios present in the TMDL.

- Calculation Approach for Wastewater Point Sources within the Baltimore Harbor Watershed
    - For permits with a daily maximum limit:

Wastewater WLA_{BH} (ton/day) = Permit flow (millions of gallons per day (MGD)) * Daily maximum permit limit (milligrams per liter (mg/l)) * 0.0042, where 0.0042 is a combined factor required to convert units to ton/day

- For permits without a daily maximum limit:

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

The aggregate MDL for the point sources in the watershed is negligible.

Table B-1: Baltimore Harbor Watershed Maximum Daily Loads of Sediment/TSS (ton/day)

MDL (ton/day)	=	LA_{BH}	+	NPDES Stormwater WLA_{BH}	+	Wastewater WLA_{BH}	+	MOS
15	=	1	+	14	+	0	+	Implicit