Total Maximum Daily Load of Polychlorinated Biphenyls in the West River and Rhode River, Mesohaline Segments, Anne Arundel County, Maryland

FINAL

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List of Abbreviations

Adj-SediBAF	Adjusted Sediment Bioaccumulation Factor
Adj-tBAF	Adjusted Total Bioaccumulation Factor
ARS	Agricultural Research Service
BAF	Bioaccumulation Factor
BCF	Bioconcentration Factor
BMP	Best Management Practice
BSAF	Biota-sediment accumulation factor
CBP	Chesapeake Bay Program
CFR	Code of Federal Regulations
COMAR	Code of Maryland Regulations
CSF	Cancer Slope Factor
CV	Coefficient of Variation
CWA	Clean Water Act
DEM	Digital Elevation Model
DOC	Dissolved Organic Carbon
DMR	Daily Monitoring Record
DRBC	Delaware River Basin Commission
EOF	Edge of Field
EOS	Edge of Stream
EPA	U.S. Environmental Protection Agency
FIBI	Fish Index of Biotic Integrity
Ft	Feet
GIS	Geographic Information System
G	Gram
Kg	Kilogram
Km^2	Square Kilometer
Kow	PCB Octanol-Water Partition Coefficient
L	Liter
Lbs	Pounds
LA	Load Allocation
LMA	Land Management Administration
LRP-MAP	Land Restoration Program Geospatial Database
M^2	Square meter
M^3	Cubic meter
MD	Maryland
MDE	Maryland Department of the Environment

MDL	Maximum Daily Load
mg	Milligram
MGD	Million gallons per day
MOS	Margin of Safety
MS4	Municipal Separate Storm Sewer Systems
ng	Nanogram
NOAA	National Oceanic & Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
PCB	Polychlorinated Biphenyl
POC	Particulate Organic Carbon
Ppb	Parts per billion
Ppt	Parts per trillion
RUSLE2	Revised Universal Soil Loss Equation Version II
SediBAF	Sediment Bioaccumulation Factor
SIC	Standard Industrial Classification
TMDL	Total Maximum Daily Load
tBAF	Total Bioaccumulation Factor
tPCB	Total PCB
TSD	Technical Support Document
TSS	Total Suspended Solids
UMCES	University of Maryland Center for Environmental Science
USDA	United States Department of Agriculture
USGS	United States Geological Survey
VA	Virginia
VCP	Voluntary Cleanup Program
WLA	Wasteload Allocation
WQA	Water Quality Analysis
WQBEL	Water Quality Based Effluent Limit
WQLS	Water Quality Limited Segment
WQS	Water Quality Standard
WWTP	Waste Water Treatment Plant
µg	Microgram

EXECUTIVE SUMMARY

This document, upon approval by the U.S. Environmental Protection Agency (EPA), establishes a Total Maximum Daily Load (TMDL) for Polychlorinated Biphenyls (PCBs) in the West and Rhode Rivers Mesohaline Chesapeake Bay Segments (2012 *Integrated Report of Surface Water Quality in Maryland* Assessment Unit ID:MD-WST-RHMH-02131004). Section 303(d) of the federal Clean Water Act (CWA) and the EPA's implementing regulations direct each State to identify and list waters, known as water quality limited segments (WQLSs), in which current required controls of a specified substance are inadequate to achieve water quality standards (WQSs). For each WQLS, the State is to either establish a TMDL of the specified substance that the waterbody can receive without violating WQSs, or demonstrate that WQSs are being met (CFR 2013a).

Maryland WQSs specify that all surface waters of the State shall be protected for water contact recreation, fishing, and the protection of aquatic life and wildlife (COMAR 2013a). The designated use of the tidal portion of the West River 8-digit basin which includes the Rhode River watershed (Basin Code: 02131004) is Use II – *Support of Estuarine and Marine Aquatic Life and Shellfish Harvesting* (COMAR 2013b). The Maryland Department of the Environment (MDE) has identified the tidal portion of the West River 8-digit basin which includes the Rhode River watershed (Integrated Report Assessment Unit ID: MD-WST-RHDMH-02131004) on the State's 2012 Integrated Report as impaired by PCBs in fish tissue (2006). The Maryland Department of the Environment (MDE) has identified the waters of the West River Mesohaline Chesapeake Bay Segment (Integrated Report Assessment Unit ID: MD-WSTMH) on the State's 2012 Integrated Report as impaired by nutrients (nitrogen & phosphorus) (1996 & 2012), total suspended solids (1996), and fecal coliform (1996). MDE has identified the waters of the Rhode River Mesohaline Chesapeake Bay Segment (Integrated Report Assessment Unit ID: MD-RHDMH) on the State's 2012 Integrated Report as impaired by nutrients (nitrogen & phosphorus) (1996 & 2012), and fecal coliform (1996). MDE has indentified the watershed of the West River (Integrated Report Assessment Unit ID: MD-02131004) on the State's 2012 Integrated Report as impaired by total suspended solids (2012) and sulfates (2012). The Fecal coliform TMDLs for the restricted areas in the West River watershed were approved by the EPA in 2006. The Chesapeake Bay nutrient and sediment TMDLs, which was approved by the EPA in December 2010, has addressed the nutrient and sediment impairment listing for the West and Rhode Rivers Mesohaline Chesapeake Bay Segments. The TMDL established herein by MDE will address the total PCB (tPCB) listing for the waters of the West and Rhode Rivers Mesohaline Chesapeake Bay Segments. The total suspended solid and sulfates impairment listing for the 1st- through 4th-order streams in the West River 8-digit watershed (MDE 2012) will be addressed at a future date. From this point on in the document the "West and Rhode Rivers Mesohaline Chesapeake Bay Segments" will be referred to as the "West and Rhode Rivers".

PCBs are a class of man-made, carcinogenic compounds with both acute and chronic toxic effects, which are also bioaccumulative and do not readily break down in the natural environment. There are 209 possible chemical arrangements of PCBs, known as congeners, which consist of two phenyl groups and one to ten chlorine atoms. The congeners differ in the number and position of chlorine atoms along the phenyl groups. PCBs were manufactured and used for a variety of industrial applications and sold as mixtures under various trade names commonly known as Aroclors (QEA 1999). Sixteen different Aroclor mixtures were produced, each formulated based on a specific chlorine composition by mass. PCBs are a concern to human health, as regular consumption of fish containing elevated levels of PCBs will cause bioaccumulation within the fatty tissues of humans, which can potentially lead to the development of cancer.

Since the West and Rhode Rivers were identified as impaired for PCBs in fish tissue, the overall objective of the tPCB TMDL established in this document is to ensure that the "fishing" designated use, which is protective of human health related to the consumption of fish, in the river is supported. However, this TMDL will also ensure the protection of all other applicable designated uses within the river. This objective was achieved via the use of extensive field observations and a one-segment Tidal Prism Model. The model incorporates the long term influences of freshwater discharge, dispersion, and exchanges between the water column and bottom sediments, thereby representing the dynamic transport within the West and Rhode Rivers. The water quality model is used to:

1. Estimate and predict PCB transport and fate based on observed tPCB concentrations in the water column and bottom sediments of the West and Rhode Rivers;
2. Simulate long-term tPCB concentrations in the water column and bottom sediments;
3. Estimate the load reductions necessary to meet the TMDL water column and sediment endpoint concentrations, which are derived from the Integrated Report fish tissue listing threshold and site specific total Bioaccumulation Factors (tBAFs);
4. Estimate the amount of time necessary for tPCB concentrations to reach the TMDL water column and sediment endpoints, given the required load reductions from the individual source sectors and an estimated rate of decline in the tPCB concentrations at the boundary between the West and Rhode Rivers and the Chesapeake Bay mainstem.

The CWA, as recently interpreted by the United States District Court for the District of Columbia, requires TMDLs to be protective of all the designated uses applicable to a particular waterbody (US District Court for the District of Columbia, 2011). Within the West and Rhode Rivers, these designated uses, as described previously, include "water contact recreation," "fishing," "the protection of aquatic life and wildlife," and "Support of Estuarine and Marine Aquatic Life and Shellfish Harvesting." The TMDL presented herein was developed specifically to be supportive of the "fishing" designated use, ensuring that the consumption of fish does not impact human health, thus addressing the impairment listings for "PCBs in fish tissue".

The water column and sediment TMDL endpoint tPCB concentrations applied within this analysis are derived from Maryland's Integrated Report fish tissue listing threshold tPCB concentration and site specific tBAFs. In the West and Rhode Rivers, the tPCB endpoint concentrations are lower than: 1) EPA's human health criterion tPCB water column concentration relative to fish consumption, and 2) both Maryland's freshwater and saltwater chronic criteria tPCB water column concentrations. This indicates that the TMDL is not only protective of the "fishing" designated use but also the "aquatic life" designated use, specifically the protection of "Support of Estuarine and Marine Aquatic Life and Shellfish Harvesting". Lastly, the designated use for "water contact recreation" is not associated with any potential human health risks due to PCB exposure. Dermal contact and consumption of water from activities associated with "water contact recreation" are not a significant pathway for the uptake of PCBs. The EPA human health criterion was developed solely based on organism consumption, as drinking water consumption does not pose any risk for cancer development at environmentally relevant levels. The only human health risk associated with PCB exposure is through the consumption of aquatic organisms, which is addressed by the water column and sediment tPCB endpoint concentrations applied within this TMDL developed to be supportive of the "fishing" designated use.

As part of this analysis, both point and nonpoint sources of PCBs have been identified throughout the West and Rhode Rivers watershed. Nonpoint sources include direct atmospheric deposition to the river, runoff from non-regulated watershed areas, resuspension and diffusion from bottom sediments, and tidal influence from the Chesapeake Bay mainstem. Point sources include National Pollutant Discharge Elimination System (NPDES) wastewater treatment plants (WWTPs) and regulated stormwater runoff within the watershed. Model estimated tPCB loads from these point and nonpoint sources represent the baseline conditions for the West and Rhode Rivers.

The objective of the TMDL established herein is to reduce current tPCB loads to the West and Rhode Rivers so that the water column and sediment TMDL endpoint tPCB concentrations are achieved. All TMDLs need to be presented as a sum of Wasteload Allocations (WLAs) for the identified point sources, Load Allocations (LAs) for nonpoint source loads generated within the assessment unit, and where applicable, natural background, tributary, and adjacent segment loads. Furthermore, all TMDLs must include a margin of safety (MOS) to account for lack of knowledge and the many uncertainties in the understanding and simulation of water quality parameters in natural systems (*i.e.*, the relationship between modeled loads and water quality) (CFR 2013a). The MOS is intended to account for such uncertainties in a manner that is conservative from the standpoint of environmental protection. An explicit MOS of 5% was incorporated into the analysis to account for such uncertainty.

A summary of the baseline load, TMDL and maximum daily load for the West and Rhode Rivers are presented in Table ES-1. When implemented, load reductions required under this TMDL will ensure that tPCB concentrations in the water column and sediment are at levels supportive of the “fishing” designated use. The transport of PCBs to the river from the Chesapeake Bay mainstem and from bottom sediment via resuspension and diffusion are currently estimated to be the major sources of PCBs. However, the load from resuspension and diffusion from bottom sediments is resultant from other point and nonpoint source inputs (both historic and current) and not considered to be a directly controllable source. In addition, this load is considered as an internal load within the modeling framework of the TMDL, therefore it is not included in the tPCB baseline load and TMDL allocation.

The water quality model developed for simulating ambient sediment and water column tPCB concentrations within the West and Rhode Rivers were used to determine the specific load reductions that would result in simulated tPCB concentrations in the sediment and water column that meet the TMDL endpoints. In this study, the model assumes that the tPCB concentrations in the Chesapeake Bay mainstem are decreasing at a rate of 5% per year as used in the Back River PCB TMDL study (MDE, 2011b). Given this rate of decline, the tPCB targets in both water column and sediment of the West and Rhode Rivers embayment will be met in about 16.8 years with the natural attenuation of tPCB concentration in the Chesapeake Bay mainstem. Loads from the watershed, including non-point and point sources, and atmospheric deposition only account for 3.2% of the total tPCB baseline load.Therefore, no reduction to these loads are necessary in order to achieve the TMDL. When the targets met, the tPCB loads from the Chesapeake Bay mainstem will be reduced about 57.8% including an explicit 5% Margin of Safety. At that time, the total load will be reduced by 53.6% from its baseline load.

Table ES-1: Summary of tPCB Baseline Loads, TMDL Allocations, Load Reductions, and Maximum Daily Loads (MDLs) in the West and Rhode Rivers

Source	Baseline Load (g/year)	Baseline Percentage (%)	TMDL (g/year)	Load Reduction (%)	MDL (g/day)
Chesapeake Bay Mainstem Influence	1,081.5	96.83	456.5	57.8	2.009
Direct Atmospheric Deposition	22.6	2.03	22.6	0	0.099
Non-regulated Watershed Runoff	11.0	0.99	11.0	0	0.048
Nonpoint Sources	***1,115.2***	***99.85***	***490.1***	***56.1***	***2.156***
WWTP	0.2	0.01	0.2	0	0.001
NPDES Regulated Stormwater	1.6	0.14	1.6	0	0.007
Point Sources	***1.7***	***0.15***	***1.7***	***0***	***0.008***
MOS (5%)	-	-	***25.9***	-	***0.114***
Total	**1,116.9**	**100.00**	**517.7**	**53.6**	**2.279**

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

Federal regulations require that TMDL analysis take into account the impact of critical conditions and seasonality on water quality (CFR 2013b). The intent of these requirements is to ensure that load reductions required by this TMDL, when implemented, will produce water quality conditions supportive of the designated use at all times. PCB levels in fish tissue become elevated due to long term exposure primarily through consumption of lower trophic level organisms, rather than a critical condition defined by acute exposure to temporary fluctuations in water column tPCB concentrations. Therefore, the selection of the annual average tPCB water column and sediment concentrations for comparison to the TMDL endpoints adequately considers the impact of seasonal variations and critical conditions on the “fishing” designated use in the river. Thus, the TMDL implicitly accounts for seasonal variations as well as critical conditions.

Despite the fact that PCB loads from resuspension and diffusion are not considered to be directly controllable, these load contributions are still expected to decrease over time as the result of the natural attenuation of PCBs in the environment. In addition, discovering and remediating any existing PCB land sources throughout the upstream Chesapeake Bay watershed via future TMDL development and implementation will further aid in the decline of the boundary condition tPCB concentrations and in meeting water quality goals in the river. MDE also monitors and evaluates concentrations of contaminants in recreationally caught fish, shellfish, and crabs throughout Maryland. MDE will use these monitoring programs to evaluate progress towards meeting the “fishing” designated use in the West and Rhode Rivers.

1.0 INTRODUCTION

This document, upon approval by the U.S. Environmental Protection Agency (EPA), establishes a Total Maximum Daily Load (TMDL) for Polychlorinated Biphenyls (PCBs) in the West and Rhode Rivers Mesohaline Chesapeake Bay Segments (2012 *Integrated Report of Surface Water Quality in Maryland* Assessment Unit ID:MD-WST-RHMH-02131004). Section 303(d) of the federal Clean Water Act (CWA) and the EPA's implementing regulations direct each State to identify and list waters, known as water quality limited segments (WQLSs), in which current required controls of a specified substance are inadequate to achieve water quality standards (WQSs). For each WQLS, the State is to either establish a TMDL of the specified substance that the waterbody can receive without violating WQSs, or demonstrate that WQSs are being met (CFR 2013a).

TMDLs are established to determine the pollutant load reductions required to achieve and maintain WQSs. A WQS 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, fish and shellfish propagation and harvest, etc. 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.

Maryland WQSs specify that all surface waters of the State shall be protected for water contact recreation, fishing, and the protection of aquatic life and wildlife (COMAR 2013a). The designated use of the tidal portion of the West River 8-digit basin which includes the Rhode River watershed (Basin Code: 02131004) is Use II – *Support of Estuarine and Marine Aquatic Life and Shellfish Harvesting* (COMAR 2013b). The Maryland Department of the Environment (MDE) has identified the tidal portion of the West River 8-digit basin which includes the Rhode River watershed (Integrated Report Assessment Unit ID: MD-WST-RHDMH-02131004) on the State's 2012 Integrated Report as impaired by PCBs in fish tissue (2006). The Maryland Department of the Environment (MDE) has identified the waters of the West River Mesohaline Chesapeake Bay Segment (Integrated Report Assessment Unit ID: MD-WSTMH) on the State's 2012 Integrated Report as impaired by nutrients (nitrogen & phosphorus) (1996 & 2012), total suspended solids (1996), and fecal coliform (1996). MDE has identified the waters of the Rhode River Mesohaline Chesapeake Bay Segment (Integrated Report Assessment Unit ID: MD-RHDMH) on the State's 2012 Integrated Report as impaired by nutrients (nitrogen & phosphorus) (1996 & 2012), and fecal coliform (1996). MDE has indentified the watershed of the West River (Integrated Report Assessment Unit ID: MD-02131004) on the State's 2012 Integrated Report as impaired by total suspended solids (2012) and sulfates (2012). The Fecal coliform TMDLs for the restricted areas in the West River watershed were approved by the EPA in 2006. The Chesapeake Bay nutrient and sediment TMDLs, which was approved by the EPA in December 2010, has addressed the nutrient and sediment impairment listing for the West and Rhode Rivers Mesohaline Chesapeake Bay Segments. The TMDL established herein by MDE will address the total PCB (tPCB) listing for the waters of the West and Rhode Rivers Mesohaline Chesapeake Bay Segments. The total suspended solid and sulfates impairment listing for the 1st- through 4th-order streams in the West River 8-digit watershed (MDE 2012) will be addressed at a future date.

From this point on in the document the "West and Rhode Rivers Mesohaline Chesapeake Bay Segments" will be referred to as the "West and Rhode Rivers".

PCBs are a class of man-made compounds that were manufactured and used for a variety of industrial applications. They consist of 209 related chemical compounds (congeners) that were manufactured and sold as mixtures under various trade names, commonly referred to as Aroclors (sixteen different Aroclor mixtures were produced, each formulated based on a specific chlorine composition by mass) (QEA 1999). Each of the 209 possible PCB compounds consists of two phenyl groups and one to ten chlorine atoms. The congeners differ in the number and position of the chlorine atoms along the phenyl group. From the 1940s to the 1970s, they were extensively used as heat transfer fluids, flame retardants, hydraulic fluids, and dielectric fluids because of their dielectric and flame resistant properties. They have been identified as a pollutant of concern due to the following:

1. They are bioaccumulative and can cause both acute and chronic toxic effects;
2. They have carcinogenic properties;
3. They are persistent organic pollutants that do not readily breakdown in the environment.

In the late 1970s, concerns regarding potential human health effects led the US government to take action to cease PCB production, restrict PCB use, and regulate the storage and disposal of PCBs. Despite these actions, PCBs are still being released into the environment through fires or leaks from old PCB containing equipment, accidental spills, burning of PCB containing oils, leaks from hazardous waste sites, etc. Since PCBs tend to bioaccumulate in aquatic organisms, including fish, people who consume fish may become exposed to PCBs. In fact, elevated levels of PCBs in edible parts of fish tissue are one of the leading causes of fish consumption advisories in the US.

The West and Rhode Rivers were originally identified as impaired by PCBs in fish tissue on Maryland's 2006 Integrated Report based on fish tissue tPCB data from MDE's monitoring program that exceeded the tPCB fish tissue listing threshold of 39 ng/g, or ppb – (wet weight) based on 4 meals per month by a 76 kg individual (MDE 2012). In addition to identifying impaired waterbodies on the State's Integrated Report, MDE also issues statewide and site specific fish consumption advisories (ranging from 0 to 4 meals per month) and recommendations (ranging from 4 to 8 meals per month). Current recreational fish consumption advisories suggest limiting the consumption of White Perch caught in the West and Rhode Rivers (MDE 2014a).

2.0 SETTING AND WATER QUALITY DESCRIPTION

2.1 General Setting

Location

The West and Rhode Rivers are located in Anne Arundel County, Maryland, on the Western Shore of the Chesapeake Bay. The West River is approximately 4 miles in length, with a watershed area of approximately 19,865 acres (80 square kilometers). Rhode River, one major tributary with a length about 4 miles, connects to the mouth of West River. The tidal range is 1.11 feet (0.34 meters) based on the United States National Oceanic and Atmospheric Administration tidal station in Kent Point, MD. The location of the West and Rhode Rivers watershed is shown in Figure 1.

Land Use

According to the United States Geological Survey's (USGS) 2006 land cover data (USGS 2013), which was specifically developed to be applied within the Chesapeake Bay Program's (CBP) Phase 5.3.2 watershed model, land use in the West River watershed (including the Rhode River) is a mixture of forest, urban, and agriculture. Forest occupies approximately 32.2% of the watershed, while 35.3% is water/wetland, 12.4% is urban, and 20.1% is agriculture. The land use distribution is displayed and summarized in Figures 2 and 3 as well as Table 1.

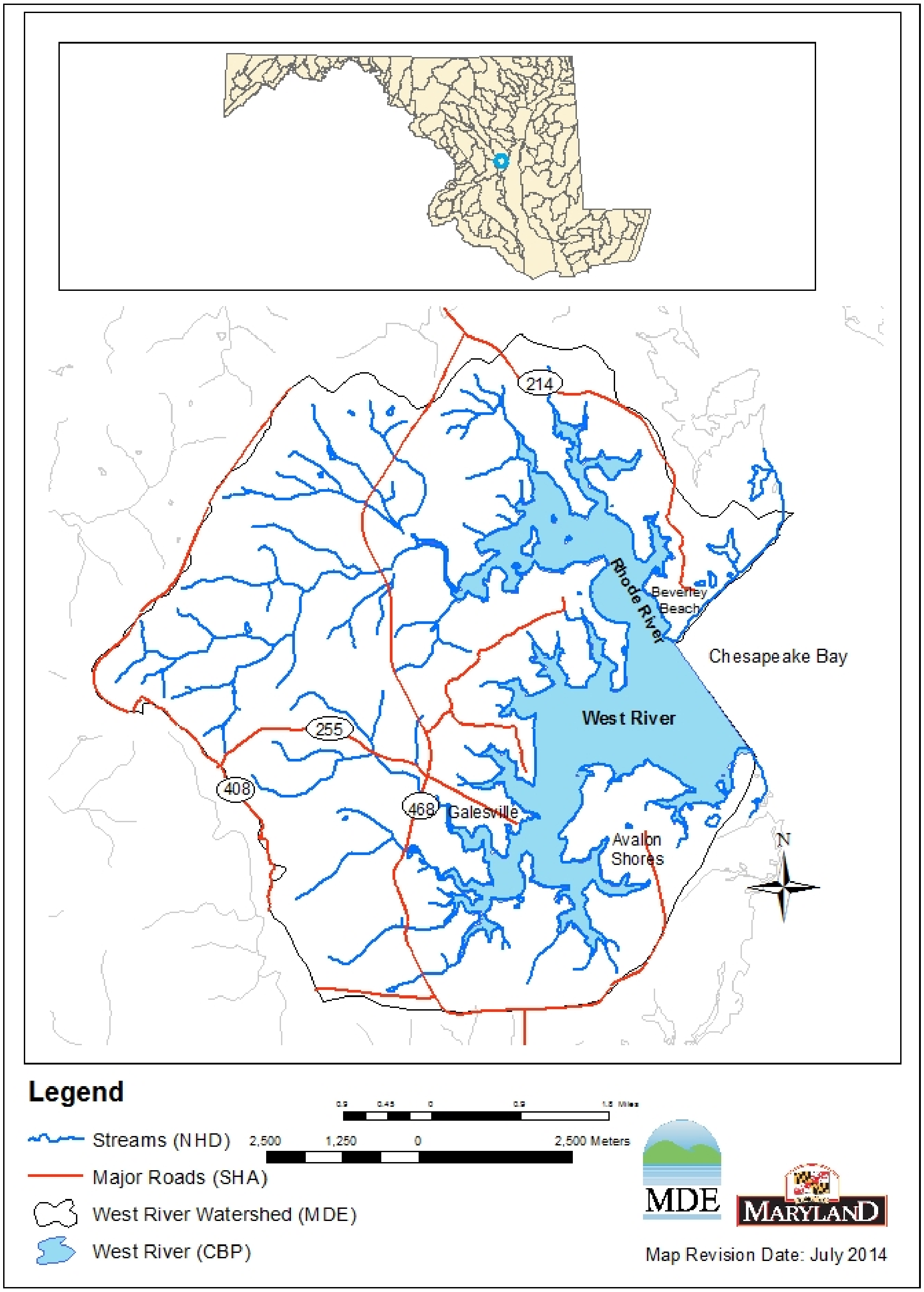

Figure 1: Location Map of the West and Rhode Rivers Watershed

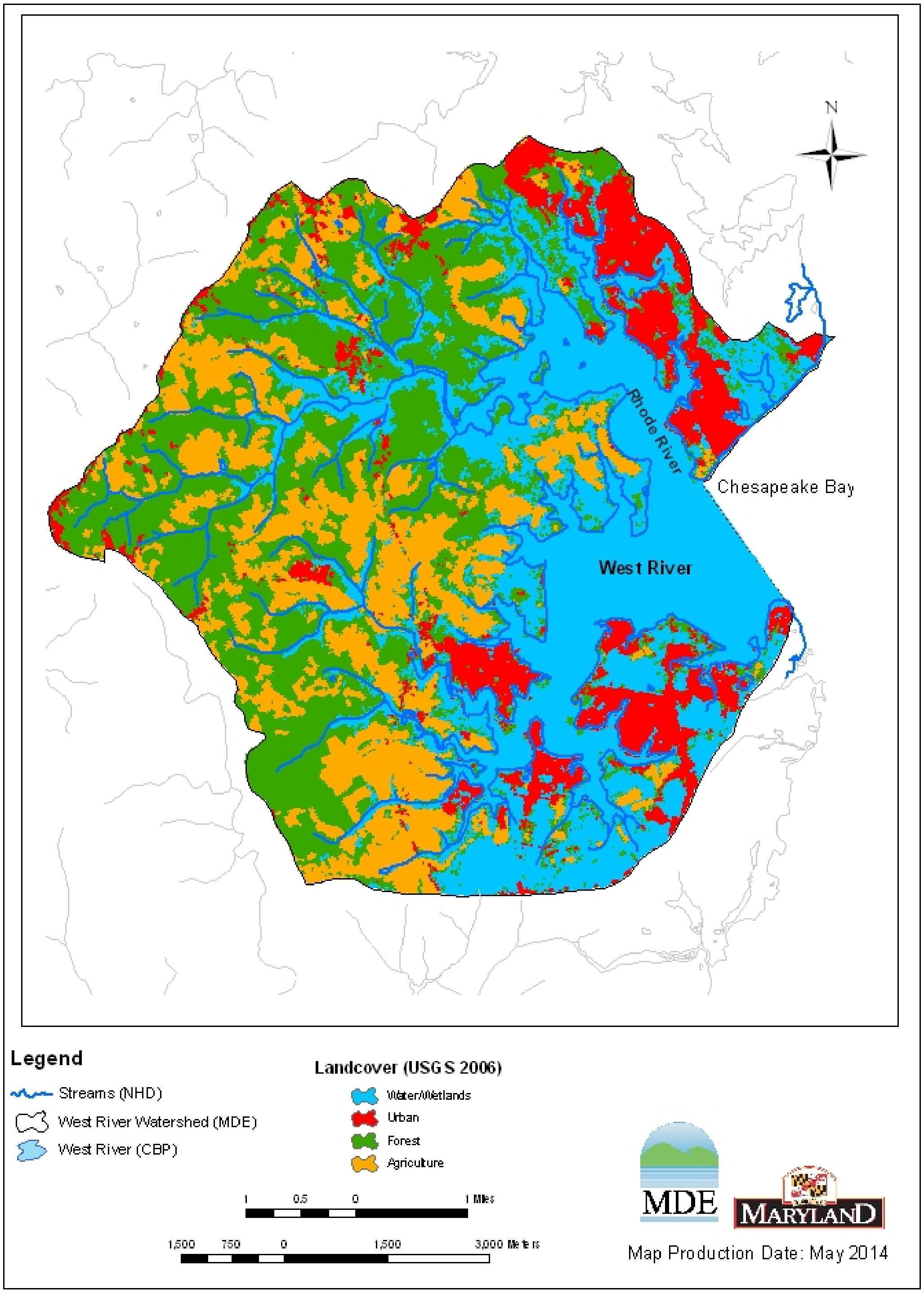

Figure 2: Land Use of the West and Rhode Rivers Watershed

Table 1: Land Use Distributions in the West and Rhode Rivers Watershed

Land Use	Area (km^2)	Percent (%) of Total
Water/Wetland	28.4	35.3
Urban	10.0	12.4
Forest	25.9	32.2
Agriculture	16.1	20.1
Total	**80.4**	**100.0**

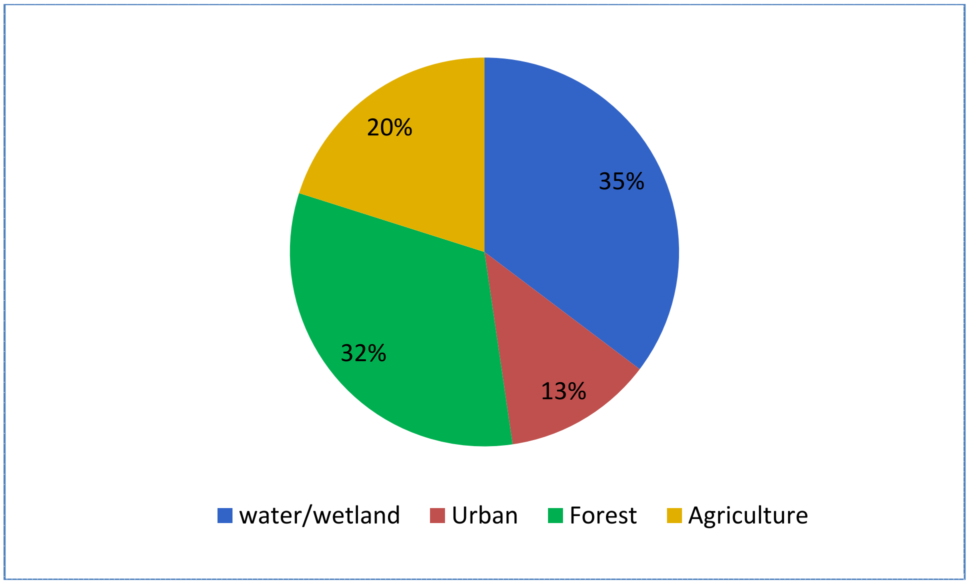

Figure 3: Land Use Distribution in the West and Rhode Rivers Watershed

2.2 Water Quality Characterization and Impairment

Maryland WQSs specify that all surface waters of the State shall be protected for water contact recreation, fishing, and protection of aquatic life and wildlife (COMAR 2013a). The designated use of the waters of the West and Rhode Rivers is use II– *Support of Estuarine and Marine Aquatic Life and Shellfish Harvesting* (COMAR 2013b). There are no "high quality", or Tier II, stream segments (Benthic Index of Biotic Integrity [BIBI] and Fish Index of Biotic Integrity [FIBI] aquatic life assessment scores > 4 [scale 1-5]) located within the direct drainage portions of the West and Rhode Rivers (COMAR 2014).

The State of Maryland has adopted three separate water column tPCB criteria: a criterion for the protection of human health associated with the consumption of PCB contaminated fish, as well as fresh and salt water chronic tPCB criteria for the protection of aquatic life. The freshwater aquatic life chronic criterion is used to assess non-tidal systems while the saltwater aquatic life chronic criterion is used to assess tidal systems. As the West and Rhode Rivers are tidal systems, the saltwater aquatic life chronic criterion is applied for assessing these waters. The Maryland human health tPCB criterion is set at 0.64 nanograms/liter (ng/L), or parts per trillion (ppt)

(COMAR 2013c; US EPA 2013a). The human health criterion is based on a cancer slope factor (CSF) of 2 milligrams/kilogram-day (mg/kg-day), a bioconcentration factor (BCF) of 31,200 liters/kilogram (L/kg), a cancer risk level of 10^{-5}, a lifetime risk level and exposure duration of 70 years, and a fish intake of 17.5 g/day. A CSF is used to estimate the risk of cancer associated with exposure to a carcinogenic substance (i.e. PCBs). A BCF is the ratio of the concentration of a chemical (i.e. tPCBs) in an aquatic organism to the concentration of the chemical in the water column. The slope factor is a toxicity value for evaluating the probability of an individual developing cancer from exposure to a chemical substance over a lifetime through ingestion or inhalation. A cancer risk level provides an estimate of the additional incidence of cancer that may be expected in an exposed population. A risk level of 10^{-5} indicates a probability of one additional case of cancer for every 100,000 people exposed. The Maryland fresh and salt water chronic aquatic life tPCB criterion are set at 14 ng/L and 30 ng/L, respectively (COMAR 2013c; US EPA 2013a). The water column mean tPCB concentration in the West and Rhode Rivers exceeds the human health tPCB criterion of 0.64 ng/L; however, none of the water column samples exceed the salt water aquatic life tPCB criterion of 30 ng/L.

In addition to the water column criteria described above, fish tissue monitoring can serve as an indicator of PCB water quality conditions. The Maryland fish tissue monitoring data is used to issue fish consumption advisories/recommendations and determine whether Maryland waterbodies are meeting the “fishing” designated use. Only data results from the analysis of skinless fillets, the edible portion of fish typically consumed by humans, is used for assessment purposes and development of this TMDL. Currently Maryland applies 39 ng/g as the tPCB fish tissue listing threshold, based on a fish consumption limit of 4 meals per month. When tPCB fish tissue concentrations exceed this threshold, the waterbody is listed as impaired for PCBs in fish tissue in Maryland’s Integrated Report as it is not supportive of the “fishing” designated use (MDE 2012). MDE collected fish tissue samples for PCB analysis in the West and Rhode Rivers and their watershed in 2002, 2003, 2011, and 2012. The tPCB concentrations in all 4 fish tissue composite samples collected in 2002 and 2003 exceed the listing threshold; 3 out of 7 fish tissue composite samples collected in 2011 and 2012 (common carp and white perch) exceed the listing threshold, demonstrating that a PCB impairment exists within the West and Rhode Rivers.

In 2011 and 2012, monitoring surveys were conducted by MDE to measure water column tPCB concentrations at tidal and non-tidal monitoring stations throughout the West and Rhode Rivers and their watershed. The non-tidal tPCB water column concentration data is required to characterize loadings from the watershed. Sediment samples were collected at tidal stations in 2011 to characterize tPCB sediment concentrations.

Table 2 summarizes the tPCB data for the fish tissue, water column, and sediment samples that were applied in developing this TMDL. Water column tPCB criteria and the tPCB fish tissue listing threshold are displayed in Table 3. Figure 4 shows a map of the PCB water column, sediment and fish tissue sampling locations in the West and Rhode Rivers. Appendix J contains figures of the sampling locations and tables of all of the tPCB data.

Table 2: Summary of Fish Tissue, Water Column, and Sediment tPCB Data

tPCB Data	Units	Sampling Years	Sample Size	tPCB Concentration		
				Mean	Maximum	Minimum
Fish Tissue	ng/g	2011, 2012	7	22.7	297	20.1
Water Column (tidal)	ng/L	2011, 2012	16	0.699	1.29	0.32
Water Column (non-tidal)	ng/l	2011, 2012	15	0.481	3.69	0.00
Sediment	ng/g	2011	9	9.03	25.1	2.11

Table 3: Water Column tPCB Criteria and tPCB Fish Tissue Listing Threshold

tPCB Criteria/Threshold	Concentration
Fresh Water Chronic Aquatic Life Criterion	14 ng/L
Salt water Chronic Aquatic Life Criterion	30 ng/L
Human Health Criterion	0.64 ng/L
Fish Tissue Listing Threshold	39 ng/g

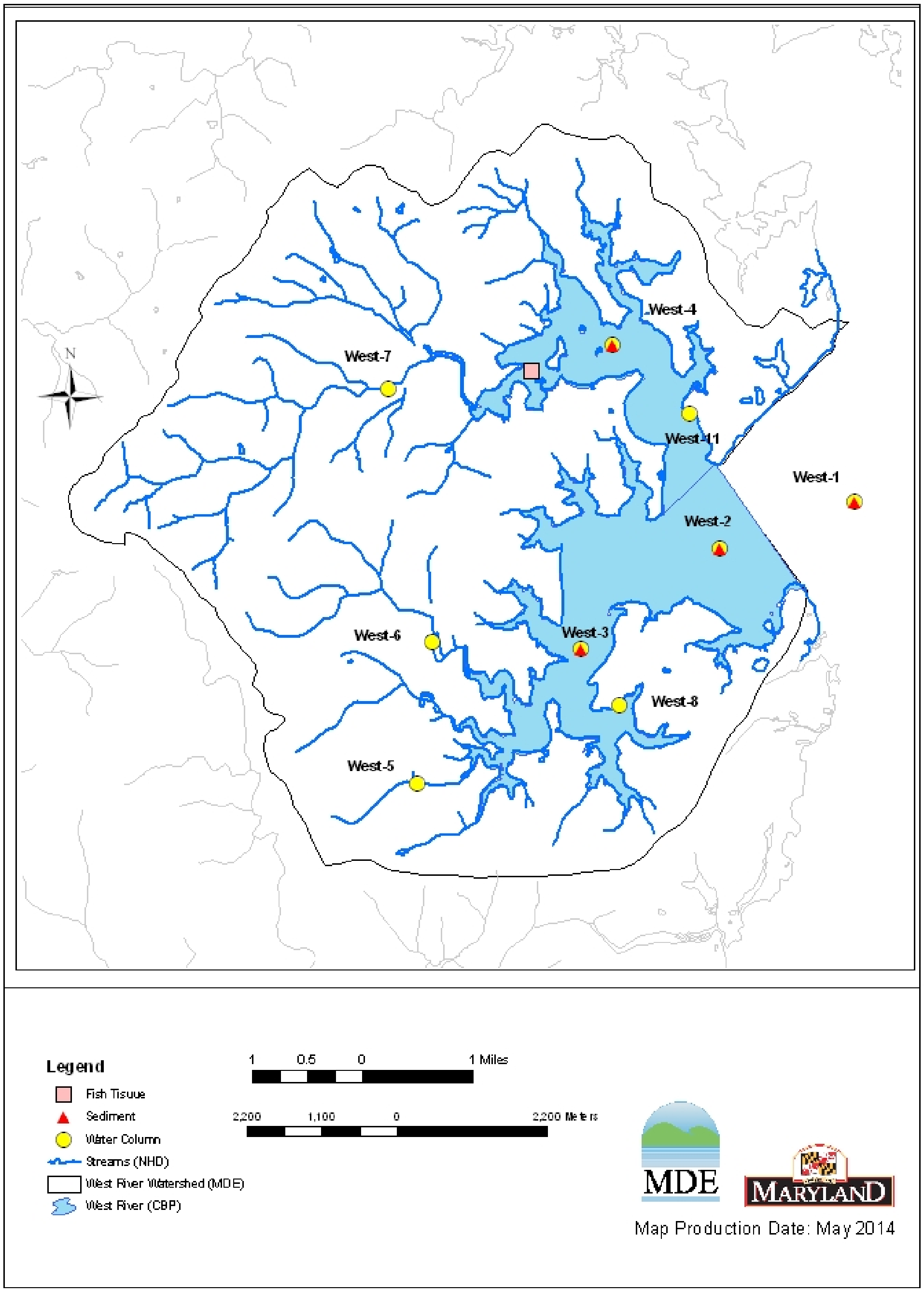

Figure 4: The Locations of PCB Water Column, Sediment and Fish Tissue Monitoring Stations in the West and Rhode Rivers

PCB analytical services were provided by the University of Maryland Center for Environmental Science (UMCES). Specific PCB congeners were identified and quantified by high resolution gas chromatography with GC-MS detection (Ayris *et al*. 1997, Holwell *et al*. 2007, Konietckka and Namiesnik 2008, Mydlová-Memersheimerová *et al*. 2009). This method is based on EPA method 8082 which was developed in 1996. Since that time the extraction protocols have been enhanced to fall in line with those of EPA method 1668a. UMCES uses a slightly modified version of the PCB congener specific method described in Ashley and Baker (1999), in which the identities and concentrations of each congener in a mixed Aroclor standard (25:18:18 mixture of Aroclors 1232, 1248, and 1262) are determined based on their chromatographic retention times relative to the internal standards (PCB 30 and PCB 204 and ten C13 labeled standards). Based on this method, upwards of 100 chromatographic peaks can be quantified. Some of the peaks contain one PCB congener, while many are comprised of two or more co-eluting congeners (Appendix A).

3.0 TARGETED WATER COLUMN AND SEDIMENT TMDL ENDPOINTS

As described in Section 2.2, MDE evaluates whether a waterbody meets PCB related WQSs based on three criteria: 1) the tPCB Integrated Report fish tissue listing threshold (39 ng/g, or ppb), 2) the human health tPCB water column criterion (0.64 ng/L, or ppt), or 3) the saltwater chronic tPCB criterion for protection of aquatic life (30 ng/L, or ppt). Since the West and Rhode Rivers were identified as impaired for PCBs in fish tissue, the overall objective of the tPCB TMDL established in this document is to ensure that the "fishing" designated use, which is protective of human health related to the consumption of fish, in the river is supported; however, this TMDL will also ensure the protection of all other applicable designated uses.

The tPCB fish tissue listing threshold was translated into an associated tPCB water column concentration to provide a TMDL endpoint as the water quality model only simulates tPCB water column and sediment concentration and does not incorporate a food web model to predict tPCB fish tissue concentrations (see Equation 3.1 and Calculation 3.1). This was accomplished using the Adjusted Total Bioaccumulation Factor (Adj-tBAF) of 64,256 L/kg for the West and Rhode Rivers, the derivation of which follows the method applied within the Potomac River tPCB TMDLs (Haywood and Buchanan, 2007). A total Bioaccumulation Factor (tBAF) is calculated per fish species, and subsequently the tBAFs are normalized by the median species lipid content and median dissolved tPCB water column concentration in their home range to produce the Adj-tBAF per species (see Appendix B for further details regarding the calculation of the Adj-tBAF). The most environmentally conservative of the Adj-tBAFs is then selected to calculate the TMDL endpoint water column concentration. This final water column tPCB concentration was then compared to the water column tPCB criteria concentrations, as described in Section 2.2, to ensure that all applicable criteria within the embayment would be attained (Calculation 3.1).

$$\text{tPCB Water Column Concentration} = \frac{\text{tPCB Fish Tissue Concentration Listing Threshold}}{\text{Adj - tBAF} \times \text{Unit Conversion}}$$

(Equation 3.1)

Substituting 39 ng/g into the equation results in:

$$\text{tPCB Water Column Concentration} = \frac{39\ \text{ng/g}}{64{,}256\ \text{L/kg} \times 1{,}000\ \text{g/kg}} = 0.61\ \text{ng/L}$$

which is < 0.64 ng/L (human health tPCB water column criterion).

(Calculation 3.1)

Based on this analysis, the water column tPCB concentration of 0.61 ng/L, derived from the tPCB fish tissue listing threshold, is selected as the TMDL endpoint for the river, which is more stringent than the value of 0.64 ng/L for human health, and the fresh and salt water chronic aquatic life tPCB criteria of 14 ng/L and 30 ng/L, respectively.

Similarly, in order to establish a tPCB TMDL endpoint for the sediment in the river, a target tPCB sediment concentration was derived from the tPCB fish tissue listing threshold as the water quality model only simulates tPCB sediment concentrations and not tPCB fish tissue concentrations (see Equation 3.2 and Calculation 3.2) to apply within this analysis as the sediment TMDL endpoint concentration. This was done using the Adjusted Sediment Bioaccumulation Factor (Adj-SediBAF) of 9.55 (unit-less) for the river, the derivation of which follows the method applied within the Potomac River tPCB TMDLs (Haywood and Buchanan 2007). Similar to the calculation of the water column Adj-tBAF, a sediment Bioaccumulation Factor (SediBAF) is calculated per fish species, and subsequently the SediBAFs are normalized by the median species lipid content and median organic carbon tPCB sediment concentration in their home range to produce the Adj-SediBAF (see Appendix B for further details regarding the calculation of the Adj-SediBAF). The most environmentally conservative of the Adj-SediBAFs is then selected to calculate the sediment TMDL endpoint tPCB concentration.

$$\text{tPCB Sediment Concentration} = \frac{\text{tPCB Fish Tissue Concentration Listing Threshold}}{\text{Adj - SediBAF}}$$

(Equation 3.2)

Substituting 39 ng/g into the equation results in:

$$\text{tPCB Sediment Concentration} = \frac{39 \text{ ng/g}}{9.55} = 4.1 \text{ ng/g}$$

(Calculation 3.2)

Based on this analysis, the tPCB level of 4.1 ng/g derived from the fish tissue listing threshold is set as the sediment TMDL endpoint.

The CWA, as recently interpreted by the United States District Court for the District of Columbia, requires TMDLs to be protective of all the designated uses applicable to a particular waterbody (US District Court for the District of Columbia 2011). In addition to the “fishing” designated use, the TMDL presented herein is also supportive of the other applicable designated uses within the impaired waters, as described in the Introduction to this report and Section 2.2. These include “marine and estuarine aquatic life”, “shellfish harvesting”, and “water contact recreation”. The water column endpoint tPCB concentrations are more stringent than Maryland’s saltwater aquatic life chronic criterion tPCB water column concentration. This indicates that the TMDLs are protective of the “aquatic life” designated use, specifically the protection of “marine and estuarine aquatic life and shellfish harvesting”. Lastly, the designated use for "water contact recreation" is not associated with any potential human health risks due to PCB exposure. Dermal contact and accidental consumption of water from activities associated with "water contact recreation" is not a significant pathway for the uptake of PCBs. The EPA human health criterion was developed solely based on aquatic organism (e.g. fish, shellfish, etc…) consumption, as drinking water consumption does not pose any risk for cancer development at environmentally relevant levels. The only human health risk associated with PCB exposure is through the consumption of aquatic organisms.

4.0 SOURCE ASSESSMENT

PCBs do not occur naturally in the environment. Therefore, unless existing or historical anthropogenic sources are present, their natural background levels are expected to be zero. Although PCBs are no longer manufactured in the United States, they are still being released to the environment via accidental fires, leaks, or spills from PCB-containing equipment still in-use; potential leaks from hazardous waste sites that contain PCBs; illegal or improper dumping or burning of PCB-containing products; and disposal of PCB-containing products (*e.g.*, transformers, old fluorescent lighting fixtures, electrical devices or appliances containing PCB capacitors, old microscope oil, and old hydraulic oil) into landfills not designed to handle hazardous waste. Once in the environment, PCBs do not readily break down and tend to cycle between various environmental media such as air, water, and soil.

PCBs exhibit low water solubility, are moderately volatile, strongly adsorb to organics, and preferentially partition to upland and bottom sediments. The major fate process for PCBs in water is adsorption to sediment or other organic matter. Adsorption and subsequent sedimentation may immobilize PCBs for relatively long periods of time. However, desorption into the water column may also occur; PCBs contained in layers near the sediment surface may be slowly released over time, while concentrations present in the lower layers may be effectively sequestered from environmental distribution (RETEC 2002).

The linkage between the "fishing" designated use and PCB concentrations in the water column is via the uptake and bioaccumulation of PCBs by aquatic organisms. Bioaccumulation occurs when the combined uptake rate of a given chemical from food, water, and/or sediment by an organism exceeds the organism's ability to remove the chemical through metabolic functions, dilution, or excretion, resulting in excess concentrations of the chemical being stored in the body of the organism. Depending on the life cycle and feeding patterns, aquatic organisms can bioaccumulate PCBs via exposure to concentrations present in the water column (in dissolved and/or particulate form) and sediments, as well as from consumption of other organisms resulting in the biomagnification of PCBs within the food chain (RETEC 2002). Humans can be exposed to PCBs via consumption of aquatic organisms, which over time have bioaccumulated PCBs.

A simplified conceptual model of PCB fate and transport in the West and Rhode Rivers is diagrammed in Figure 5. PCB sources, resulting primarily from historical uses of these compounds and potential releases to the environment as described above, include point and nonpoint sources. This section provides a summary of these existing nonpoint and point sources that have been identified as contributing tPCB loads to the West and Rhode Rivers.

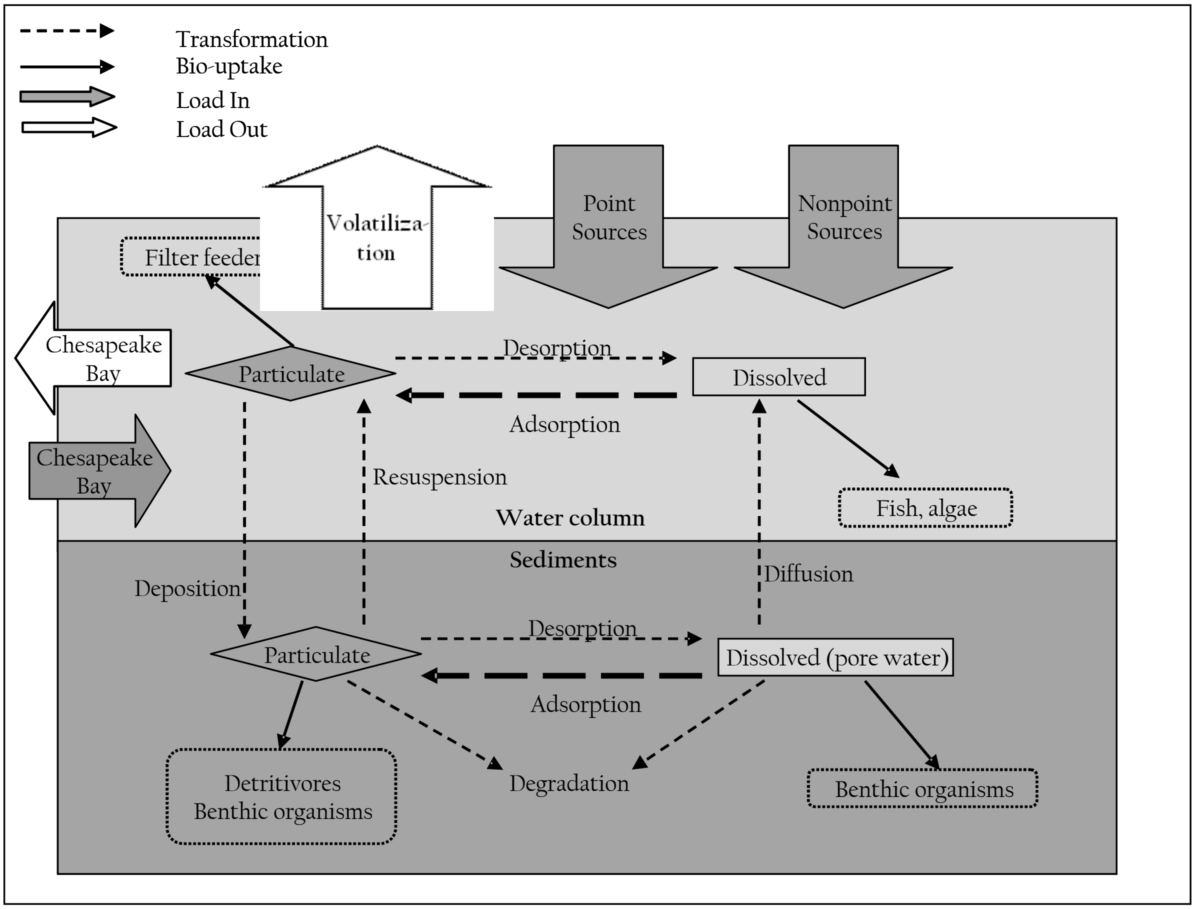

Figure 5: Conceptual Model of the Key Transport and Transformation Processes of PCBs in Surface Water and Bottom Sediments of the West and Rhode Rivers and Entry Points to the Food Chain

4.1 Nonpoint Sources

For the purpose of this TMDL, under current conditions, the following nonpoint sources of PCBs have been identified: 1) Chesapeake Bay mainstem tidal influence, 2) direct atmospheric deposition to the river and 3) runoff from non-regulated watershed areas within the West and Rhode Rivers' direct drainage. No contaminated sites were identified in the West and Rhode Rivers watershed with the potential to discharge PCBs, based upon a review of the MDE Land Restoration Program's Geospatial Database (MDE 2014b). The transport of PCBs from bottom sediments to the water column through resuspension and diffusion can also be a major source of PCBs in estuarine systems; however, under the framework of this TMDL it is not considered a source. A detailed explanation of each nonpoint source category will be presented in the following sections including additional information on resuspension and diffusion from bottom sediments.

Chesapeake Bay Mainstem Tidal Influence

The West River embayment is highly influenced by tidal exchange of PCBs from the Chesapeake Bay mainstem. The tidal prism model, using observed tPCB concentrations measured at the mouth of the West and Rhode Rivers and within the West and Rhode Rivers embayment, predicts a gross tPCB input of 1,082 g/year from the bay to the river and a gross tPCB output of 1,232 g/year from the river to the bay. These loads result in a net tPCB transport of 150 g/year from the river to the bay (see Table 5 and Table G-1 in Appendix G). However, with the attenuation of tPCB concentration in the Chesapeake Bay mainstem, this net transport of PCBs from the River to the Bay could shift in the future.

Atmospheric Deposition

PCBs enter the atmosphere through volatilization. There is no recent study of the atmospheric deposition of PCBs to the surface of the West and Rhode Rivers. CBP's Atmospheric Deposition Study (US EPA 1999) estimated a net deposition of 16.3 micrograms/square meter/year ($\mu g/m^2$/year) of tPCBs for urban areas and a net deposition of 1.6 $\mu g/m^2$/year of tPCBs for regional (non urban) areas. In the Delaware River estuary, an extensive atmospheric deposition monitoring program conducted by the Delaware River Basin Commission (DRBC) found PCB deposition rates ranging from 1.3 (non urban) to 17.5 (urban) $\mu g/m^2$/year of tPCBs (DRBC 2003). Since urban land use comprises less than one fifth of the West and Rhode Rivers watershed (12%, see Table 1), the 1.6 $\mu g/m^2$/year tPCB depositional rate for non-urban areas resultant from CBP's 1999 study is appropriate for the West and Rhode Rivers. Therefore, this value was used in the development of this TMDL. The direct atmospheric deposition load to the surface of the rivers of 22.6 g/year was calculated by multiplying the surface area of the rivers (14.2 km^2) and the deposition rate of 1.6 $\mu g/m^2$/year.

Similarly, the atmospheric deposition load to the direct watershed can be calculated by multiplying 1.6 $\mu g/m^2$/year by the watershed area of 66.2 km^2, which results in a load of 106 g/year. However, according to Totten *et al*. (2006), only a portion of the atmospherically deposited tPCB load to the terrestrial part of the watershed is expected to be delivered to the embayment. Applying the PCB pass-through efficiency estimated by Totten *et al*. (2006) for the Delaware River watershed of approximately 1%, the atmospheric deposition load to West and Rhode Rivers from the watershed is approximately 1.1 g/year. This load is accounted for within the loading from the watershed and is inherently modeled as part of the non-regulated watershed runoff and the National Pollutant Discharge Elimination System (NPDES) Regulated Stormwater loads described below and in Section 4.2.

Watershed Sources: Non-regulated Watershed Runoff

The non-regulated watershed runoff tPCB load corresponds to the non-urbanized areas (*i.e.*, primarily forest, agricultural and wetland areas) of the watershed. The load associated with the urbanized area of the watershed represents the NPDES Regulated Stormwater tPCB load which is presented in Section 4.2 under Point Sources.

MDE collected water column samples for PCB analysis at 5 non-tidal monitoring stations in West and Rhode Rivers on April, August, and November of 2011 and February of 2012 (See Appendix J). To calculate the watershed flow, the daily flow rates from January 1, 2004 to December 31, 2013 at the nearest United States Geological Survey (USGS) station located at Patuxent River near Bowie (USGS 01594440, Figure 4) were obtained and the mean flows were calculated. The flow from West and Rhode Rivers watershed (29.3 cubic feet per second) was calculated by dividing its closest USGS station mean flow (399 cubic feet per second) by the

USGS drainage area (901 km^2), and multiplying this quotient by the watershed area (66.3 km^2) (Equation 4.1).

$$\text{Subwatershed Flow} = \frac{\text{USGS Mean Flow}}{\text{USGS Drainage Area}} \times \text{Subwatershed Area} \qquad \text{(Equation 4.1)}$$

The West and Rhode Rivers watershed baseline tPCB loading (12.6 g/year) was calculated by multiplying its average flow and mean measured tPCB concentration (0.481 ng/L). The mean measured tPCB concentration is the average of all the concentration data at the 5 watershed stations.

As mentioned above, about 1.1 g/year of the West and Rhode Rivers watershed's baseline load is attributed to atmospheric deposition to the land surface of the direct drainage, and is inherently captured within the total watershed tPCB baseline load of 12.6 g/year.

The non-regulated watershed runoff tPCB baseline load (11.0 g/year) was estimated by multiplying the percentage of non-urban land use (87.6 %) within the watershed by the total watershed baseline load (12.6 g/year).

Resuspension and Diffusion from Bottom Sediments

The transport of PCBs from bottom sediments to the water column through resuspension and diffusion can be a major source of PCBs in estuarine systems; however, under the framework of this TMDL it is not considered a non-point source. The water quality model developed for this TMDL simulates conditions within the water column and sediment as a single system therefore exchanges between the sediment and water column are considered an internal loading. Only external sources to the system are assigned a baseline load or allocation within a TMDL. As PCBs bind to the organic carbon fraction of suspended sediment in the water column and settle onto the embayment floor, a large portion of the tPCB loads delivered from various point and non-point sources to the embayment deposits within the bottom sediments. This accumulation of PCBs can subsequently become a significant source of PCBs to the water column via the disturbance and resuspension of sediments. Dissolved tPCB concentrations in sediment pore water will also diffuse into the water column. Under current conditions, due to elevated particulate tPCB concentrations resultant from PCB adsorption to the organic carbon component of suspended sediment in the water column, when compared to tPCB concentrations in the bottom sediment, there is a net transport of PCBs to the bottom sediment from the water column in the West and Rhode Rivers through settling and deposition. The water quality model, applying observed tPCB concentrations in the water column and sediment, predicts a net tPCB transport of 387 g/year from the water column to the bottom sediment in the West and Rhode Rivers under baseline condition. Even if resuspension and diffusion from bottom sediments served as a source of PCBs to the water column, the load contribution is resultant from other point and nonpoint source inputs (both historic and current) and is not considered to be a directly controllable (reducible) source. Therefore, it would not be assigned a baseline load or allocation.

4.2 Point Sources

Point Sources in the West and Rhode Rivers watershed include one waste water treatment plant (WWTP) (Anne Arundel County Mayo Water Reclamation Facility), four industrial process water discharges, and several storm water discharges regulated under Phase I and Phase II of the NPDES stormwater program. This section provides detailed explanations regarding the calculation of the point source tPCB baseline loads.

WWTPs

No tPCB effluent concentration data is available for Anne Arundel County Mayo Water Reclamation Facility WWTP, so the concentration was estimated based on the median tPCB effluent concentration from 13 WWTPs monitored by MDE in the Chesapeake Bay watershed (MDE 2006). The baseline tPCB loadings from this facility was calculated based on the discharge monitoring record (DMR) average discharge flows and the estimated median tPCB concentration. Table 4 provides information on the data used in calculating the baseline loads.

Table 4: Summary of Municipal WWTP tPCB Baseline Loads

Facility Name	NPDES #	Average Concentration (ng/L)	Average Flow (MGD)	tPCB Baseline Load (g/year)
Anne Arundel County –Mayo Water Reclamation WWTP	MD0061794	0.906	0.493	0.163

Industrial Process Water Facility

Industrial process water facilities are included in Maryland's PCB TMDL analyses if: 1) they are located within the applicable watershed, and 2) they have the potential to discharge PCBs. Per guidance developed by Virginia for monitoring point sources in support of TMDL development, specific types of industrial and commercial operations are more likely than others to discharge PCBs based on historic or current activities. The State identified specific types of permitted industrial and municipal facilities based on their Standard Industrial Classification (SIC) codes as having the potential to contain PCBs within their process water discharge (VADEQ 2009). This methodology was previously applied within Maryland's Baltimore Harbor PCB TMDLs which has been approved by the EPA (MDE 2011a).

Four industrial discharges were identified within the West and Rhode Rivers watershed; one "non-construction dewatering discharge," two marinas, and one aquaculture facility. These four facilities with their SIC code defined in Virginia's guidance have no potential to discharge PCBs. Therefore there is no PCB load from these four industrial facilities.

NPDES Regulated Stormwater

The Department applies EPA's requirement that "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 Wasteload Allocation (WLA) portion of a TMDL" (US EPA 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.

A list of all the NPDES regulated stormwater permits within the West and Rhode Rivers watershed that could potentially convey tPCB loads to the river is presented in Appendix H.

MDE estimates pollutant loads from NPDES regulated stormwater areas based on urban land use classification within a given watershed. The 2006 USGS spatial land cover, which was used to develop CBP's Phase 5.3.2 watershed model land use, was applied in this TMDL to estimate the NPDES Regulated Stormwater tPCB Baseline Load.

The West and Rhode Rivers watershed is entirely located within Anne Arundel County, Maryland. The NPDES stormwater permits within the watershed include: (i) the area covered under Anne Arundel County's Phase I jurisdictional MS4 permit, (ii) the State Highway Administration's Phase I MS4 permit, (iii) and state and federal general Phase II MS4s, (iv) industrial facilities permitted for stormwater discharges, and (v) construction sites (see Appendix H for a list of all NPDES regulated stormwater permits).

The NPDES Regulated Stormwater tPCB Baseline Load (1.6 g/year) was estimated by multiplying the percentage of urban land use (12.4%) of the direct drainage by the total direct drainage baseline load (12.6 g/year).

4.3 Source Assessment Summary

From this source assessment all point and nonpoint sources of PCBs to the West and Rhode Rivers watershed have been identified and characterized. Nonpoint sources of PCBs have been identified: 1) Chesapeake Bay mainstem tidal influence, 2) direct atmospheric deposition to the river, 3) runoff from non-regulated watershed areas within the West and Rhode Rivers' direct drainage. Point sources include one municipal WWTP and NPDES regulated stormwater runoff. Estimated tPCB loads from these point and nonpoint sources represent the baseline conditions for the watershed.

A summary of the tPCB baseline loads for the West and Rhode Rivers is presented in Table 5. The total tPCB load is 1,116.9 g/year (1.12 kg/year). In order to address the long term PCB load variation, the watershed loads are calculated using a 10-year mean flow from January 1, 2004 to December 31, 2013 (PCB water column concentration samples were taken in 2011 and 2012).

As explained in Section 4.1, since the loads from resuspension and diffusion from bottom sediments are not considered to be directly controllable (reducible) loads and are considered as internal loads within the modeling framework of the TMDL, they are not included in the tPCB baseline load summaries.

Table 5: Summary of tPCB Baseline Loads in the West and Rhode Rivers

Source	**Baseline Load (g/year)**	**Percent of Total Baseline Load (%)**
Chesapeake Bay Mainstem Influence	1,081.5	96.83
Direct Atmospheric Deposition (to the Surface of the Embayment)	22.6	2.03
Non-regulated Watershed Runoff	11.0	0.99
Nonpoint Sources	***1,115.2***	***99.85***
WWTP	0.2	0.01
NPDES Regulated Stormwater	1.6	0.14
Point Sources	***1.7***	***0.15***
Total	**1,116.9**	**100.00**

5.0 TOTAL MAXIMUM DAILY LOADS AND LOAD ALLOCATION

5.1 Overview

A TMDL is the total amount of an impairing substance that a waterbody can receive and still meet WQSs. The TMDL may be expressed as a mass per unit time, toxicity, or other appropriate measure and should be presented in terms of WLAs, load allocations (LAs), and either an implicit or explicit margin of safety (MOS) (CFR 2013a):

$$TMDL = WLAs + LAs + MOS \qquad \text{(Equation 5.1)}$$

This section describes how the tPCB TMDL and the corresponding LAs and WLAs have been developed for the West and Rhode Rivers. The analysis framework for simulating PCB concentrations is described in Section 5.2. Section 5.3 addresses critical conditions and seasonality, and Section 5.4 presents the allocation of loads between point and nonpoint sources. The MOS and model uncertainties are discussed in Section 5.5, and the TMDL is summarized in Section 5.6.

5.2 Analysis Framework

A tidal prism model that incorporates the influences of both fresh water discharge and tidal flushing was used to simulate the dynamic interactions between the water column and bottom sediments within the West and Rhode Rivers embayment and the Chesapeake Bay mainstem (MDE 2005, Kuo et al.2005). Within the West and Rhode Rivers embayment, the tidal exchange with the Chesapeake Bay mainstem, freshwater inputs, exchanges with the atmosphere due to deposition and volatilization, and the exchange with the bottom sediments through diffusion, resuspension, and settling are the dominant processes affecting the transport of PCBs in the water column. The burial of PCBs to deeper inactive layers of sediment and exchanges at the sediment-water column interface through diffusion, resuspension, and settling are the dominant processes affecting the transport of PCBs in the bottom sediments. A detailed description of the model is presented in Appendices D and E.

The observed average tPCB concentrations in the water column and sediment (2011, 2012) were used to characterize the initial (baseline) model conditions. Based on the study of Ko and Baker (2004), on average the tPCB concentrations in the Upper Chesapeake Bay are decreasing at a rate of 6.5% per year. As a conservative estimation, this study assumes a PCB attenuation rate of 5.0% per year at the boundary between the West and Rhode Rivers and the Chesapeake Bay mainstem as used in the Back River PCB TMDL study (MDE, 2011b). All other inputs (i.e., fresh water inputs, tidal exchange rates, sediment and water column exchange rates, atmosphere deposition, and burial rate) were kept constant.

The model was initially run for 30,000 days to predict the time needed for the water column tPCB concentration to meet the site-specific tPCB water column TMDL endpoint. The results indicated that when the site-specific water column TMDL endpoint (0.61 ng/L) was met, the tPCB sediment concentration was still higher than the site-specific sediment TMDL endpoint (4.1 ng/g). Consequently, the model was run again for 30,000 days to predict the time needed for the sediment concentrations to reach the TMDL endpoint. Figure 6 shows the simulated results: after 6,137 days (about 16.8 years) the tPCB sediment concentration reached 4.1 ng/g, at which time the water column tPCB concentration was equal to 0.24 ng/L.

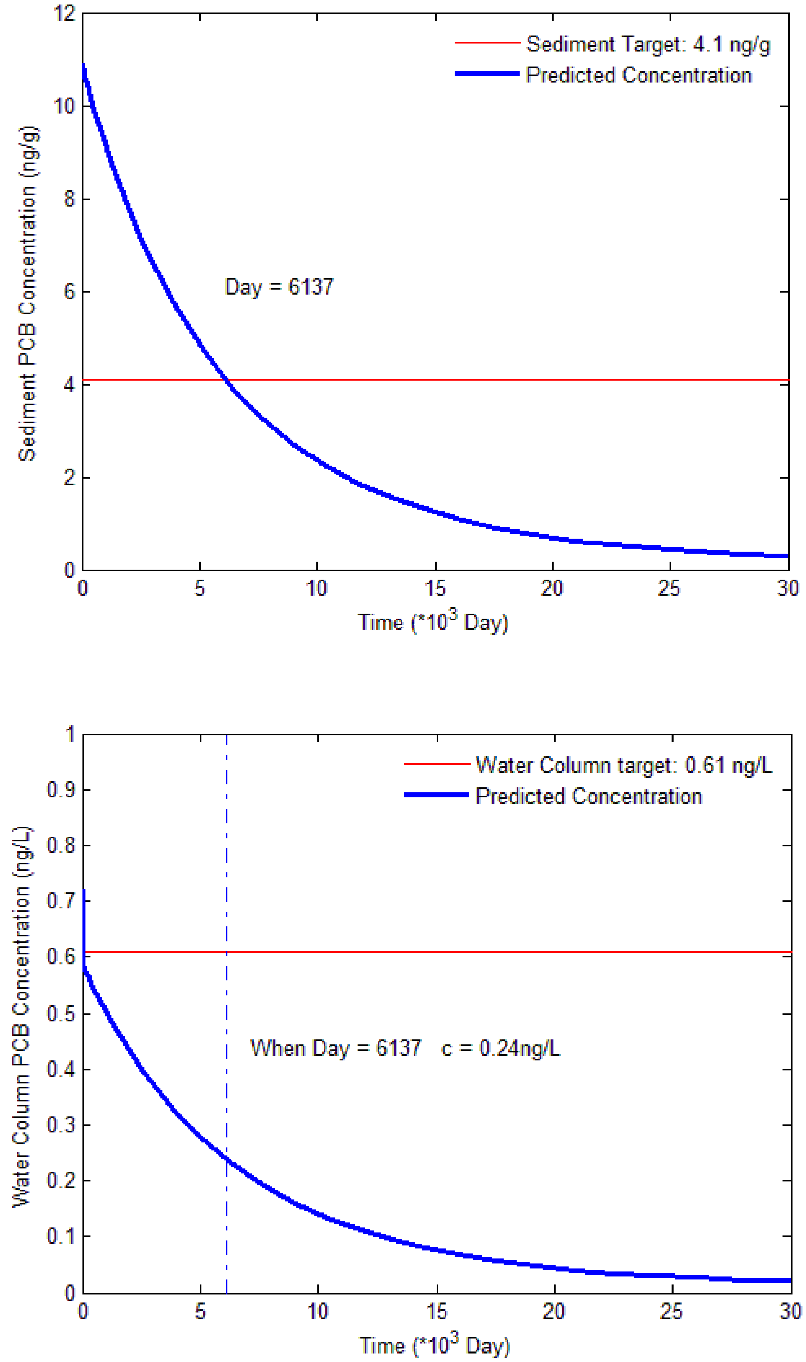

Figure 6: Change of Average Water Column and Bottom Sediment tPCB Concentrations with Time within the West and Rhode Rivers (Natural Attenuation Only)

As stated in Section 4, the Chesapeake Bay mainstem tidal influence is the primary source of tPCB baseline loads resulting in the PCB impairment in the West and Rhode Rivers embayment. The transport of PCBs from bottom sediments to the water column through resuspension and diffusion can also be a major source of PCBs in estuarine systems; however, under the framework of this TMDL it is not considered a source. Attainment of the site-specific tPCB water quality TMDL endpoints is expected to take place over time as the Chesapeake Bay mainstem tPCB concentrations continue to decline, which also results in the natural attenuation of tPCB levels in the surface layer of the sediments (i.e., the covering of contaminated sediments with newer, less contaminated materials, flushing of sediments during periods of high stream flow, and biodegradation). Assuming that the tPCB concentrations in the Chesapeake Bay mainstem will continue to decline, at or above the current rate of 5% per year, no additional tPCB reductions will be necessary to meet the "fishing" designated use in the West and Rhode Rivers embayment.

5.3 Critical Condition and Seasonality

Federal regulations require TMDL analysis to take into account the impact of critical conditions and seasonality on water quality (CFR 2013a). The intent of this requirement is to ensure that water quality is protected when it is most vulnerable.

This TMDL is protective of human health at all times; thus, it implicitly accounts for seasonal variations as well as critical conditions. Achievement of the TMDL endpoints for sediment and water column through the implementation of load reductions will result in PCB levels in fish tissue acceptable for human consumption without posing a risk for development of cancer. Bioaccumulation of PCBs in fish is driven by long-term exposure through respiration, dermal contact, and consumption of lower order trophic level organisms. The critical condition, defined by acute exposure to temporary fluctuations in PCB water column concentrations during storm events, is not a significant pathway for uptake of PCBs. Monitoring of PCBs was conducted on a quarterly basis to account for seasonal variation in establishing the baseline condition for ambient water quality in the West and Rhode Rivers and estimation of watershed loadings. Since PCB levels in fish tissue become elevated due to long-term exposure, it has been determined that the selection of the annual average tPCB water column and sediment concentrations for comparison to the endpoints applied within the TMDL adequately considers the impact of seasonal variations and critical conditions on the "fishing" designated use in the West and Rhode Rivers. Furthermore, the water column TMDL endpoint is also supportive of the "protection of aquatic life" designated use at all times, as it is more stringent than the freshwater chronic tPCB criterion.

5.4 TMDL Allocations

All TMDLs need to be presented as a sum of WLAs for point sources and LAs for nonpoint source loads generated within the assessment unit, and if applicable LAs for the natural background, tributary, and adjacent segment loads (CFR 2013b). The State reserves the right to revise these allocations provided the revisions are consistent with achieving WQSs. The allocations described in this section summarize the tPCB TMDL established to meet the "fishing" designated use in the West and Rhode Rivers. These allocations are also supportive of the ‘protection of aquatic life” designated use as explained above.

As stated in Section 4.3, the PCB loads from the Chesapeake Bay mainstem are the major source for the West and Rhode Rivers embayment, which account for about 96.83% of total baseline loads to the River. In Section 5.2, model simulation results show that both the water column and sediment PCB targets will be met in about 16.8 years with only natural attenuation of tPCB concentration at the Chesapeake Bay mainstem. Therefore, no reduction is assigned to the watershed loads, including non-point source and point source loads from the watershed. When the targets met, the tPCB load from the Chesapeake Bay mainstem will be reduced by about 57.8% from its baseline load, including an explicit 5% Margin of Safety which is discussed below (Table 6).

5.5 Margin of Safety

All TMDLs must include a MOS to account for the lack of knowledge and the many uncertainties in the understanding and simulation of water quality parameters in natural systems (*i.e.*, the relationship between modeled loads and water quality). The MOS is intended to account for such uncertainties in a manner that is conservative from the standpoint of environmental protection. Uncertainty within the model framework includes the estimated rate of decline in tPCB concentrations within the Chesapeake Bay mainstem as well as the initial condition of mean tPCB concentrations that was selected for the model. In order to account for these uncertainties, MDE applied an explicit 5% MOS, in order to provide an adequate and environmentally protective TMDL.

5.6 Maximum Daily Loads

All TMDLs must include maximum daily loads (MDLs) consistent with the average annual TMDL. For this TMDL, tPCB MDLs are developed for each source category by converting daily time-series loads into TMDL values consistent with available EPA guidance on generating daily loads for TMDLs (US EPA 2007). The approach builds upon the TMDL modeling analysis that was conducted to ensure that average annual load targets result in compliance with the TMDL endpoint tPCB concentrations and considers a daily load level of a resolution based on specific data for each source category. The detailed calculation of MDLs is stated in Appendix G and the results are shown on Table 6.

5.7 TMDL Summary

Table 6 summarizes the tPCB baseline loads, TMDL allocations, load reductions, and MDLs for the West and Rhode Rivers.

Table 6: Summary of tPCB Baseline Loads, TMDL Allocations, Load Reductions, and Maximum Daily Loads (MDLs) in the West and Rhode Rivers

Source	Baseline Load (g/year)	Baseline Percentage (%)	TMDL (g/year)	Load Reduction (%)	MDL (g/day)
Chesapeake Bay Mainstem Influence	1081.5	96.83	456.5	57.8	2.009
Direct Atmospheric Deposition	22.6	2.03	22.6	0	0.099
Non-regulated Watershed Runoff	11.0	0.99	11.0	0	0.048
Nonpoint Sources	***1,115.2***	***99.85***	***490.1***	***56.1***	***2.156***
WWTP	0.2	0.01	0.2	0	0.001
NPDES Regulated Stormwater	1.6	0.14	1.6	0	0.007
Point Sources	***1.7***	***0.15***	***1.7***	***0***	***0.008***
MOS (5%)	-	-	***25.9***	-	***0.114***
Total	**1,116.9**	**100.00**	**517.7**	**53.6**	**2.279**

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

6.0 ASSURANCE OF IMPLEMENTATION

This section provides the basis for reasonable assurance that the tPCB TMDLs for the West and Rhode Rivers will be achieved and maintained.

As discussed in the previous sections, the Chesapeake Bay mainstem tidal influence and resuspension and diffusion from the bottom sediments have been identified as the two major sources of tPCBs to the West and Rhode Rivers embayment. Since the loads from resuspension and diffusion from bottom sediments are not considered to be directly controllable (reducible) loads and are considered as internal loads within the modeling framework of the TMDL, they are not included in the tPCB baseline load and TMDL allocation. Given that PCBs are no longer manufactured, and their use has been substantially restricted, it is reasonable to expect that with time PCB concentrations in the aquatic environment will decline. In this study, it is assumed that the tPCB concentrations in the Chesapeake Bay mainstem are decreasing at a rate of 5% per year as used in the Back River PCB TMDL study (MDE, 2011b). Other processes, such as the burial of contaminated sediments with newer, less contaminated materials, flushing of sediments during periods of high stream flow, and biodegradation will contribute to this natural attenuation. Model scenarios predict that with the natural attenuation of tPCB concentrations in the Chesapeake Bay mainstem, the tPCB targets in both water column and sediment of West and Rhode Rivers embayment will be met in about 16.8 years. Loads from the watershed, including non-point and point sources, and atmospheric deposition only account for 3.2% of the total tPCB baseline load. Therefore, no reductions to these loads are necessary in order to achieve the TMDL.

A new Chesapeake Bay Watershed Agreement was signed on June 16, 2014 which includes goals and outcomes for toxic contaminants including PCBs (CBP 2014). The toxic contaminant goal is to "ensure that the Bay and its rivers are free of effects of toxic contaminants on living resources and human health." Objectives for the toxic contaminant outcomes regarding PCBs include 1) characterizing the occurrence, concentrations, sources and effects of PCBs, 2) identifying best management practices (BMPs) that may provide benefits for reducing toxic contaminants in waterways, 3) improving practices and controls that reduce and prevent the effects of toxic contaminants, and 4) building on existing programs to reduce the amount and effects of PCBs in the Bay and watershed. Implementation of the toxic contaminant goal and outcomes under the new Bay agreement as well as discovering and minimizing any existing PCB land sources throughout the Chesapeake Bay watershed via future TMDL development and implementation efforts could further help to meet water quality goals in the West and Rhode Rivers.

Aside from the processes of natural attenuation, an alternative approach that can assist in reducing the tPCB concentrations in the water column so as to meet WQSs is the physical removal of the PCB-contaminated sediments (*i.e.*, dredging). This process would minimize one of the primary, potential sources of tPCBs to the water column. When considering dredging as an option, the risk versus benefit must be weighed as the removal of contaminated sediment may potentially damage the habitat and health of the existing benthic community. The process of stirring up suspended sediments during dredging may damage the gills and/or sensory organs of benthic macroinvertebrates and fish. Suspended sediments can also affect the prey gathering ability of sight-feeding fish during dredging operations. In addition, the resuspension of contaminated sediments causes additional exposure of PCBs to aquatic organisms. In the case of the West and Rhode Rivers, by allowing for natural attenuation of PCBs in the sediment, water quality supportive of the "fishing" designated use will be achieved within 16.8 years while avoiding disturbance of the benthic habitat.

MDE's Environmental Assessment and Standards Program will periodically monitor and evaluate concentrations of contaminants in recreationally caught fish, shellfish, and crabs throughout Maryland. This information will be used to evaluate the PCB impairment in the West and Rhode Rivers embayment on an ongoing basis. Any future monitoring should include congener specific analytical methods. Ideally, the most current version of EPA Method 1668 should be used or other equivalent methods capable of providing low-detection level, congener specific results. In establishing the necessity and extent of data collection within Maryland, MDE will collaborate with the affected stakeholders, and take into account data that is already available as well as the proper characterization of intake (or pass through) conditions, consistent with NPDES program "reasonable potential" determinations and the applicable provisions of the Environment Article and COMAR for permitted facilities. Similar approaches may be applicable for all upstream jurisdictions with regards to PCB monitoring and stakeholder collaboration.

Under certain conditions, EPA's NPDES regulations allow the use of non-numeric, BMP water quality based effluent limits (WQBELs). BMP WQBELs can be used where "numeric effluent limitations are infeasible; or the practices are reasonably necessary to achieve effluent limitations and standards or to carry out the purposes and intent of the CWA" (CFR 2013c). For example, MDE's Phase I MS4 permits require restoration targets for impervious surfaces (*i.e.*, restore 10% or 20% of a jurisdiction's total impervious cover with no stormwater management/BMPs), and these restoration efforts have known total suspended solids (TSS) reduction efficiencies. Since PCBs are known to adsorb to sediments and their concentrations correlate with TSS concentrations, the significant restoration requirements in the MS4 permits, which will lead to a reduction in sediment loads entering the West and Rhode Rivers, will also contribute toward tPCB load reductions and meeting PCB water quality goals. Implementation of similar restoration measures within upstream jurisdictions would also contribute additional reductions to PCB loadings from the West and Rhode Rivers watershed and provide progress towards achieving the TMDL. Other BMPs that focus on PCB source tracking and elimination at the source rather than end-of-pipe controls are also warranted.

Numerous stormwater dischargers are located in the watershed including Municipal Phase I MS4, the SHA Phase I MS4, industrial facilities, and any construction activities on area greater than 1 acre (see Appendix H of this document to view the current list of known NPDES stormwater dischargers).

An example of one jurisdiction with a PCB TMDL implementation plan is Montgomery County. The current Montgomery County Phase I MS4 permit requires that the jurisdiction develop implementation plans to meet its assigned NPDES Regulated Stormwater WLAs. In this TMDL, because its load was estimated as only 0.14% of the total PCB baseline load, the Anne Arundel County Phase I MS4 permit was not assigned a reduction and therefore no PCB implementation plan will be required. Development of implementation plans by regulated stormwater dischargers within upstream jurisdictions would also contribute additional reductions to PCB loadings from the Chesapeake Bay and provide progress towards achieving the TMDL.

PCBs are still being released to the environment via accidental fires, leaks, or spills from older PCB-containing equipment still in-use; potential leaks from hazardous waste sites that contain PCBs; illegal or improper dumping or burning of PCB containing products; and disposal of PCB containing products (*e.g.*, transformers, old fluorescent lighting fixtures, electrical devices, or appliances containing PCB capacitors, old microscope oil, and old hydraulic oil) into landfills that are not designed to handle hazardous waste. MDE will continue to monitor PCB levels in fish and evaluate the PCB impairment in the West and Rhode Rivers embayment on an ongoing basis.

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Appendix A: List of Analyzed PCB Congeners

PCB analytical services were provided by the University of Maryland Center for Environmental Science (UMCES). Specific PCB congeners were identified and quantified by high resolution gas chromatography with GC-MS detection (Ayris *et al*. 1997, Holwell *et al*. 2007, Konietckka and Namiesnik 2008, Mydlová-Memersheimerová *et al* 2009). This method is based on EPA method 8082 which was developed in 1996. Since that time the extraction protocols have been enhanced to fall in line with those of EPA method 1668a. UMCES uses a slightly modified version of the PCB congener specific method described in Ashley and Baker (1999), in which the identities and concentrations of each congener in a mixed Aroclor standard (25:18:18 mixture of Aroclors 1232, 1248, and 1262) are determined based on their chromatographic retention times relative to the internal standards (PCB 30 and PCB 204 and ten C13 labeled standards). Based on this method, upwards of 100 chromatographic peaks can be quantified. Some of the peaks contain one PCB congener, while many are comprised of two or more co-eluting congeners. PCB congeners identified under this method are displayed in Table A-1. The PCB analysis presented in this document is based on tPCB concentrations that are calculated as the sum of the detected PCB congeners/congener groups representing the most common congeners that were historically used in the Aroclor commercial mixtures.

Table A-1: List of Analyzed PCB Congeners

1	45	110, 77	177
3	46	114	180
4, 10	47, 48	118	183
6	49	119	185
7, 9	51	123, 149	187, 182
8, 5	52	128	189
12, 13	56, 60	129, 178	191
16, 32	63	132, 153, 105	193
17	66, 95	134	194
18	70, 76	135, 144	197
19	74	136	198
22	81, 87	137, 130	199
24	82, 151	141	201
25	83	146	202, 171, 156
26	84, 92	157, 200	203, 196
29	89	158	205
31, 28	91	163, 138	206
33, 21, 53	97	167	207
37, 42	99	170, 190	208, 195
40	100	172	209
41, 64, 71	101	174	
44	107	176	

Appendix B: Derivation of Adj-tBAF and Adj-SediBAF

This appendix describes how the Adj-tBAF and Adj-SediBAF were derived. The method followed the Potomac River tPCB TMDL (Haywood and Buchanan 2007).

I. Data Description

The observation-based Adj-tBAF and Adj-SediBAF were calculated for the fish species within the West and Rhode Rivers from the available fish tissue, water column, and sediment tPCB data. Each fish species was assigned a trophic level and a home range (see Table B-1). The Adj-tBAF and Adj-SediBAF were calculated based on the geometric mean tPCB concentrations of all the samples within the home range for each species.

Table B-1: Species Trophic Levels and Home Ranges

Common Name	Scientific Name	Trophic Level	Home Range (miles)
White Perch	*Morone americana*	Predator	10
Common Carp	*Cyprinus carpio*	Benthivore-generalist	2

II. Total BAFs

First, the tBAFs were calculated using Equation B-1 (US EPA 2003):

$$\text{tBAF} = \frac{[\text{tPCB}]_{\text{fish}}}{[\text{tPCB}]_{\text{Water}}} \qquad \text{(B-1)}$$

Where: $[\text{tPCB}]_{\text{fish}}$ = tPCB concentration in wet fish tissue (ng/kg)
$[\text{tPCB}]_{\text{water}}$ = water column tPCB concentration in fish species home range (ng/L)

III. Baseline BAFs

As the tBAFs vary depending on the food habits and lipid concentration of each fish species as well as the freely-dissolved tPCB concentrations in the water column, the baseline BAFs were calculated as recommended by US EPA (2000):

$$\text{Baseline BAF} = \frac{[\text{PCB}]_{\text{fish}} / \%\text{Lipid}}{[\text{PCB}]_{\text{Water}} \times \% fd} \qquad \text{(B-2)}$$

Where: %fd = fraction of the tPCB concentration in water that is freely-dissolved
%lipid = fraction of tissue that is lipid (if the lipid content was not available for a certain fish, the average lipid content of the whole ecosystem was used.)

The freely-dissolved tPCBs are those not associated with dissolved organic carbon (DOC) or particulate organic carbon (POC). The %fd can be calculated as (US EPA 2003):

$$\%\text{fd} = \frac{1}{1 + \text{POC} \times \text{K}_{\text{ow}} + \text{DOC} \times 0.08 \times \text{K}_{\text{ow}}} \qquad \text{(B-3)}$$

Where: K_{ow} is the PCB octanol-water partition coefficient, POC and DOC are the particulate and dissolved organic carbon concentrations in the water column.

The K_{ow} of PCB congeners have large ranges. Therefore, a %fd was calculated for each PCB homolog using the midpoint of the homolog's K_{ow} range [see Table B-2 (Hayward and Buchanan 2007)].

Table B-2: K_{ow} Values of Homologs Used in the Baseline BAF Calculation

Homolog	Midpoint K_{ow}
Mono+Di	47,315
Tri	266,073
Tetra	1,011,579
Penta	3,349,654
Hexa	5,370,318
Hepta	17,179,084
Octa	39,810,717
Nona	82,224,265
Deca	151,356,125

The %fd for tPCBs (PCB %fd) was derived by dividing the freely-dissolved PCB concentrations by the water column tPCB concentrations:

$$\text{PCB \%fd} = \frac{\sum(\text{Homolog \%fd} \times \text{Homolog Concentration})}{[\text{tPCB}]_{\text{water}}} \qquad \text{(B-4)}$$

The PCB %fd was used in Equation B-2 to calculate the baseline BAFs.

IV. Adjusted Total BAFs

The baseline BAFs were normalized by the species median lipid content and a single freely-dissolved PCB concentration (*i.e.*, median %fd within the fish's home range) representative of the ecosystem, resulting in no variability attribution to differences in fish lipid content or freely-dissolved PCB concentration in the water column:

$$\text{Adj - tBAF} = (\text{Baseline BAF} \times \text{Median \% Lipid} + 1) \times \text{Median \%fd} \qquad \text{(B5)}$$

The tPCB fish tissue listing threshold of 39 ng/g can then be divided by the median Adj-tBAF for each species to translate an associated tPCB water column threshold concentration. According to the data requirement for listing a waterbody as impaired by PCB in fish tissue (http://www.mde.state.md.us/programs/Water/TMDL/Integrated303dReports/Pages/Programs/WaterPrograms/TMDL/maryland%20303%20dlist/ir_listing_methodologies.aspx), minimum data requirement is 5 fish (individual or composite of the same resident species) for a given waterbody and all fish that comprise a composite sample must be within the same size class, i.e., the smallest fish must be within seventy-five percent of the total length of the largest fish. The lowest tPCB water column concentration of all the fish species will be selected as the TMDL endpoint in order to be supportive of the "fishing" designated use (Table B-3). In West and Rhode Rivers, the lowest concentration (0.61 ng/L) is associated with White Perch. There are five fish composites for White Perch and each composite is from 5 fish. The length and weight for these fish are shown in Table B-4. For West and Rhode Rivers, 0.61 ng/L from White Perch is selected as the water column endpoint.

Table B-3: tBAF, Baseline BAF, Adj-tBAF, and Water Column TMDL Endpoint tPCB Concentrations for Each Species

Species Name	Number of Fish (composite)	tBAF (L/kg)	Baseline BAF (L/kg)	Adj-tBAF (L/kg)	Water Column TMDL Endpoint tPCB Concentration (ng/L)
White Perch	25(5)	74,180	33,467,801	64,256	0.61
Common Carp	10(2)	38,955	17,407,110	22,706	1.72

Table B-4: Individual Fish Length and Weight in White Perch Composite

Composite ID Number	Number fish in Composite	Individual Fish Field ID Number	Length (cm)	Weight (g/lbs.)
2011FTC_WES_A	5	10/2011_WES_01	30.5	538
-	-	10/2011_WES_02	29.5	382
-	-	10/2011_WES_03	28.5	372
-	-	10/2011_WES_04	29.0	381
-	-	10/2011_WES_05	28.0	348
2011FTC_WES_B	5	10/2011_WES_06	26.5	274
-	-	10/2011_WES_07	26.0	317
-	-	10/2011_WES_08	26.5	274
-	-	10/2011_WES_09	26.5	284
-	-	10/2011_WES_10	27.8	296
2012FTC_WES_D	5	03/2012_WES_01	29.8	486
-	-	03/2012_WES_02	26.6	355
-	-	03/2012_WES_03	26.5	343
-	-	03/2012_WES_04	27.0	332
-	-	03/2012_WES_05	26.0	331
2012FTC_WES_E	5	03/2012_WES_06	24.8	281
-	-	03/2012_WES_07	24.5	259
-	-	03/2012_WES_08	24.1	272
-	-	03/2012_WES_09	23.6	263
-	-	03/2012_WES_10	24.0	232
2012FTC_WES_F	5	03/2012_WES_11	23.6	200
-	-	03/2012_WES_12	23.6	226
-	-	03/2012_WES_13	22.9	214
-	-	03/2012_WES_14	22.5	198
-	-	03/2012_WES_15	22.1	175

V. Biota-Sediment Accumulation Factors and Adjusted Sediment BAFs

The biota-sediment accumulation factors (BSAFs) were derived by the following equation:

$$BSAF = \frac{tPCB_{tissue} / \%\ Lipid}{tPCB_{sediment} / \%\ Oraganic\ Carbon} \qquad (B-6)$$

where: % Organic Carbon is the species home range's average sediment organic carbon fraction.

Since there is no available % Organic Carbon information for some of the study sites, a default values of 1% was used (US EPA 2004). Each species' BSAF was then standardized to a common condition by normalizing them to the median lipid content of the species and a sediment organic carbon fraction representative of the ecosystem:

$$Adj\text{-}SedBAF = BSAF \times \frac{Median\ \%\ Lipid}{Median\ \%\ Oraganic\ Carbon} \qquad (B-7)$$

The tPCB fish tissue listing threshold of 39 ng/g can then be divided by the median Adj-SedBAF for each species to translate an associated tPCB sediment threshold concentration. The lowest tPCB sediment concentration of all the fish species will be selected as the TMDL endpoint in order to be supportive of the "fishing" designated use (Table B-5). In the West and Rhode Rivers, the lowest concentration (white perch, 4.1 ng/g) is selected as the sediment TMDL endpoint.

Table B-5: BSAF, Adj-SedBAF, and Sediment TMDL Endpoint tPCB Concentrations

Species Name	BSAF	Adj-SedBAF	Sediment TMDL Endpoint tPCB Concentration (ng/g)
White Perch	4.75	9.55	4.1
Common Carp	1.75	2.73	14.3

Appendix C: Method Used to Estimate Watershed tPCB Load

In April, May, August, and November of 2011 and February of 2012, MDE collected water column samples for PCB analysis at 5 watershed monitoring stations in the non-tidal tributaries of the West and Rhode Rivers (Stations WST5, WST6, WST7, WST8, and WST11) (Figure C-1). In order to assess whether or not these samples covered all flow ranges so that they could be used to calculate watershed loads, the daily average flow rates from January 1, 2004 to September 30, 2013 of the USGS Station 1594440 located at Patuxent River near Bowie (Figure C-1) was used to generate the flow duration curves. The flows for the dates on which the watershed samples were collected were identified on the flow duration curve (Figure C-2). This comparison indicates that the PCB samples are mainly located in the medium to high flow region. It was therefore not justifiable to use the regression method applied in the Back River tPCB TMDL (MDE 2011b) to the West and Rhode Rivers.

To calculate the watershed flow, the daily flow rates from January 1, 2004 to December 31, 2013 of the USGS Station 1594440 were averaged. The West and Rhode Rivers watershed flow (29.33 cubic feet per second) was calculated by dividing the USGS station mean flow (398.7 cubic feet per second) by the USGS drainage area (901 km^2), and multiplying the West and Rhode Rivers watershed area (66.3 km^2). The West and Rhode Rivers watershed baseline tPCB loading (12.6 g/year) was calculated by multiplying the average flow and mean measured tPCB concentration (0.481 ng/L) of five watershed stations (WSTH5 – WST8, and WST11).

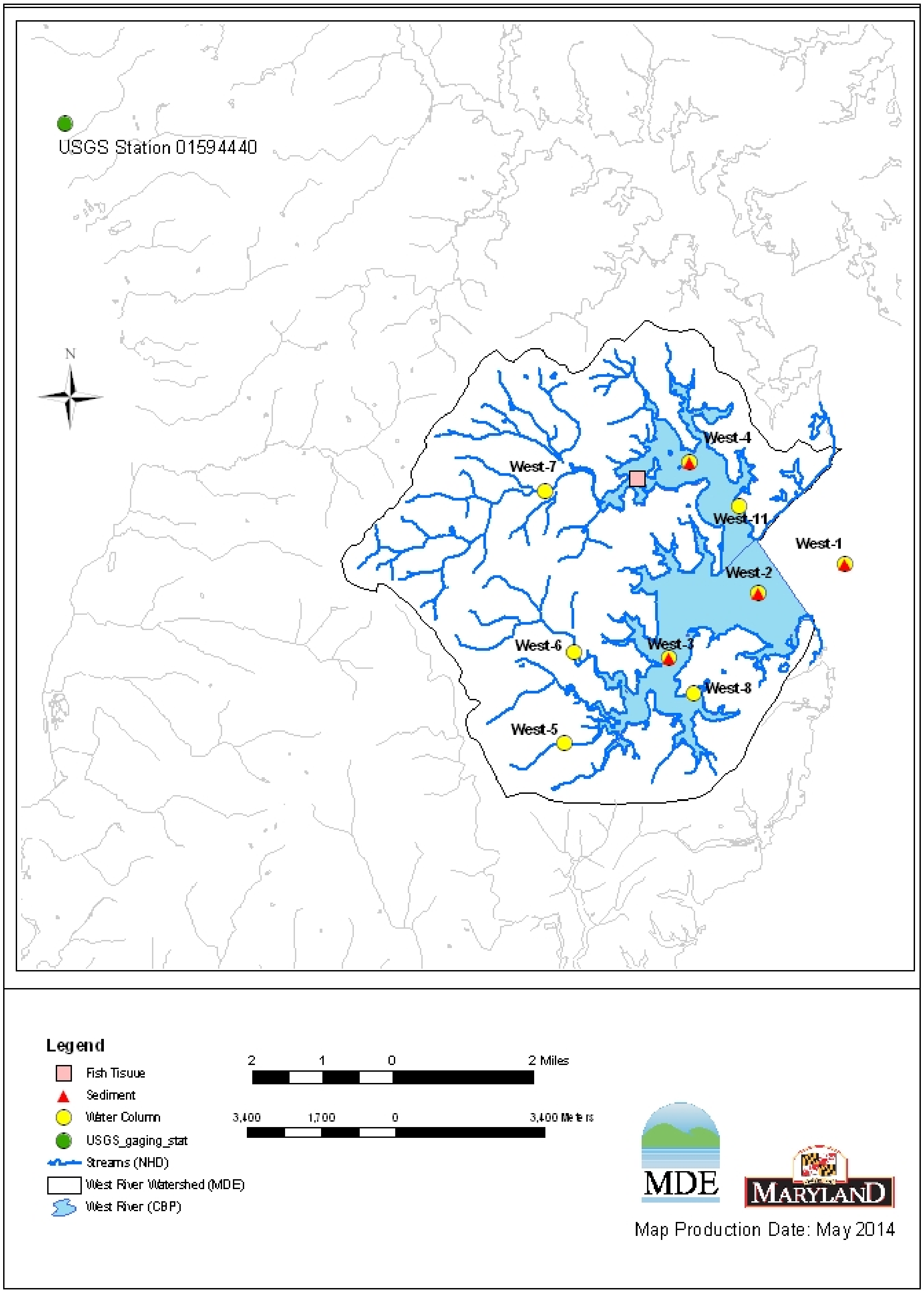
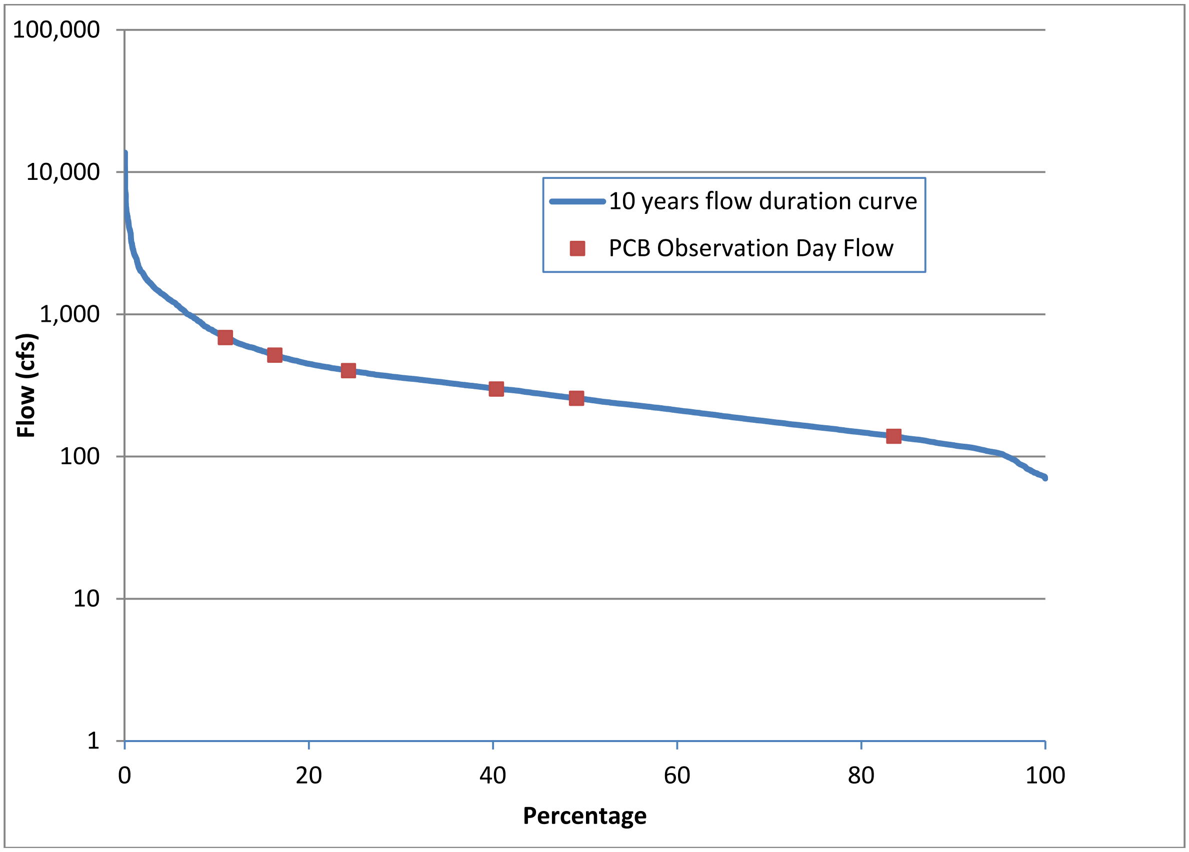


Figure C-1: Locations of PCB Water Column, Sediment and Fish Tissue Monitoring Stations and the USGS station in the West and Rhode Rivers



Note: The red points represent the locations of the watershed station sample flows

Figure C-2: Relative Locations of PCB Water Column Measurement Station Sampling Date Flow on the Flow Duration Curve

Appendix D: Tidal Prism Model

A description of the tidal prism model applied in the development of the West and Rhode Rivers embayment PCB TMDL is presented in this Appendix. The model assumes that a single volume can represent a waterbody, and that the pollutant is well mixed in the waterbody, as shown in Figure D-1. Assuming no decay, PCBs can enter the water column via loads from watershed sources and the atmosphere (L_f), loads from the Chesapeake Bay mainstem (Q_0C_0), resuspension from the bottom sediments (V_rAC_2), and the diffusion between the sediment-water column interface ($V_dA(F_{do2}C_2 - F_{do1}C)$). PCBs leave the water column via volatilization ($V_vAF_{do1}C_1$), flows to the Chesapeake Bay mainstem (Q_bC_1), and sedimentation ($V_sAF_{p1}C_1$). In the sediment, PCBs enter the system via settling ($V_sAF_{p1}C_1$), and leave the system via diffusion ($V_dA(F_{do2}C_2 - F_{do1}C)$), resuspension ($V_rAC_2$), and burial to a deeper layer (V_bAC_2). Specifically, the mass balance for the PCBs in the water column and sediment can be written as:

$$\frac{dV_1C_1}{dt} = L_f - V_vAF_{do1}C_1 + (1-\alpha)Q_0C_0 - Q_bC_1 + V_rAC_2 - V_sAF_{p1}C_1 + V_dA(F_{do2}C_2 - F_{do1}C_1) \quad \text{(D-1)}$$

$$\frac{dV_2C_2}{dt} = -V_rAC_2 + V_sAF_{p1}C_1 - V_dA(F_{do2}C_2 - F_{do1}C_1) - V_bAC_2 \quad \text{(D-2)}$$

Where:

L_f = PCB load from upstream (point and nonpoint sources) and direct atmosphere deposition and the load from the atmosphere to the river surface;
V_v = volatilization coefficient (m/d);
α = return ratio, which is the percentage of water that flowed to the Chesapeake Bay during the previous ebb tide and flows back to the embayment during the flood tide;
A = area of the embayment (m^2);
Q_0 = quantity of water that enters the embayment through the open boundary (m^3/d);
Q_b = quantity of water that leaves the embayment through the open boundary (m^3/d);
C_0 = tPCB concentrations in the water column of the Chesapeake Bay (ng/L);
C_1 = tPCB concentrations in the water column of the embayment (ng/L);
C_2 = tPCB concentrations in the sediment of the embayment (ng/L);
V_1 = volume of the water column in the embayment (m^3);
V_2 = volume of the active sediment layer of the embayment (m^3);
V_d = diffusive mixing velocity;
F_{p1} = fraction of particular-associated PCBs in the water column;
F_{do1} = fraction of truly dissolved and DOC-associated PCBs in the water column;
F_{do2} = fraction of truly dissolved and DOC-associated PCBs in the sediment;
V_r = rates of resuspension (m/d);
V_s = rates of settling (m/d);
V_b = rates of burial (m/d).

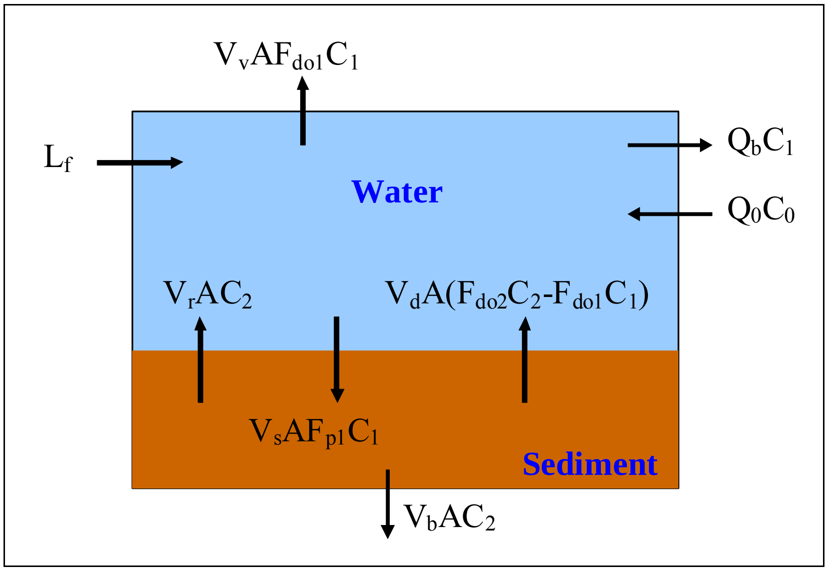


Figure D-1: Schematic Diagram of the Tidal Prism Model and PCB Budget

Appendix E: Tidal Prism Model Calculations for the West and Rhode Rivers Embayment

For the West and Rhode Rivers embayment tidal prism model, the parameter values are as follows:

L_f = 71,607 µg/day. It was obtained by summing all the upstream point and nonpoint source loads and the load from the atmosphere to the river surface.

V_v = 91.6 m/year = 0.251 m/day [derived using the method of Chapra (1997), assuming a wind speed of 1 m/s and a temperature of 10℃]

α = 0.5 (return ratio varies from 0.1 to 0.9)

A = 14,154,800 (m^2).

Q_0 = A × Tidal range ÷ Tidal circle×24 hours = 14,158,800×0.338÷12.42×24 = 9,245,067 (m^3/d).

Q_b = Q_f (Volume of water entering the embayment from the watershed) + Q_0×(1-α) = 71,943 + 9,245,067 ×(1-0.5) = 4,694,477 (m^3/d) (Q_f is the estimated daily watershed flow)

C_0 = 0.641×$(0.95)^t$ (ng/L) (The measurement at the station WST-1 was used as the baseline boundary condition of the model. The TMDL methodology assumes that on average the tPCB concentrations at the West and Rhode Rivers boundary are decreasing at a rate of 5% per year (

C_1 = 0.719 (ng/L, measured and averaged)

C_2 = Measured tPCB concentration on a dry sediment base × Sediment density × (1-porosity) ÷ Fraction of particular-associated PCBs in the sediment = 10.9×2,500×(1-0.80) ÷ 0.9983 = 5,459 (ng/L) [the porosity (water content on a volume base) of 0.80 is selected based on observations and reference (Thomann and Mueller 1987)]

V_1 = 23,906,042 (m^3) (average depth of 1.69 meters)

V_2 = A × Active sediment layer thickness = 14,154,800 ×0.10=1,415,480 (m^3) (active sediment layer thickness value of 0.10 m is a typical value frequently used in water quality models)

V_d = 69.35× Porosity × (Molecular weight of PCBs)$^{-2/3}$ ÷ 365 = 69.35 × 0.8× $(305.6)^{-2/3}$ ÷ 365 = 0.00335 (m/d; Thomann and Mueller 1987)

F_{p1} = 0.352; F_{do1} = 0.648; F_{do2}= 0.00171 (see Appendix F for derivation)

V_s= 1 (m/d) (a default value of settling rate normally used in literature)

V_b = 3.935×10^{-6} (m/d, average of the measured sedimentation rates of Northeast River, Corsica River, Bohemia River, and Sassafras River through ^{210}Pb technology)

V_r can be calculated via mass balance of the sediment in the active sediment layer at steady state:

$$\frac{d\rho(1-\varphi)}{dt} = V_s \times TSS - V_r \times \rho \times (1-\varphi) - V_b \times \rho \times (1-\varphi) = 0 \qquad \text{(E-1)}$$

Where: TSS is the total suspended solid concentration (g/m^3, measured)
ρ is the sediment density (g/m^3; Thomann and Mueller, 1987)
φ is the porosity.

Rearrange Equation E-1:

$$V_r = \frac{V_s \times TSS}{\rho \times (1-\varphi)} - V_b = \frac{1 \times 15.56}{2500000 \times (1-0.80)} - 3.935 \times 10^{-6} = 2.72 \times 10^{-5} \text{ (m/d)} \qquad \text{(E-2)}$$

Appendix F: Calculation of Fractions of Different PCB Forms

The fractions in equations D-1 and D-2 can be calculated as follows:

$$F_{p1} = \frac{TSS \times 10^{-6} K_{oc} \times f_{oc1}}{1 + (K_{oc} \times 10^{-6})(TSS \times f_{oc1} + DOC_1)} \quad \text{(E-1)}$$

$$F_{do1} = \frac{1 + (K_{oc} \times 10^{-6}) DOC_1}{1 + (K_{oc} \times 10^{-6})(TSS \times f_{oc1} + DOC_1)} \quad \text{(E-2)}$$

$$F_{do2} = \frac{\phi + \phi(K_{oc} \times 10^{-6}) DOC_2}{\phi + (K_{oc} \times 10^{-6})(f_{oc2} \times \rho \times (1-\phi) + \phi DOC_2)} \quad \text{(E-3)}$$

Where:

K_{oc} = the organic carbon/water partition coefficient of PCBs (L/kg). It describes the ratio of a compound adsorbed to solids and in solution, normalized for organic carbon content. It can be calculated via the relationship of $\log_{10} K_{oc} = 0.00028 + 0.983 \times \log_{10} K_{ow}$ (Hoke *et al*. 1994), where K_{ow} is the octanol-water partition coefficient with $\log_{10}K_{ow}$ equals to 6.261 (De Bruijn *et al*. 1989).

f_{oc1} and f_{oc2} = the fractions of organic carbon in suspended solids in the water column and the sediment solids, respectively (US EPA 2004).

DOC_1 and DOC_2 = the dissolved organic carbon concentration in water column and pore water, respectively.

φ = the porosity of the sediment.

Appendix G: Technical Approach Used to Generate Maximum Daily Loads

I. Summary

This appendix documents the technical approach used to define MDLs of tPCBs consistent with the average annual TMDL, which is protective of the "fishing" designated use, which is protective of human health related to the consumption of fish, in the West and Rhode Rivers. The approach builds upon the modeling analysis that was conducted to determine the loads of tPCBs 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 load targets result in compliance with the TMDL endpoint tPCB concentrations;
- The approach converts daily time-series loads into TMDL values in a manner that is consistent with available EPA guidance on generating daily loads for TMDLs;
- The approach considers a daily load level of a resolution based on the specific data that exists for each source category.

II. Introduction

This appendix documents the development and application of the approach used to define TMDLs on a daily basis. It is divided into sections discussing:

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

III. 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 tPCB TMDL is that the baseline tPCB load rates result in tPCB levels in fish tissue that exceed the tPCB fish tissue listing threshold. Thus, the average annual tPCB TMDL was calculated to be protective of the "fishing" designated use, which is protective of human health related to the consumption of fish.
- **Draft EPA guidance document entitled *Developing Daily Loads for Load-based TMDLs***: This guidance provides options for defining MDLs when using TMDL approaches that generate daily output.

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 value to a MDL – in a manner consistent with EPA guidance and available information.

VI. Options Considered

The draft EPA guidance document for developing daily loads does not specify a single approach that must be adhered to, but rather, it contains a range of acceptable options. 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 the MDL for the West and Rhode Rivers.

Level of Resolution

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

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

Probability Level

All TMDLs have some probability of being exceeded, with the specific probability being 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 load 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 best professional judgment of the developers. This statistical measure represents how often the MDL is expected/allowed to be exceeded. The primary options for selecting this level of protection would be:

1. **The MDL reflects some central tendency:** In this option, the MDL is based upon the mean or median value of the range of loads expected to occur. The variability in the actual loads is not addressed.

2. **The MDL reflects a level of protection implicitly provided by the selection of some "critical" period**: In this option, the MDL is based upon the allowable load that is

predicted to occur during some critical period examined during the analysis. The developer does not explicitly specify the probability of occurrence.

3. **The MDL is a value that will be exceeded with a pre-defined probability:** In this option, a "reasonable" upper bound percentile is selected for the MDL based upon a characterization of the variability of daily loads. For example, selection of the 95th percentile value would result in a MDL that would be exceeded 5% of the time.

V. Selected Approach

The approach selected for defining a West and Rhode Rivers 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 NPDES Regulated Stormwater Point Sources
- Approach for WWTPs

VI. Approach for Nonpoint Sources and NPDES Regulated Stormwater Point Sources

The level of resolution selected for the West and Rhode Rivers MDL was a representative daily load, expressed as a single daily load for each load source. This approach was chosen due to the nature of PCBs and the focus of this study on a TMDL endpoint protective of the "fishing" designated use. Daily flow and temporal variability do not affect the rate of PCB bioaccumulation in fish tissue over the long term thus establishing no influence on achievement of the TMDL endpoint. A MDL at this level of resolution is unwarranted.

The MDL was estimated based on three factors: a specified probability level, the average annual tPCB TMDL, and the coefficient of variation (CV) of the initial condition for ambient water column tPCB concentrations in the West and Rhode Rivers. The probability level (or exceedance frequency) is based upon guidance from US EPA (1991) where examples suggest that when converting from a long-term average to a daily value, the z-score corresponding to the 99th percentile of the log-normal probability distribution should be used.

The CV was calculated using the arithmetic mean and standard deviation of the baseline ambient water column tPCB concentrations in the West and Rhode Rivers. The resulting CV of 0.493 was calculated using the following equation:

$$CV = \frac{\beta}{\alpha} \qquad \text{(Equation G-1)}$$

Where,
CV = coefficient of variation
α = mean (arithmetic)
β = standard deviation (arithmetic)

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

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

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

Using a z-score associated with the 99^{th} percent probability of 2.33, a CV of 0.493, and consistent units, the resulting dimensionless conversion factor from long-term average loads to a maximum daily value is 1.6. The average annual tPCB TMDL in the West and Rhode Rivers is reported in g/year, and the conversion from g/year to a maximum daily load in g/day is 0.0044 (*e.g.* 1.6/365)

VIII. Approach for WWTPs

The TMDL also considers contributions from NPDES permitted WWTPs that discharge quantifiable concentrations of tPCBs to the West and Rhode Rivers. The MDLs were calculated for these WWTPs based on the guidance provided in the Technical Support Document (TSD) for Water Quality-based Toxics Control (US EPA 1991). The long-term average annual TMDL was converted to maximum daily limits using Table 5-2 of the TSD assuming a coefficient of variation of 0.6 and a 99^{th} percentile probability. This results in a dimensionless multiplication factor of 3.11. The average annual West and Rhode Rivers TMDL of PCBs is reported in g/year, and the conversion from g/year to a maximum daily load in g/day is 0.0085 (*i.e.* 3.11/365). It should be noted that the WWTP Load was considered to be *de minims*.

IX. Results of Approach

Table G-1 lists the results of the selected approach to define the West and Rhode Rivers MDLs.

Table G-1: Summary of tPCB Maximum Daily Load

Source	TMDL (g/year)	MDL (g/day)
Chesapeake Bay Mainstem Influence	456.5	2.009
Direct Atmospheric Deposition	22.6	0.099
Non-regulated Watershed Runoff	11.0	0.048
Nonpoint Sources	490.1	2.156
WWTP	0.2	0.001
NPDES Regulated Stormwater	1.6	0.007
Point Sources	1.7	0.008
MOS (5%)	25.9	0.114
Total	517.7	2.279

Appendix H: List of NPDES Regulated Stormwater Permits

Table H-1: NPDES Regulated Stormwater Permit Summary for the West and Rhode Rivers Watershed[1]

MDE Permit	NPDES	Facility	City	County	Type	TMDL
05-SF-5501	MDR055501	State Highway Administration (MS4)	State-wide	All Phase I (Anne Arundel)	WMA6	Stormwater WLA
09-GP-0000	MDR100000	MDE General Permit to Construct	All	All		Stormwater WLA
04-DP-3316	MD0068306	Anne Arundel Phase I MS4	County-wide	Anne Arundel	WMA6	Stormwater WLA
02-SW-1744	MDR001744	Anne Arundel County-Mayo Water Reclamation Facility	Edgewater	Anne Arundel	WMA5	Stormwater WLA

Note: [1] Although not listed in this table, some individual process water permits incorporate stormwater requirements and are accounted for within the NPDES Stormwater WLA, as well as additional Phase II permitted MS4s, such as military bases, hospitals, etc.

Appendix I: Total PCB Concentrations and Locations of the PCB Monitoring Stations

Tables I-1 through I-3 list the tPCB concentrations in the sediment, fish tissue, and water column samples collected in West and Rhode Rivers. Figure I-1 shows the locations of water column, sediment and fish tissue monitoring stations.

Table I-1: Sediment tPCB Concentrations (ng/g) in the West and Rhode Rivers

Station	Date	Conc.
WST1	4/25/2011	2.91
WST1	11/3/2011	2.11
WST2	4/25/2011	10.89
WST2	4/25/2011	11.02
WST2	11/3/2011	6.96
WST3	4/25/2011	13.67
WST3	11/3/2011	5.80
WST4	4/25/2011	25.09
WST4	11/3/2011	2.76

Table I-2: Fish Tissue tPCB Concentrations (ng/g) in the West and Rhode Rivers

Site ID	Date	Conc. (ng/g)	Number Fish in Composite	Mean Length(cm)	Mean Weight (g)	Species
RWR	5/8/2002	186.83	4	21.9	191.2	White Perch
RWR	5/8/2002	163.60	4	23.9	236.5	White Perch
RRWBB	6/26/2003	133.86	5	26.1	287.0	White Perch
RRWBB	6/26/2003	77.24	5	26.8	297.0	White Perch
WES-A	10/26/2011	24.8	5	29.1	404.2	White Perch
WES-B	10/26/2011	23.4	5	26.7	289.0	White Perch
WES-C	10/26/2011	20.1	5	36.3	936.8	Carp
WES-D	3/15/2012	46.0	5	27.2	369.4	White Perch
WES-E	3/15/2012	71.6	5	24.2	261.4	White Perch
WES-F	3/15/2012	297.0	5	22.9	202.6	White Perch
WES-G	3/15/2012	25.3	5	39.2	1025.4	Carp

Table I-3: Water Column tPCB Concentrations (ng/L) in the West and Rhode Rivers

Date	Station	Type	Conc.
4/25/2011	WST-1	Tidal (Boundary)	0.598
8/18/2011	WST-1	Tidal (Boundary)	0.407
11/3/2011	WST-1	Tidal (Boundary)	0.358
2/16/2012	WST-1	Tidal (Boundary)	1.204
4/25/2011	WST-2	Tidal	0.358
8/18/2011	WST-2	Tidal	0.377
11/3/2011	WST-2	Tidal	0.663
2/16/2012	WST-2	Tidal	1.003
4/25/2011	WST-3	Tidal	0.320
8/18/2011	WST-3	Tidal	1.088
11/3/2011	WST-3	Tidal	0.981
2/16/2012	WST-3	Tidal	1.290
4/25/2011	WST-4	Tidal	0.394
8/18/2011	WST-4	Tidal	0.370
11/3/2011	WST-4	Tidal	0.856
2/16/2012	WST-4	Tidal	0.924
4/25/2011	WST-5	Non-tidal	0.126
8/18/2011	WST-5	Non-tidal	-
11/3/2011	WST-5	Non-tidal	0017
2/16/2012	WST-5	Non-tidal	0.162
4/25/2011	WST-6	Non-tidal	0.190
8/18/2011	WST-6	Non-tidal	0.112
11/3/2011	WST-6	Non-tidal	0.058
2/16/2012	WST-6	Non-tidal	0.369
4/25/2011	WST-7	Non-tidal	0.118
8/18/2011	WST-7	Non-tidal	0.131
11/3/2011	WST-7	Non-tidal	0.000
2/16/2012	WST-7	Non-tidal	0.239
5/4/2011	WST-8	Stormwater	0.295
2/29/2012	WST-8	Stormwater	3.661
5/4/2011	WST-11	Stormwater	0.451
2/29/2012	WST-11	Stormwater	1.286

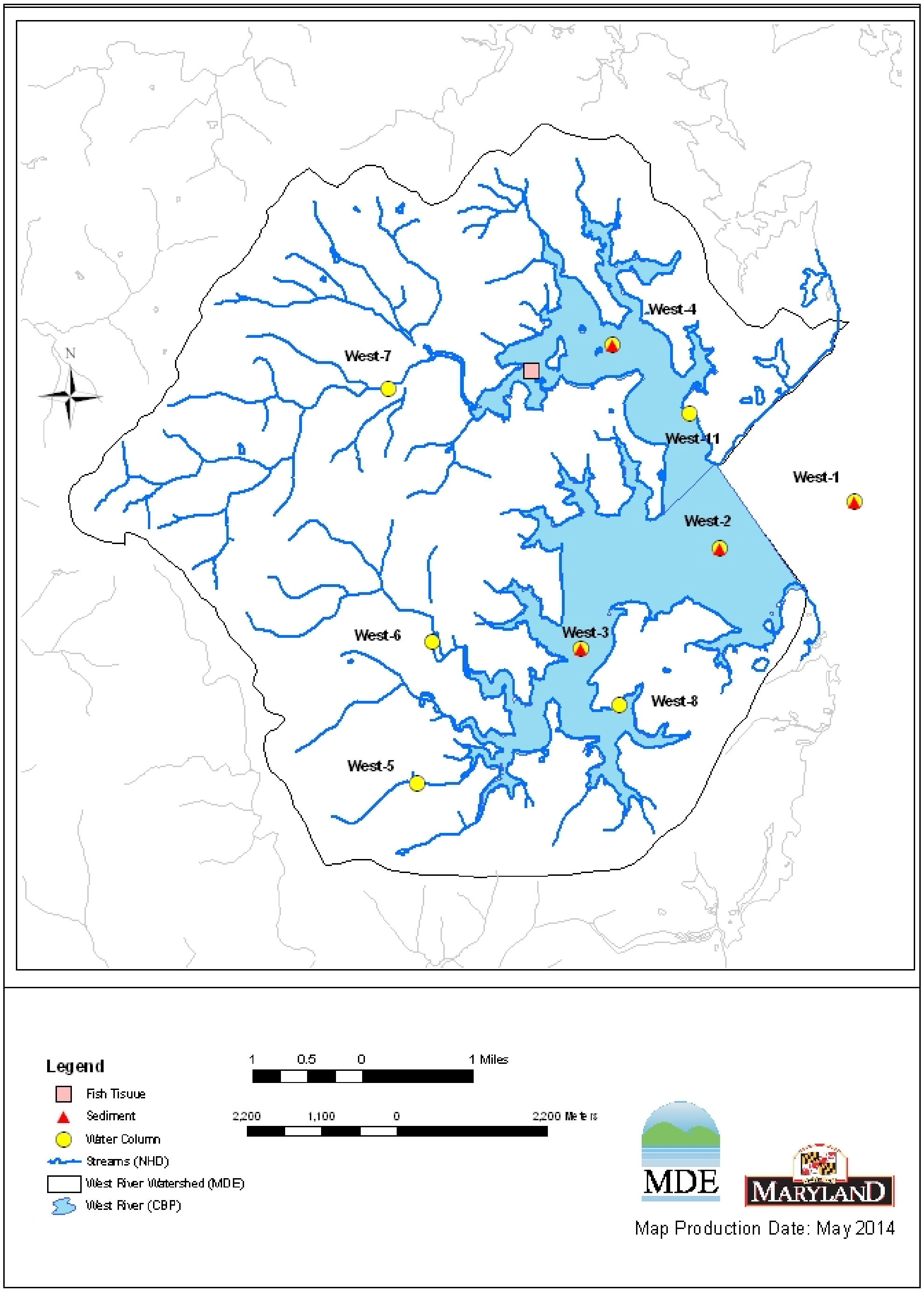


Figure I-1: The Locations of PCB Water Column, Sediment and Fish Tissue Monitoring Stations in the West and Rhode Rivers