# Total Maximum Daily Load of Polychlorinated Biphenyls in the Patuxent River Mesohaline, Oligohaline and Tidal Fresh Chesapeake Bay Segments

**FINAL**

MARYLAND
DEPARTMENT OF THE ENVIRONMENT
1800 Washington Boulevard, Suite 540
Baltimore MD 21230-1718

Submitted to:

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

August, 2017

EPA Submittal Date: April 18, 2017
EPA Approval Date: September 19, 2017

## Table of Contents

## List of Figures

## List of Tables

## List of Abbreviations

| | |
|---|---|
| Adj-SediBAF | Adjusted Sediment Bioaccumulation Factor |
| Adj-tBAF | Adjusted Total Bioaccumulation Factor |
| BAF | Bioaccumulation Factor |
| BCF | Bioconcentration Factor |
| BIBI | Benthic Index of Biotic Integrity |
| 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 |
| DMR | Discharge Monitoring Report |
| DOC | Dissolved Organic Carbon |
| 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 |
| $K_{oc}$ | PCB Organic Carbon-Water Partition Coefficient |
| $K_{ow}$ | PCB Octanol-Water Partition Coefficient |
| L | Liter |
| lbs | Pounds |
| LA | Load Allocation |
| LMA | Land Management Administration |
| LRP-MAP | Land Restoration Program Geospatial Database |
| m | Meter |

| | |
|---|---|
| $m^2$ | Square meter |
| $m^3$ | Cubic meter |
| MD | Maryland |
| MDE | Maryland Department of the Environment |
| MDL | Maximum Daily Load |
| mg | Milligram |
| MOS | Margin of Safety |
| MS4 | Municipal Separate Storm Sewer System |
| 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 |
| US | The United States of America |
| 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 | Wastewater Treatment Plant |
| µg | Microgram |

## *EXECUTIVE SUMMARY*

Section 303(d) of the federal Clean Water Act (CWA) and the U.S. Environmental Protection Agency'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 Total Maximum Daily Load (TMDL) for the specified substance that the waterbody can receive without violating WQSs, or demonstrate that WQSs are being met (CFR 2016a). 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 Patuxent River Mesohaline, Oligohaline, and Tidal Fresh Chesapeake Bay Tidal Segments. From this point on in the Executive Summary the "Patuxent River Mesohaline, Oligohaline, and Tidal Fresh Chesapeake Bay Tidal Segments" will be referred to as the "PAXMH, PAXOH, and PAXTF tidal segments" and the corresponding "Patuxent River Mesohaline, Oligohaline, and Tidal Fresh Chesapeake Bay Segmentsheds" will be referred to as the "PAXMH, PAXOH, and PAXTF watersheds".

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 2016a). The designated use class of the waters of the PAXMH, PAXOH, and PAXTF tidal segments is Use Class II – *Support of Estuarine and Marine Aquatic Life and Shellfish Harvesting* (COMAR 2016b).

The Maryland Department of the Environment (MDE) identified the tidal portion of the "Patuxent River Lower" 8-digit basin (basin code – 02131101), which includes the waters of the PAXMH and PAXOH tidal segments, on the State's 2014 Integrated Report of surface water quality as impaired by PCBs in fish tissue (first listed in 2008 based on fish tissue data collected in 2005). Recently collected fish tissue data has demonstrated that the PAXMH and PAXOH tidal segments are impaired by PCBs for different species of fish. Therefore, the listing will be separated into individual listings for the PAXMH and PAXOH tidal segments in the State's 2016 Integrated Report. In addition, the fish tissue data has demonstrated that the PAXTF tidal segment is impaired for PCBs in fish tissue and this segment will also be listed in the State's 2016 Integrated Report. The TMDL established herein by MDE will address total PCB (tPCB) listing for the PAXMH, PAXOH, and PAXTF tidal segments.

PCBs are a class of man-made compounds that were manufactured and used for a variety of industrial applications. 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. 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.
PCBs are a concern to human health, as regular consumption of fish containing elevated levels of PCBs will cause bioaccumulation within the fatty tissue of humans, which can potentially lead to the development of cancer.

Since the PAXMH, PAXOH, and PAXTF tidal segments have been identified as impaired for PCBs in fish tissue, the overall objective of the Total PCB (tPCB) TMDL established in this document is to ensure that the "fishing" designated use, in particular the protection of human health related to the consumption of fish from the PAXMH, PAXOH, and PAXTF tidal segments, is supported. This objective was achieved via the use of field monitoring and a multi-segment water quality model. The model incorporates the influences of tide, atmospheric deposition, freshwater inputs, and exchanges between the water column and bottom sediments, thereby representing realistic dynamic transport within the area.

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 PAXMH, PAXOH, and PAXTF tidal segments;
2. Simulate long-term tPCB concentrations in the water column and bottom sediments;
3. Estimate the load reductions necessary to meet the water column and sediment TMDL endpoint tPCB 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 PAXMH tidal segment and the Chesapeake Bay mainstem.

The CWA requires TMDLs to be protective of all the designated uses applicable to a particular waterbody. Within the PAXMH, PAXOH, and PAXTF tidal segments, these designated uses, include "water contact recreation," "fishing," "the protection of aquatic life and wildlife," and the "support of estuarine and marine aquatic life and shellfish harvesting". The TMDLs presented herein were 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". In establishing a load that is protective of the fishing designated use, this TMDL will also ensure the protection of all other applicable designated uses within the PAXMH, PAXOH, and PAXTF tidal segments.

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 PAXMH, PAXOH, and PAXTF tidal segments, the resulting site specific water column TMDL endpoint tPCB concentration is 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 (*i.e.*, water column TMDL endpoint tPCB concentrations $<$ saltwater chronic tPCB criterion). 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 significant pathways 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 endpoint tPCB 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 PAXMH, PAXOH, and PAXTF watersheds. Nonpoint sources include direct atmospheric deposition to the river, runoff from non-regulated watershed areas, one contaminated site, and tidal influence from the Chesapeake Bay mainstem. Point sources include National Pollutant Discharge Elimination System (NPDES) regulated stormwater runoff within the watershed, 21 NPDES permitted municipal wastewater treatment plants (WWTPs), and one NPDES permitted industrial process water facility.

The transport of PCBs from bottom sediments to the water column through re-suspension 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. The water quality model developed for this TMDL simulates conditions within the water column and sediment as a single system, so exchanges between the sediment and water column are considered an internal load. Only external sources to the system are assigned a baseline load or allocation within a TMDL. Therefore, PCB transport from bottom sediments through re-suspension and diffusion will not be assigned a baseline load or allocation.

The transport of PCBs into the PAXMH tidal segment due to tidal influences from the Chesapeake Bay mainstem is a source of PCBs to the system; however, this load contribution results from other point and nonpoint source inputs (both historic and current) and is not considered to be a directly controllable source. Therefore this load will only be presented in this document for informational purposes and not be assigned a baseline load or allocation within the TMDL. The modeling of this TMDL does, however, account for the attenuation of PCBs in Chesapeake Bay water that is expected to occur over time due to natural processes such as the burial of contaminated sediment.

The objective of the TMDL established herein is to reduce current tPCB loads to the PAXMH, PAXOH, and PAXTF tidal segments 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 2016a). 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.

Summaries of the baseline loads, TMDL allocations, and maximum daily loads (MDLs) for the PAXMH, PAXOH, and PAXTF tidal segments are presented in Table ES-1. Additionally, the baseline loads and TMDL allocations only consider current sources of PCBs that are deemed to be directly controllable loads. When implemented, these TMDLs will ensure that the resulting tPCB concentrations in the sediment and water column are at levels supportive of the "fishing" designated use in the PAXMH, PAXOH, and PAXTF tidal segments.

In the PAXMH, PAXOH, and PAXTF tidal segments, a TMDL modeling scenario was developed using the water quality model to assign load reductions and to establish WLAs, and LAs for all the source categories. As applied in previous PCBs TMDLs developed in Maryland (e.g. Back River [MDE 2011a]), the model assumes that water column tPCB concentration decreases at a rate of 5% per year at the tidal boundary between the PAXMH tidal segment and Chesapeake Bay mainstem. The primary source of PCBs to the atmosphere is from volatilization of PCB contaminated land sources which will be eliminated as these sources are remediated through implementation of the non-regulated watershed runoff LA and NPDES regulated stormwater WLA. The resultant TMDL scenario requires a 95.3% load reduction of the total baseline load from the point and non-point sources in the PAXTF tidal watershed segment in order to achieve the sediment and water column TMDL endpoint tPCB concentrations in the PAXMH, PAXOH, and PAXTF tidal segments. No reductions are necessary in the PAXMH and PAXOH watersheds to achieve the TMDL endpoints as the loading from the PAXTF watershed is orders of magnitude greater than PCB loadings from these other segment's watersheds. An explicit MOS of 5% was applied to the PAXTF watershed where load reductions were required in order to achieve the TMDL in the PAXMH, PAXOH, and PAXTF tidal segments.

Federal regulations require that TMDL analysis take into account the impact of critical conditions and seasonality on water quality (CFR 2016b). 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 PAXMH, PAXOH, and PAXTF tidal segments. The TMDL implicitly accounts for seasonal variations as well as critical conditions.

Despite the fact that PCB loads from re-suspension 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 meeting water quality goals in the PAXMH, PAXOH, and PAXTF tidal segments. 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 PAXMH, PAXOH, and PAXTF tidal segments.

**Table ES-1: Summary of Baseline tPCB Baseline Loads, TMDL Allocations, Load Reductions, and MDLs in the PAXMH, PAXOH, and PAXTF Tidal Segments**

| Tidal Segment | Source | Baseline Load (g/year) | Baseline Load (%) | TMDL (g/year) | Load Reduction (%) | MDL (g/day) |
|---|---|---|---|---|---|---|
| PAXMH | Non-regulated Watershed Runoff | 119.2 | 40.62% | 119.2 | 0.0% | 2.453 |
| | Atmospheric Deposition | 172.1 | 58.64% | 172.1 | 0.0% | 3.541 |
| | ***Nonpoint Sources*** | ***291.4*** | ***99.26%*** | ***291.4*** | ***0.0%*** | ***5.993*** |
| | NPDES Regulated Stormwater[4] | | | | | |
| | Prince George's | 0.6 | 0.20% | 0.6 | 0.0% | 0.012 |
| | Calvert[2] | 0.0 | 0.01% | 0.0 | 0.0% | 0.000 |
| | St. Mary's | 0.1 | 0.02% | 0.1 | 0.0% | 0.001 |
| | Charles | 1.5 | 0.52% | 1.5 | 0.0% | 0.031 |
| | ***Point Sources*** | ***2.2*** | ***0.74%*** | ***2.2*** | ***0.0%*** | ***0.045*** |
| | ***MOS (5%)*** | - | - | | | |
| | ***Total PAXMH*** | ***293.6*** | ***100.00%*** | ***293.6*** | ***0.0%*** | ***6.038*** |
| PAXOH | Non-regulated Watershed Runoff | 73.5 | 74.93% | 73.5 | 0.0% | 0.952 |
| | Atmospheric Deposition | 22.9 | 23.30% | 22.9 | 0.0% | 0.296 |
| | ***Nonpoint Sources*** | ***96.4*** | ***98.23%*** | ***96.4*** | ***0.0%*** | ***1.248*** |
| | NPDES Regulated Stormwater[4] | | | | | |
| | Anne Arundel | 0.3 | 0.31% | 0.3 | 0.0% | 0.004 |
| | Calvert[2] | 0.0 | 0.01% | 0.0 | 0.0% | 0.000 |
| | Prince George's | 1.4 | 1.44% | 1.4 | 0.0% | 0.018 |
| | ***Point Sources*** | ***1.7*** | ***1.77%*** | ***1.7*** | ***0.0%*** | ***0.022*** |
| | ***MOS (5%)*** | - | - | | | |
| | ***Total PAXOH*** | ***98.1*** | ***100.00%*** | ***98.1*** | ***0.0%*** | ***1.271*** |
| PAXTF | Non-regulated Watershed Runoff[3] | 1,118.9 | 65.32% | 1.0 | 99.9% | 0.011 |
| | Atmospheric Deposition | 7.1 | 0.41% | 0.0 | 99.9% | 0.000 |
| | Contaminated Sites[1,2] | 0.0 | 0.00% | 0.0 | 0.0% | 0.000 |
| | ***Nonpoint Sources*** | ***1,126.0*** | ***65.74%*** | ***1.0*** | ***99.9%*** | ***0.011*** |
| | NPDES Regulated Stormwater [3,4] | | | | | |
| | Anne Arundel | 100.4 | 5.86% | 0.1 | 99.9% | 0.001 |
| | Frederick[1] | 0.2 | 0.01% | 0.2 | 0.0% | 0.002 |
| | Howard | 228.6 | 13.35% | 0.1 | 99.9% | 0.001 |
| | Montgomery | 32.2 | 1.88% | 0.0 | 99.9% | 0.000 |
| | Prince George's | 154.6 | 9.03% | 0.1 | 99.9% | 0.001 |
| | WWTPs | 70.8 | 4.13% | 75.2 | -6.3% | 0.639 |
| | ***Point Sources*** | ***586.9*** | ***34.26%*** | ***75.7*** | ***87.1%*** | ***0.645*** |
| | ***MOS (5%)*** | - | - | ***4.0*** | - | ***0.035*** |
| | ***Total PAXTF*** | ***1,712.9*** | ***100.00%*** | ***80.7*** | ***95.3%*** | ***0.690*** |

[1]Contaminated sites, and Frederick NPDES regulated stormwater tPCB baseline loads are considered insignificant (less than 0.01% of the total baseline load) and no reductions are assigned.
[2]Baseline load, TMDLs and MDLs appear as zero since their actual values are less than the number of significant decimal digits.
[3]Baseline loads from WWTPs which discharge to the PAXTF watershed have been subtracted proportionally from the non-regulated watershed runoff and NPDES regulated stormwater baseline load to avoid double counting.
[4]NPDES regulated stormwater baseline loads and WLAs are an aggregate of loadings from areas covered under the following permits: (i) Phase I & II jurisdictional MS4 permits, (ii) the State Highway Administration's Phase I MS4 permit, (iii) industrial facilities permitted for stormwater discharges, and (iv) MDE general permit to construction sites.
Note: Columns may not precisely add to totals due to rounding.

## 1.0 INTRODUCTION

Section 303(d) of the federal Clean Water Act (CWA) and the U.S. Environmental Protection Agency'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 for the specified substance that the waterbody can receive without violating WQSs, or demonstrate that WQSs are being met (CFR 2016a). 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 Patuxent River Mesohaline, Oligohaline, and Tidal Fresh Chesapeake Bay Tidal Segments. From this point on in the report the "Patuxent River Mesohaline, Oligohaline, and Tidal Fresh Chesapeake Bay Tidal Segments" will be referred to as the "PAXMH, PAXOH, and PAXTF tidal segments" and the corresponding "Patuxent River Mesohaline, Oligohaline, and Tidal Fresh Chesapeake Bay Segmentsheds" will be referred to as the "PAXMH, PAXOH, and PAXTF watersheds".

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 protection of aquatic life and wildlife (COMAR 2016a). The designated use class of the waters of the PAXMH, PAXOH, and PAXTF tidal segments is Use Class II – *Support of Estuarine and Marine Aquatic Life and Shellfish Harvesting* (COMAR 2016b).

The Maryland Department of the Environment (MDE) has identified the waters of the PAXMH, PAXOH, and PAXTF tidal segments on the State's 2014 Integrated Report of surface water quality as impaired for the contaminants summarized in Table 1. The table includes the tidal segment, 8-digit basin (code), assessment unit ID, listing type, listing year, impairment, and status of TMDL development. The tidal portion of the "Patuxent River Lower" 8-digit basin (basin code – 02131101) which includes the waters of the PAXMH and PAXOH tidal segments is currently listed for PCBs in fish tissue. Recently collected fish tissue data from 2014 and 2015 has demonstrated that the PAXMH and PAXOH tidal segments are impaired by PCBs for different species of fish (See Section 2.2 for more detailed information). Therefore, the listing will be separated into individual listings for the PAXMH and PAXOH tidal segments in the State's 2016 Integrated Report. In addition, the fish tissue data demonstrated that the PAXTF tidal segment is impaired for PCBs in fish tissue and this segment will also be listed in the State's 2016 Integrated Report. The TMDL established herein by MDE will address total PCB (tPCB) listings for the PAXMH, PAXOH, and PAXTF tidal segments, for which a data solicitation was conducted, and all readily available data have been considered.

**Table 1: PAXMH, PAXOH, and PAXTF Tidal Segment Impairment Listings**

| Tidal Segment | 8-digit Basin (Code) | Assessment Unit ID | Listing Type | Listing | Listing Year | TMDL |
|---|---|---|---|---|---|---|
| PAXMH | Patuxent River Lower (02131101) | MD-PAXMH (Multiple tidal sub-segments) | Tidal Segment | Fecal Coliform | 1996 1998 2010 2012 2014 | 2005 2009 |
| | | MD-PAXMH-SWSAV* | Tidal Segment | TSS | 1996 | (Chesapeake Bay TMDLs) 2010 |
| | | MD-PAXMH | Tidal Segment | Nitrogen | 1996/ 2012 | |
| | | MD-PAXMH | Tidal Segment | Phosphorus | 1996 2012 | |
| | | MD-PAXMH | Tidal Segment | Impacts to Biological Community | 2006 | Future Development |
| | | MD-PAXMH-OH-02131101 | 8-digit Basin (Tidal Portion) | PCBs in Fish Tissue | 2008** | - |
| PAXOH | | MD-PAXOH | Tidal Segment | Phosphorus | 1996 2012 | (Chesapeake Bay TMDLs) 2010 |
| | | MD-PAXOH | Tidal Segment | Nitrogen | 1996 2012 | |
| | | MD-PAXOH-SWSAV* | Tidal Segment | TSS | 2010 | |
| | | MD-PAXOH | Tidal Segment | Impacts to Biological Community | 2010 | Future Development |
| | | MD-PAXOH | Tidal Segment | Fecal Coliform | 2012 | 2007 |
| PAXTF | Patuxent River Middle (02131102) | MD-PAXTF | Tidal Segment | Nitrogen | 1996 2012 | (Chesapeake Bay TMDL) 2010 |
| | | MD-PAXTF | Tidal Segment | Phosphorus | 1996 2012 | |
| | | MD-PAXTF-SWSAV* | Tidal Segment | TSS | 2010 | |
| | | MD-PAXTF | Tidal Segment | PCBs in Fish Tissue | 2016*** | - |

*SWSAV-Shallow Water Submerged Aquatic Vegetation
**PCBs in fish tissue listing for the tidal portion of the Patuxent River Lower 8-digit Basin (02131101) will be redefined in the 2016 Integrated Report as two separate listings for the PAXMH and PAXOH tidal segments
***PAXTF tidal segment will be listed for PCBs in fish tissue in the 2016 Integrated Report

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, or the inadvertent production during manufacturing processes. 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.

MDE lists waters as impaired for PCBs in fish tissue in the State's Integrated Report when tPCB fish tissue concentrations exceed 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 2014a). In addition to identifying impaired waterbodies in 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 for the PAXMH, PAXOH, and PAXTF suggest limiting the consumption of the following fish species: American eel (3 meals per month for general population), channel catfish (3 meals per month for general population), and white perch (8 meals per month for general population and 7 meals per month for children) (MDE 2014b).

## 2.0 SETTING AND WATER QUALITY DESCRIPTION

### 2.1 General Setting

**Location**

The Patuxent River is a tidal tributary of the Chesapeake Bay located in Maryland's Western Shore that drains portions of Anne Arundel, Calvert, Charles, Frederick, Howard, Montgomery, Prince George's and St. Mary's Counties. The tidal river consisting of the PAXMH, PAXOH, and PAXTF tidal segments has a length of approximately 70 kilometers (km).

The PAXMH and PAXOH watersheds each contain a portion of the Patuxent River Lower 8-digit Basin (Basin Code: 02131101) and the PAXTF watershed includes the following seven 8-digit Basins: Patuxent River Middle (02131102), Western Branch (02131103), Patuxent River Upper (02131104), Little Patuxent River (02141105), Rocky Gorge Dam (02131107), Middle Patuxent River (02131106), and Brighton Dam (02131108). The PAXTF watershed also contains the drainage area of the Western Branch Tidal Fresh Chesapeake Bay Tidal Segment (WBRTF). The PAXMH, PAXOH, and PAXTF watershed areas are 471 square kilometers ($km^2$), 299 $km^2$, and 1,505 $km^2$, respectively with a total watershed area of 2,275 $km^2$. The location of the PAXMH, PAXOH, and PAXTF watersheds are displayed in Figure 1.

**Land Use**

The land use distribution for the PAXMH, PAXOH, and PAXTF watersheds are displayed in Figure 2 and presented in Table 2. The table includes the watershed; and distribution of urban, forest, agriculture, and water/wetland land uses. The land use distribution was calculated using the United States Geological Survey's (USGS) 2006 land cover data (USGS 2006), which was specifically developed to be applied within the Chesapeake Bay Program's (CBP) Phase 5.3.2 watershed model.

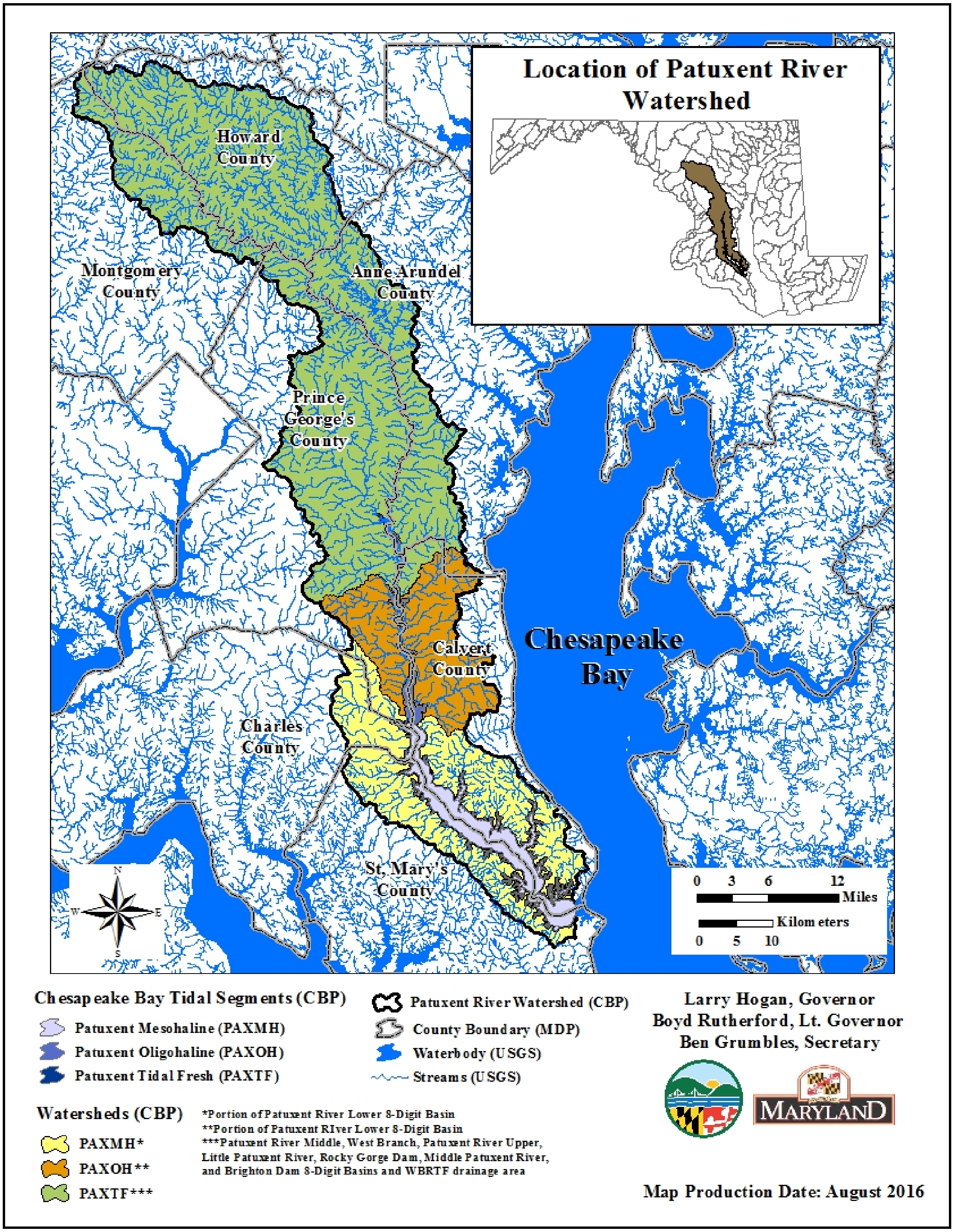


**Figure 1: Location Map of PAXMH, PAXOH, and PAXTF Watersheds**

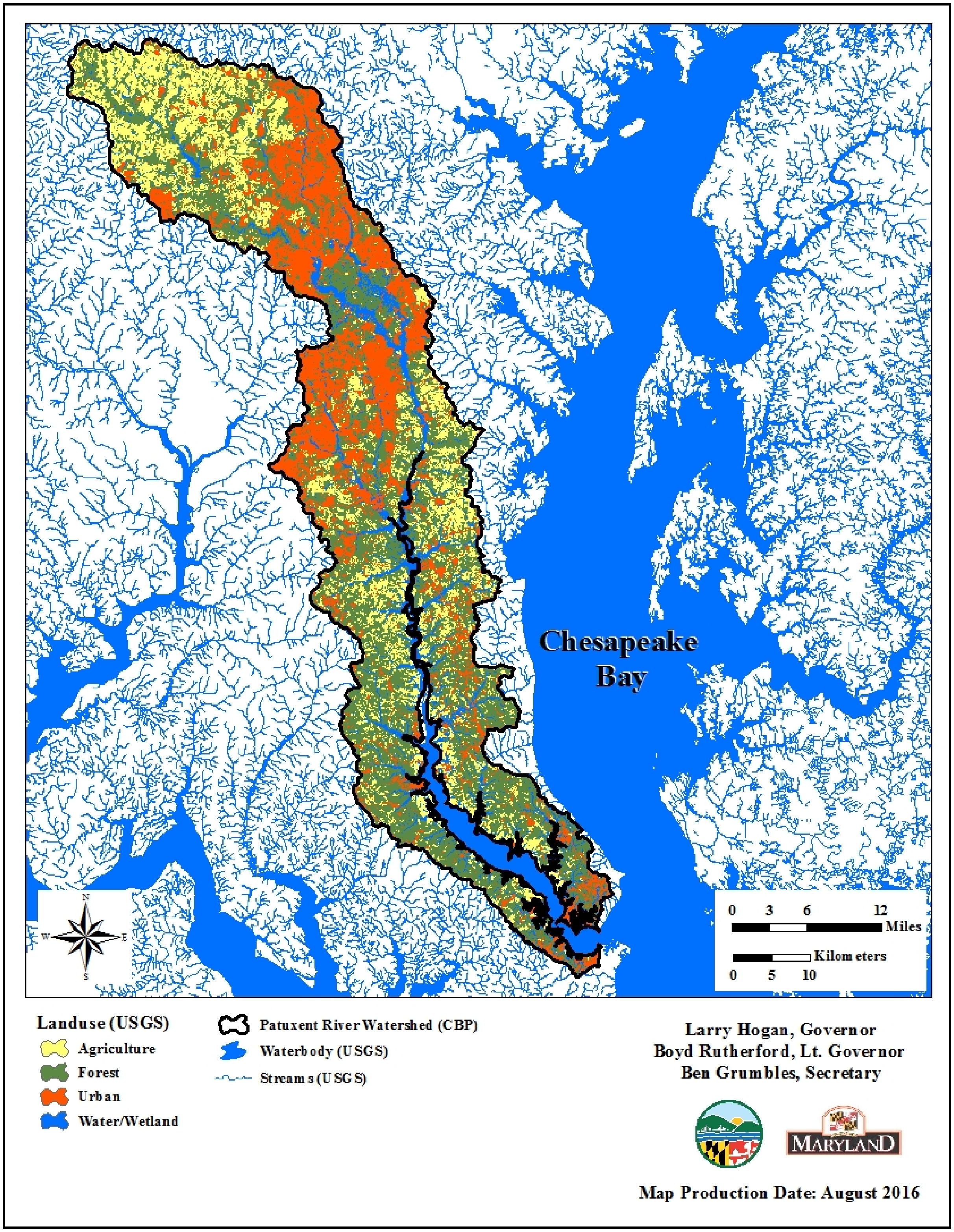


**Figure 2: Land Use in the PAXMH, PAXOH, and PAXTF Watersheds**

**Table 2: Land Use Distribution in the PAXMH, PAXOH, and PAXTF Watersheds**

| Watershed | Landuse | Urban | Forest | Agriculture | Water/Wetland |
|---|---|---|---|---|---|
| PAXMH | Area ($km^2$) | 70 | 266 | 80 | 56 |
| | Area (%) | 14.8% | 56.5% | 16.9% | 11.8% |
| PAXOH | Area ($km^2$) | 37 | 157 | 72 | 33 |
| | Area (%) | 12.3% | 52.5% | 24.2% | 11.0% |
| PAXTF | Area ($km^2$) | 470 | 556 | 371 | 108 |
| | Area (%) | 31.2% | 36.9% | 24.7% | 7.2% |

## 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 2016a). The designated use class of the waters of the PAXMH, PAXOH, and PAXTF tidal segments is Use Class II – *Support of Estuarine and Marine Aquatic Life and Shellfish Harvesting* (COMAR 2016b).

**Water Column Characterization**

The State of Maryland has adopted three separate water column tPCB criteria to account for different aspects of water quality. There is (1) a human health criterion of 0.64 nanograms/liter (ng/L) or parts per trillion (ppt) that addresses the consumption of PCB-contaminated fish, (2) a freshwater chronic criterion of 14 ng/L that is protective of aquatic life in non-tidal systems, and (3) a saltwater chronic criterion of 30 ng/L that is protective of aquatic life in tidal systems (COMAR 2016d). Since the human health criterion is more stringent than the fresh water and saltwater aquatic life criteria, if the human health criterion is met, all applicable water quality criteria would be satisfied.

The State defines the waters of the "Patuxent River Area" (MD 6-Digit Code: 021311) as fresh water above a line connecting Chalk Point and God's Grace point which is the boundary between the PAXMH and PAXOH tidal segments (COMAR 2016e). Thus, the saltwater aquatic life criterion will be applicable to the PAXMH tidal segment and the freshwater aquatic life criterion will be applicable to the PAXOH and PAXTF when assessing water quality. Maryland's water quality criteria are presented in Table 3.

The human health tPCB 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 fish intake of 17.5 g/day. A CSF 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 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 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.

**Table 3: Water Column tPCB Criteria**

| tPCB Criteria/Threshold | Concentration (ng/L) |
|---|---|
| Salt Water Chronic Aquatic Life Criterion | 30 |
| Fresh Water Chronic Aquatic Life Criterion | 14 |
| Human Health Criterion | 0.64 |

In 2013 and 2014, water quality monitoring surveys were conducted by MDE to measure water column tPCB concentrations in the PAXMH, PAXOH, and PAXTF tidal segments. Tidal water column sampling was conducted at eight stations within the tidal segments. In addition to providing assessment data, the monitoring plan was developed in order to fully characterize the impairment and inform model development. One of the tidal stations was located at the boundary between the PAXMH tidal segment and the main stem of the Chesapeake Bay, to evaluate the tidal influences from the Bay. Sediment sampling was also conducted at each tidal station within the Patuxent River to characterize tPCB sediment concentrations.

Non-tidal water column sampling was conducted concurrently with tidal monitoring at six stations throughout the PAXMH, PAXOH, and PAXTF watersheds. This data was required to estimate loads from the watersheds. Figure 3 provides a map of the tidal and non-tidal monitoring stations. The water quality data for the PAXMH, PAXOH, and PAXTF tidal segments is summarized in Table 4. The table includes the tidal segment, sample media, sample type, sample size, year in which samples were collected; and mean, maximum, and minimum tPCB concentrations for water column and sediment samples. Appendix G contains tables of all the water column and sediment tPCB concentration data.

**Table 4: Water Quality Data Summary for the PAXMH, PAXOH, and PAXTF Tidal Segments**

| Tidal Segment | Sample Media | Sample Type | Sample Years | Sample Size | tPCB Concentration (ng/L) | | |
|---|---|---|---|---|---|---|---|
| | | | | | Mean | Max | Min |
| PAXMH | Water Column | Tidal | 2013/2014 | 11 | 1.0 | 4.3 | 0.01 |
| | | Non-Tidal | 2013/2014 | 8 | 1.0 | 4.3 | 0.01 |
| | | Tidal Boundary | 2013/2014 | 4 | 2.9 | 11.0 | 0.01 |
| | Sediment | Tidal | 2013/2014 | 6 | 2.2 | 3.9 | 1.2 |
| PAXOH | Water Column | Tidal | 2013/2014 | 8 | 3.3 | 9.3 | 0.3 |
| | | Non-Tidal | 2013/2014 | 8 | 1.6 | 8.6 | 0.02 |
| | Sediment | Tidal | 2013/2014 | 5 | 5.6 | 8.6 | 2.9 |
| PAXTF | Water Column | Tidal | 2013/2014 | 8 | 4.4 | 12.4 | 0.3 |
| | | Non-Tidal | 2013/2014 | 8 | 3.7 | 12.8 | 0.05 |
| | Sediment | Tidal | 2013/2014 | 2 | 3.3 | 6.2 | 0.4 |

Water quality data analysis indicates that the mean water column tPCB concentrations for tidal samples in the PAXMH, PAXOH, and PAXTF tidal segments exceed the human health tPCB criterion of 0.64 ng/L, but do not exceed either the fresh water (14 ng/L) or saltwater (30 ng/L) chronic aquatic life criteria for tPCBs.

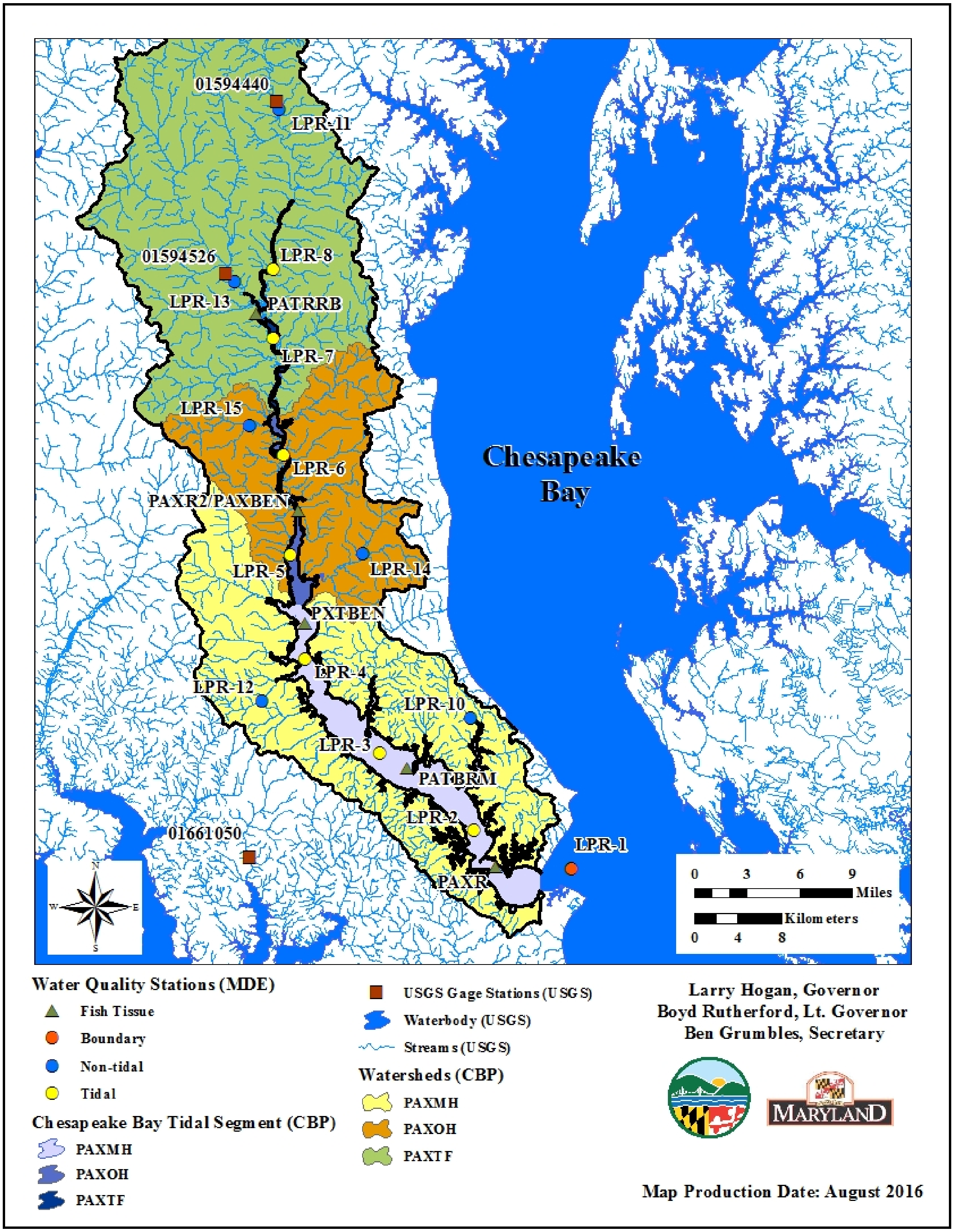


**Figure 3: Water Quality Monitoring Stations in the PAXMH, PAXOH, and PAXTF Watersheds**

## Fish Tissue Characterization

In addition to the water column criteria described above, fish tissue monitoring is also used as an indicator of PCB water quality conditions. Maryland regularly collects and analyzes fish tissue data in order to issue fish consumption advisories and recommendations, and determine whether Maryland waterbodies are meeting the "fishing" designated use. The State's tPCB fish tissue listing threshold of 39 ng/g is based on a fish consumption limit of 4, 8-ounce meals per month, and is applied to the skinless fillet of the fish, the edible portion typically consumed by humans. 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 2014a).

MDE collected 11 fish tissue composite samples (55 total fish) in the PAXMH tidal segment, 9 fish tissue composite samples (43 total fish) in the PAXOH tidal segment, and 4 fish tissue composite samples (20 total fish) in the PAXTF tidal segment. Samples were collected in September 2009, May 2014, and September 2015 and analyzed for tPCBs. The fish tissue tPCB data for the PAXMH, PAXOH, and PAXTF tidal segments is summarized in Table 5. The table includes the tidal segment, year in which samples were collected, fish species, number of composites (individual fish tissue samples); mean, maximum, and minimum tPCB concentrations for fish tissue samples; and number of composites that exceed the listing threshold. Appendix G contains a table of all the fish tissue tPCB concentration data.

**Table 5: Fish Tissue Data Summary for the PAXMH, PAXOH, and PAXTF Tidal Segments**

| Tidal Segment | Sample Years | Fish Species | Composites (Individual Fish) | tPCB Concentration (ng/g) | | | Listing Threshold Exceedances |
|---|---|---|---|---|---|---|---|
| | | | | Mean | Max | Min | |
| PAXMH | 2014 2015 | White Perch | 11 (55) | 48.0 | 105.5 | 9.5 | 7 |
| PAXOH | 2009 2014 | White Perch | 4 (20) | 14.0 | 18.4 | 9.6 | 0 |
| | | Channel Catfish | 5 (23) | 138.3 | 268.9 | 48.9 | 5 |
| PAXTF | 2015 | White Perch | 2 (10) | 39.9 | 46.7 | 33.1 | 1 |
| | | Channel Catfish | 2 (10) | 120.3 | 125.5 | 115.1 | 2 |

The mean tPCB concentrations of composites of white perch in the PAXMH tidal segment, channel catfish in the PAXOH tidal segment, and white perch and channel catfish in the PAXTF tidal segment, exceed the listing threshold, indicating that there is a tPCB impairment in all three tidal segments. The tidal portion of the Patuxent River Lower 8-digit basin, which includes the waters of the PAXMH and PAXOH tidal segments, is listed for

PCBs in fish tissue in the 2016 Integrated Report of surface water quality, based on data from 2009. The more recently collected fish tissue data from 2014 and 2015 has demonstrated that the PAXMH and PAXOH tidal segments are impaired by tPCBs for different species of fish, white perch in the PAXMH tidal segment and channel catfish in the PAXOH tidal segment. Therefore, the listing will be separated into individual listings for the PAXMH and PAXOH tidal segments in the State's 2016 Integrated Report. In addition the fish tissue data has also demonstrated that the PAXTF tidal segment is impaired for PCBs in fish tissue (channel catfish) and this segment will also be listed in the State's 2016 Integrated Report.

**Analytical Methods**

PCB analytical services were provided by the University of Maryland Center for Environmental Science (UMCES), using 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 are determined based on their chromatographic retention times relative to the internal standards. This approach was based on the approved EPA Method 8082 which was developed in 1996. A detailed description of this method is provided in 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 four criteria: 1) the Integrated Report fish tissue tPCB listing threshold (39 ng/g), 2) the human health water column tPCB criterion (0.64 ng/L), 3) the freshwater chronic tPCB criterion for protection of aquatic life (14 ng/L), and 4) the saltwater chronic tPCB criterion for protection of aquatic life (30 ng/L). Since the PAXMH, PAXOH, and PAXTF tidal segments were identified as impaired for PCBs in fish tissue, the overall objective of the tPCB TMDLs established in this document is to ensure that the "fishing" designated use, which is protective of human health related to the consumption of fish, is supported. However, this TMDL will also ensure the protection of all other applicable designated uses.

The fish tissue tPCB listing threshold concentration is translated into an associated water column tPCB threshold concentration to provide a TMDL endpoint, as the water quality model only simulates water column and sediment tPCB concentration and does not incorporate a food web model to predict fish tissue tPCB concentrations (see Equation 3.1). This was accomplished using Adjusted Total Bioaccumulation Factors (Adj-tBAFs), the derivation of which follows the method applied within the Potomac River tPCB TMDLs (Haywood and Buchanan, 2007). First, a total Bioaccumulation Factor (tBAF) is calculated per fish species, and subsequently the tBAFs are normalized by the species median lipid content and median dissolved water column tPCB 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). Then the most environmentally conservative of the Adj-tBAFs is then selected to calculate the water column tPCB threshold concentration. Finally, this final water column tPCB threshold concentration is subsequently compared to the water column tPCB criteria concentrations, as described in Section 2.2, to identify the most stringent concentration which is selected as the TMDL endpoint to ensure that all applicable criteria within the embayment are attained. The water column tPCB threshold concentrations for the PAXMH, PAXOH, and PAXTF tidal segments are presented in Table 6. The table includes the tidal segment, Adj-tBAF, fish tissue tPCB listing threshold concentration, water column tPCB threshold concentrations, and water quality criteria.

$$C_{WCLT} = \frac{C_{FTLT}}{\text{Adj-tBAF} \times \text{Unit Conversion}} \qquad \text{(Equation 3.1)}$$

$C_{WCLT}$ = Water Column tPCB Threshold Concentration (ng/L)
$C_{FTLT}$ = Fish Tissue tPCB Listing Threshold Concentration (ng/g)
Adj-tBAF = Adjusted Total Bioaccumulation Factor (L/kg)
Unit Conversion = 0.001 (kg/g)

**Table 6: Water Column tPCB Threshold Concentrations for the PAXMH, PAXOH, and PAXTF Tidal Segments**

| Tidal Segment | Adj-tBAF (L/kg)* | Fish Tissue tPCB Listing Threshold Concentration (ng/g) | Water Column tPCB Threshold Concentration (ng/L)** | Aquatic Life Chronic tPCB Criterion*** (ng/L) | Human Health tPCB Criterion (ng/L) |
|---|---|---|---|---|---|
| PAXMH | 108,659 | 39 | 0.36 | 30 | 0.64 |
| PAXOH | 96,365 | | 0.40 | 14 | |
| PAXTF | 65,457 | | 0.60 | 14 | |

* Adj-tBAF calculations presented in Appendix B
**Water column tPCB threshold concentrations are applied as TMDL endpoints for the water column
***Saltwater Aquatic Life Criterion is applied to the PAXMH tidal segment and Freshwater Aquatic Life Criteria are applied to the PAXOH and PAXTF tidal segments

The water column tPCB threshold concentrations for the PAXMH (0.36 ng/L), PAXOH (0.40 ng/L), and PAXTF (0.60 ng/L) tidal segments are more stringent than the aquatic life chronic and human health criterion and thus selected as the TMDL endpoints.

A similar method was used to relate fish tissue tPCB concentrations to a tPCB endpoint for the sediment in the river (see Equation 3.2). This was accomplished using the Adjusted Sediment Bioaccumulation Factors (Adj-SediBAFs), 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 per species (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 tPCB threshold concentration which is applied as the TMDL endpoint for sediment. The sediment tPCB threshold concentrations for the PAXMH, PAXOH, and PAXTF tidal segments are presented in Table 7. The table includes the tidal segment, Adj-SediBAF, fish tissue tPCB listing threshold concentration, and sediment tPCB threshold concentrations.

$$C_{SLT} = \frac{C_{FTLT}}{\text{Adj-SediBAF}} \qquad \text{(Equation 3.2)}$$

$C_{SLT}$ = Sediment tPCB Threshold Concentration (ng/g)
$C_{FTLT}$ = Fish Tissue tPCB Listing Threshold Concentration (ng/g)
Adj-SediBAF = Adjusted Total Bioaccumulation Factor (unitless)

**Table 7: Sediment tPCB Threshold Concentrations for the PAXMH, PAXOH, and PAXTF Tidal Segments**

| Tidal Segment | Adj-SediBAF* | Fish Tissue tPCB Listing Threshold Concentration (ng/g) | Sediment tPCB Threshold Concentration** (ng/g) |
|---|---|---|---|
| PAXMH | 15.61 | 39 | 2.50 |
| PAXOH | 28.76 | | 1.36 |
| PAXTF | 75.68 | | 0.52 |

* Adj-SediBAF calculations presented in Appendix B
**Sediment tPCB threshold concentrations are applied as TMDL endpoints for sediment

The sediment tPCB threshold concentrations for the PAXMH (2.50 ng/g), PAXOH (1.36 ng/g), and PAXTF (0.52 ng/g) tidal segments are selected as the TMDL endpoints.

The CWA requires TMDLs to be protective of all the designated uses applicable to a particular waterbody. 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 Sections 1.0 and 2.2. These include “marine and estuarine aquatic life”, “shellfish harvesting”, and “water contact recreation”. The water column tPCB TMDL endpoint concentrations, whose derivations are described above, will be used in this TMDL analysis and are more stringent than Maryland’s saltwater and freshwater aquatic life chronic tPCB criteria. 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 or shellfish) consumption, as drinking water consumption does not pose any risk for cancer development at environmentally relevant levels.

## 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 U.S., they are still being released to the environment via accidental fires, leaks, and spills from PCB-containing equipment; potential leaks from hazardous waste sites that contain PCBs; illegal or improper dumping; 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; and through inadvertent production during manufacturing processes. 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 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 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 PAXMH, PAXOH, and PAXTF tidal segments is diagramed in Figure 4. PCB sources, resulting primarily from historical uses of these compounds and potential releases to the environment as described above, include both point and nonpoint sources. This section provides a summary of these existing sources that have been identified as contributing tPCB loads to the impaired waters.

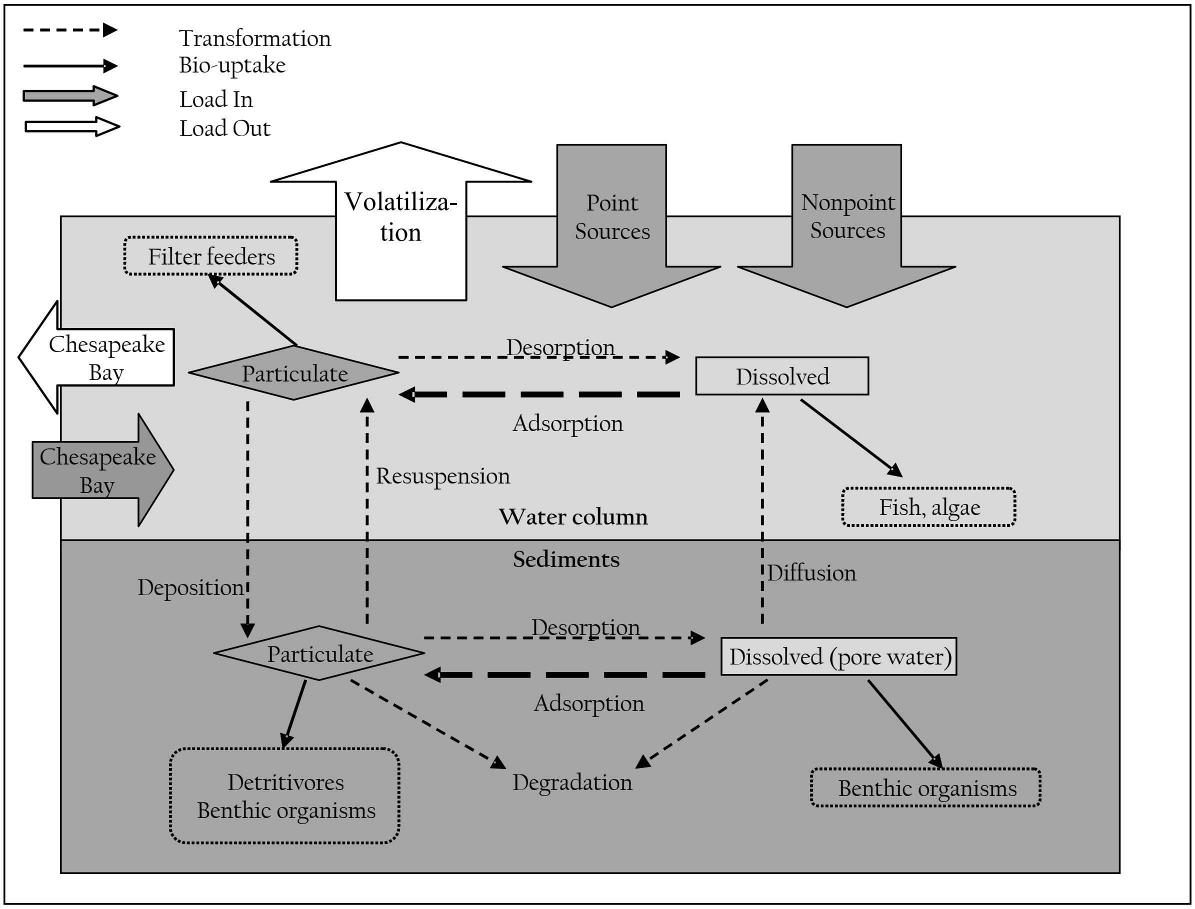


**Figure 4: Conceptual Model of the Key Transport and Transformation Processes of PCBs in Surface Water and Bottom Sediments of the PAXMH, PAXOH, and PAXTF Tidal Segments and Entry Points to the Food Chain**

### 4.1 Nonpoint Sources

For the purpose of this TMDL, under current conditions, the following nonpoint sources of PCBs have been identified in the PAXMH, PAXOH, and PAXTF tidal segments: 1) Chesapeake Bay mainstem tidal influence, 2) direct atmospheric deposition to the surface water of the tidal segments, 3) contaminated sites (areas with known PCB soil contamination, as documented by state or federal hazardous waste cleanup programs), and 4) runoff from non-regulated watershed areas.

The transport of PCBs from bottom sediments to the water column through re-suspension 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 re-suspension and diffusion from bottom sediments.

## Chesapeake Bay Mainstem Tidal Influence

The water quality model, applying the observed tPCB concentrations measured near the mouth of the PAXMH tidal segment, predicts a gross tPCB input of 3,631 g/year from the Chesapeake Bay to the PAXMH tidal segment and a gross tPCB output of 3,112 g/year from the PAXMH tidal segment to the Bay. These loads result in a net tPCB transport of 519 g/year from the Bay to the PAXMH tidal segment. Even though the tidal influence from the Chesapeake Bay mainstem serves as a source of PCBs to the PAXMH tidal segment, the load contribution is resultant from other point and nonpoint source inputs (both historic and current) from the upper Chesapeake Bay watershed and is not considered to be a directly controllable (reducible) source. Therefore this load will not be assigned a baseline load or allocation within the TMDL. Although no allocation is assigned, the modeling of this TMDL does account for the attenuation of PCBs in Chesapeake Bay water that is expected to occur over time due to natural processes such as the burial of contaminated sediment.

## Atmospheric Deposition

PCBs enter the atmosphere through volatilization. There is no recent study of the atmospheric deposition of PCBs to the surface of the PAXMH, PAXOH, and PAXTF tidal segments. An Atmospheric Deposition Study by the Chesapeake Bay Program (CBP) estimated a net deposition of 16.3 micrograms/square meter/year (µg/m$^2$/year) of tPCBs for urban areas and a net deposition of 1.6 µg/m$^2$/year of tPCBs for regional (non urban) areas (US EPA 1999). 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) µg/m$^2$/year of tPCBs (DRBC 2003). The urban deposition rate defined in CBP's study is a result of heavily urbanized areas comprised primarily of high density residential, industrial and commercial land uses.

Non-urban land use accounts for the majority of the watersheds: 85.2%, 87.7%, and 68.8% of the PAXMH, PAXOH, and PAXTF watersheds, respectively. Thus, the tPCB depositional rate of 1.6 µg/m$^2$/year for non-urban areas observed in CBP's 1999 study will be applied for the entire watershed. The atmospheric deposition tPCB load directly to the surface of the watershed was calculated by multiplying the non-urban depositional rate of 1.6 µg/m$^2$/year by the PAXMH, PAXOH, and PAXTF watershed areas. 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. A PCB pass-through efficiency of approximately 1% was estimated by Totten *et al*. (2006) for the Delaware River watershed and applied to estimate the portion of the atmospheric deposition tPCB load delivered to the PAXMH, PAXOH, and PAXTF tidal segments from the watershed. This load is accounted for within the estimated load 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 tPCB loads described below and in Section 4.2.

The atmospheric deposition tPCB load directly to the surface of the PAXMH, PAXOH, and PAXTF watersheds and atmospheric deposition tPCB loads delivered from the watersheds to the tidal segments are presented in Table 8. The table includes the watershed, watershed area, atmospheric deposition tPCB load to the PAXMH, PAXOH, and PAXTF watersheds, and atmospheric deposition tPCB loads delivered from the watersheds to the tidal segments.

**Table 8: Atmospheric Deposition tPCB Loads in the PAXMH, PAXOH, and PAXTF Watersheds**

| Watershed | Watershed Area ($km^2$) | Atmospheric Deposition tPCB Load (g/year) | |
|---|---|---|---|
| | | Direct | Delivered |
| PAXMH | 470.9 | 753.5 | 7.5 |
| PAXOH | 298.9 | 478.3 | 4.8 |
| PAXTF | 1,504.7 | 2,407.5 | 24.1 |

Similarly, the direct atmospheric deposition tPCB loads to the surface of the PAXMH, PAXOH, and PAXTF tidal segments was calculated by multiplying the surface area of the tidal segments and the deposition rate of 1.6 $\mu g/m^2/year$. The atmospheric deposition tPCB loads to the PAXMH, PAXOH, and PAXTF tidal segments are presented in Table 9. The table includes the tidal segment, surface water area, and atmospheric deposition tPCB loads to the PAXMH, PAXOH, and PAXTF tidal segments.

**Table 9: Atmospheric Deposition tPCB Baseline Loads to the PAXMH, PAXOH, and PAXTF Tidal Segments**

| Tidal Segment | Surface Area ($km^2$) | Atmospheric Deposition tPCB Load (g/year) |
|---|---|---|
| PAXMH | 107.6 | 172.1 |
| PAXOH | 14.3 | 22.9 |
| PAXTF | 4.4 | 7.1 |

## Contaminated Sites

'Contaminated sites' refer to areas with known PCB soil contamination, as documented by state or federal hazardous waste cleanup programs (*i.e.*, state or federal Superfund programs). When compared against the human health screening criteria for soil and groundwater exposure pathways, PCBs are not necessarily a contaminant of concern at these sites, but they have been screened for, reported, and detected during formal site investigations.

Potentially contaminated sites were identified based on information gathered from MDE's Land Restoration Program Geospatial Database (LRP-MAP) (MDE 2016). Within the PAXMH, PAXOH, and PAXTF watersheds, only one site, the Patuxent Wildlife Research Center (located in the PAXTF watershed), was identified with tPCB soil contamination. Soil concentration data was obtained from MDE Land Management Administration's (LMA) contaminated site survey and investigation records. The location of the contaminated site is displayed in Figure 5.

The median soil tPCB concentration was multiplied by the soil loss rate, which is a function of soil type, pervious area, and land cover, to estimate the tPCB baseline load. The contaminated site tPCB baseline load is presented in Table 10. The table includes the site name, MDE site ID, median tPCB soil concentration, soil loss rate, and tPCB baseline load. A detailed description of the methodology used to estimate the contaminated site tPCB baseline load is presented in Appendix H.

**Table 10: Contaminated Site tPCB Baseline Loads in the PAXTF Watershed**

| Site Name | MDE LRP Site ID | Median tPCB Concentration (ng/g) | Soil Loss Rate (lbs/year) | tPCB Baseline Load (g/year) |
|---|---|---|---|---|
| Patuxent Wildlife Research Center | MD-267 | 1,312.4 | 20.9 | 0.012 |

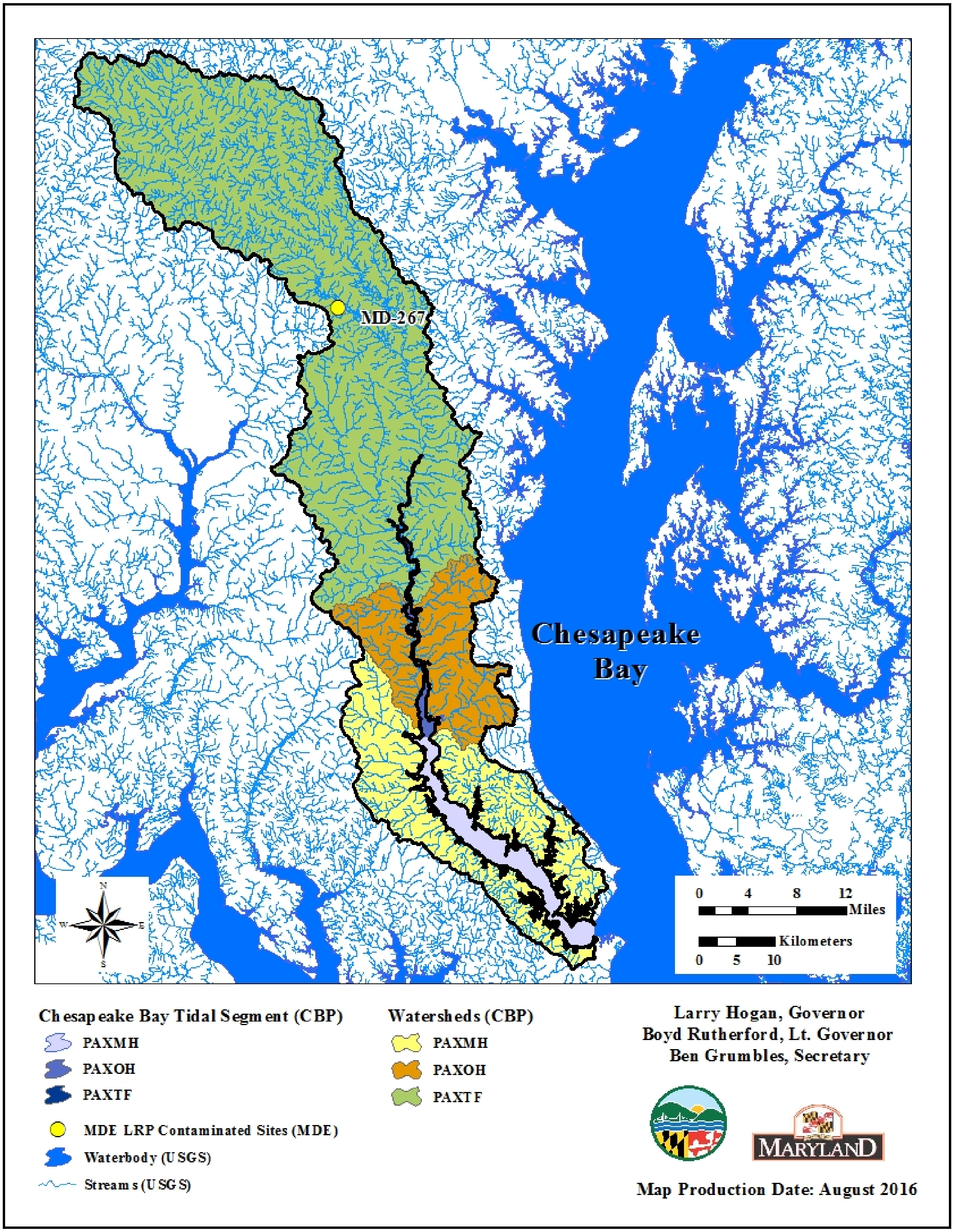


**Figure 5: Location of PCB Contaminated Site in the PAXMH, PAXOH, and PAXTF Watersheds**

## Watershed Sources: Non-regulated Watershed Runoff

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

The PAXMH, PAXOH, and PAXTF watersheds were divided into 15 subwatershed segments in order to estimate tPCB loads into the corresponding tidal subsegments in the water quality model. The subwatershed segmentation is displayed in Figure 6. The PAXMH watershed includes subwatershed segments SW-1 through SW-6, the PAXOH watershed includes subwatershed segments SW-7 through SW-9, and the PAXTF watershed includes subwatershed segments SW-10 through SW-15.

To estimate the non regulated watershed runoff load, first the total tPCB baseline load from each subwatershed is calculated by multiplying the subwatershed flow by the average tPCB concentration of the corresponding non-tidal monitoring stations (See Appendix C for detailed information on subwatershed flow and baseline tPCB loads). The total (regulated and non-regulated) PAXMH, PAXOH, and PAXTF watershed baseline tPCB loads (121.4 g/year, 75.2 g/year, and 1,680.7 g/year, respectively) are calculated from adding the corresponding subwatershed tPCB loads.

As described earlier on pages 19 and 20, atmospheric deposition to the land surface accounts for 7.5 g/year, 4.8 g/year, and 24.1 g/year of the PAXMH, PAXOH, and PAXTF watersheds' tPCB baseline loads, respectively; and are inherently captured within the PAXMH, PAXOH, and PAXTF watershed regulated and non-regulated baseline tPCB loads.

Then, the non-regulated watershed runoff tPCB baseline loads were estimated by multiplying the percentage of non-urban and non-regulated urban land use within the PAXMH, PAXOH, and PAXTF watersheds and the corresponding watershed tPCB baseline loads. The non-regulated watershed runoff tPCB baseline loads from the PAXMH, PAXOH, and PAXTF watersheds are presented in Table 11. The table includes the watershed, non-urban land use percentage, and non-regulated watershed runoff tPCB baseline loads.

**Table 11: Non-regulated Watershed Runoff tPCB Baseline Loads in the PAXMH, PAXOH, and PAXTF watersheds**

| Watershed | Total Watershed tPCB Load (g/year) | Non-Urban and Non-Regulated Urban Land Use (%) | Non-Regulated Watershed Runoff tPCB Load (g/year) |
|---|---|---|---|
| PAXMH | 121.4 | 98.3% | 119.3 |
| PAXOH | 75.2 | 97.7% | 73.5 |
| PAXTF | 1,680.7 | 68.4% | 1,148.8 |

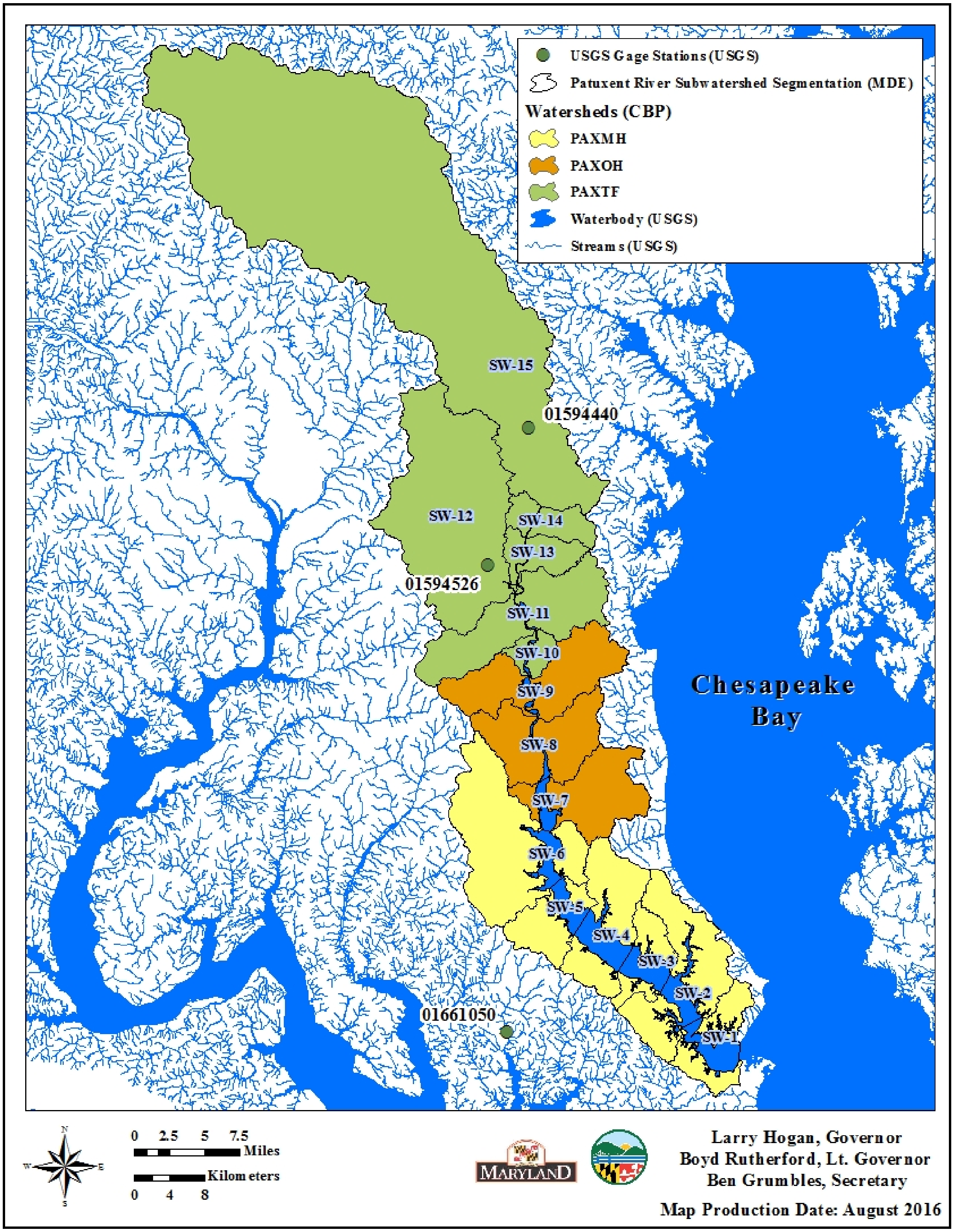


**Figure 6: Subwatershed Segmentation in the PAXMH, PAXOH, and PAXTF Watersheds**

**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 load. Only external sources to the system are assigned a baseline load within the TMDL.

PCBs accumulate in the bottom sediment as they preferentially sorb to the organic carbon fraction of the suspended sediment in the water column and settle to the embayment floor. This accumulation of PCBs can also subsequently become a source of PCBs to the water column via the disturbance and re-suspension of sediments. Dissolved tPCB concentrations in sediment pore water will also diffuse into the water column.

The gross tPCB loads from resuspension, diffusion, and settling; and net tPCB load (settling – resuspension + diffusion) in the PAXMH, PAXOH, and PAXTF tidal segments as predicted by the water quality model under initial conditions are presented in Table 12. More details on how these loads were estimated can be found in Appendix D.

**Table 12: Gross Resuspension, Diffusion, and Settling tPCB Loads in the PAXMH, PAXOH, and PAXTF Tidal Segments**

| Tidal Segment | Gross Resuspension tPCB Load (g/year) | Gross Diffusion tPCB Load (g/year) | Gross Settling tPCB Load (g/year) | Net tPCB Load* (g/year) |
|---|---|---|---|---|
| PAXMH | 739.0 | 221.1 | 2,487.2 | 1,527.1 |
| PAXOH | 1,092.4 | 81.9 | 1,467.2 | 292.9 |
| PAXTF | 187.1 | 17.9 | 321.7 | 116.8 |

*Net tPCB load is from the water column to the sediment

Under initial conditions, there is a net load of PCBs from the water column to the sediment in the PAXMH, PAXOH, and PAXTF tidal segments. The gross tPCB load from settling exceeds the gross tPCB load from diffusion and resuspension.

## 4.2 Point Sources

Point Sources in the PAXMH, PAXOH, and PAXTF watersheds include NPDES-regulated municipal WWTPs and industrial process water facilities, as well as stormwater 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.

**Municipal WWTPs**

There are 21 municipal WWTPs located in the PAXOH (1 facility) and PAXTF (20 facilities) watersheds. Of the 21 muncipal WWTPs, eight are major facilities (discharge flow greater than 1 MGD) and 13 are minor facilities (discharge flow less than 1 MGD). The locations of the WWTPs are displayed in Figure 8. The tPCB baseline loads from the WWTPs are calculated by multiplying the average discharge flow and estimated tPCB effluent concentration. The average discharge flows from the facilities were based on a Discharge Monitoring Report (DMR) flow record for the period January 2011 through May 2016. No tPCB effluent concentration data is available for the WWTPs. In order to estimate tPCB loads from these facilities, the median tPCB effluent concentration (0.91 ng/L) from 13 WWTPs monitored by MDE in the Chesapeake Bay watershed in 2006 was applied (MDE 2006). The tPCB baseline loads were calculated by multiplying their average daily flows based on their DMRs with the median tPCB effluent concentration. The WWTP tPCB baseline loads are presented in Table 13. The table includes the facility name, NPDES permit, tidal segment, average flow, and tPCB baseline loads. The total WWTP loads from the minor facilities, 0.01 g/year and 1.07 g/year in the PAXOH and PAXTF watersheds, only account for a relatively small percentage (0.01% and 0.06%) of their respective total watershed loads. The total WWTP loads from the minor facilities are considered insignificant and will not be assigned baseline loads or allocations. No appreciable environmental benefit would be gained from reducing these loads.

**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 the Commonwealth of 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. Virginia has 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 has been applied previously within several of Maryland's EPA approved PCB TMDLs (e.g., MDE 2011b).

Within the PAXMH, PAXOH, and PAXTF watersheds, one industrial process water facility, Genon Mid-Atlantic, LLC. – Chalk Point Generation Station (NPDES # MD0002658), has an SIC Code (4931) defined in Virginia's guidance as having the potential to discharge PCBs. This facility is located in the PAXMH watershed and discharges directly to the tidal segment (See Figure 7).

The tPCB load from this facility is calculated by multiplying the average discharge flow and average tPCB effluent concentration. The average discharge flow from the facility was based on a DMR flow record for the period January 2011 through May 2016. The average tPCB effluent concentration was based on effluent samples collected from the facility's non-contact cooling water outfall for tPCB analysis in November and December 2015. The industrial process water facility tPCB load is presented in Table 14. The table includes the facility name, NPDES permit, average discharge flow, average tPCB effluent concentration, and tPCB load.

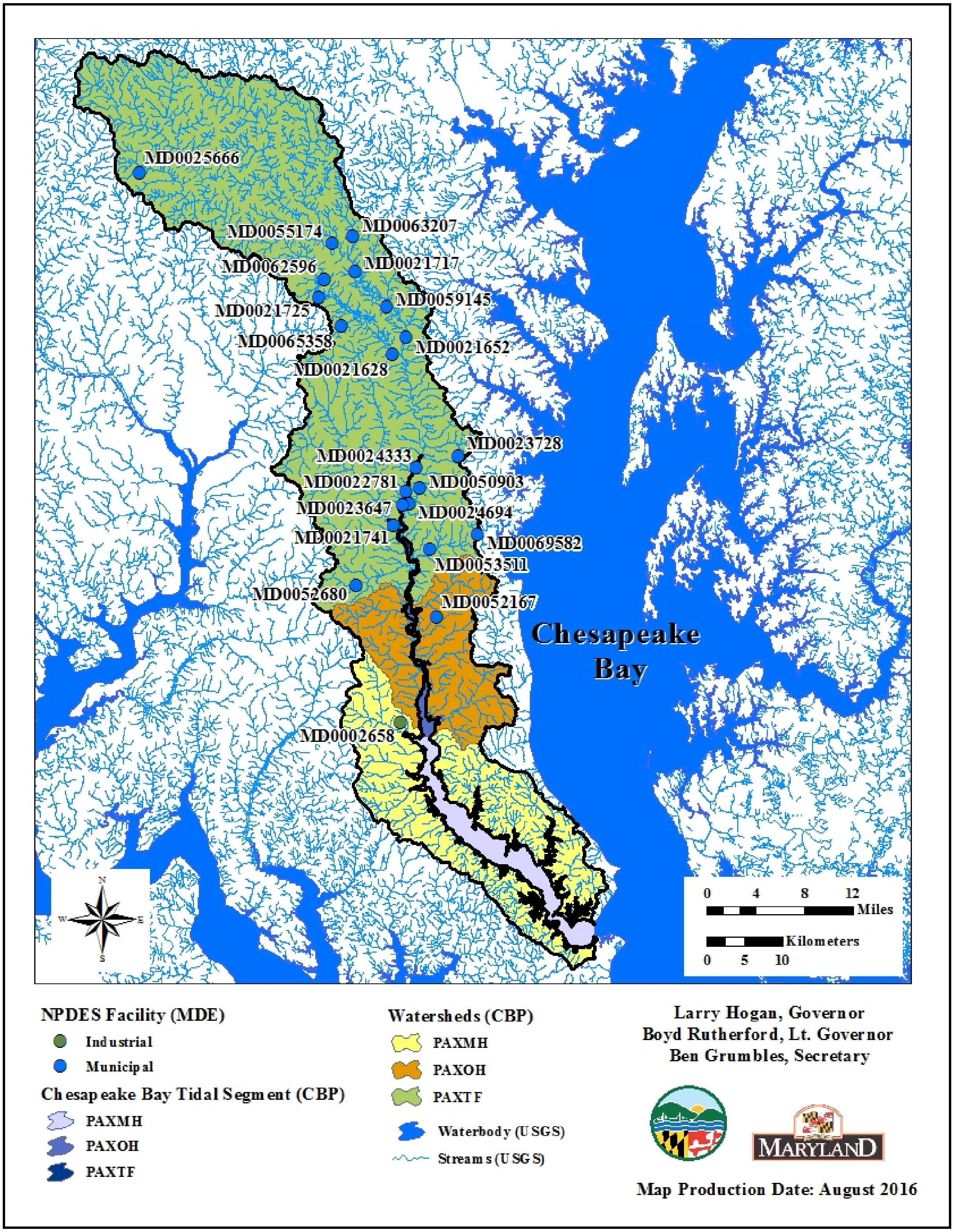


**Figure 7: NPDES Municipal and Industrial Facilities in the PAXMH, PAXOH, and PAXTF Watersheds**

**Table 13: Municipal WWTP tPCB Baseline Loads in the PAXMH, PAXOH, and PAXTF Watersheds**

| Facility Name | NPDES Permit | Permit Type | Tidal Segment | Average Flow (MGD*) | WWTP tPCB Load (g/year) |
|---|---|---|---|---|---|
| WSSC - Western Branch WWTP | MD0021741 | Major | PAXTF | 20.065 | 25.11 |
| Dorsey Run Advanced WWTP | MD0063207 | Major | PAXTF | 1.344 | 1.68 |
| Little Patuxent Water Reclamation Plant | MD0055174 | Major | PAXTF | 17.950 | 22.47 |
| Patuxent River Water Reclamation Plant | MD0021652 | Major | PAXTF | 5.298 | 6.63 |
| Fort Meade WWTP | MD0021717 | Major | PAXTF | 2.416 | 3.02 |
| Maryland City Water Reclamation Facility | MD0062596 | Major | PAXTF | 1.114 | 1.39 |
| Bowie WWTP | MD0021628 | Major | PAXTF | 1.862 | 2.33 |
| WSSC - Parkway WWTP | MD0021725 | Major | PAXTF | 6.500 | 8.14 |
| **Total WWTP Load (Majors)** | | | | | **70.78** |
| Northern High School WWTP | MD0052167 | Minor | PAXOH | 0.008 | 0.01 |
| Boones Mobile Estate WWTP | MD0050903 | Minor | PAXTF | 0.064 | 0.08 |
| Lyons Creek Mobile Home Park WWTP | MD0053511 | Minor | PAXTF | 0.054 | 0.07 |
| Maryland Manor WWTP | MD0024333 | Minor | PAXTF | 0.052 | 0.07 |
| Henson Valley Motessori School WWTP | MD0052680 | Minor | PAXTF | 0.005 | 0.01 |
| Patuxent Mobile Estates WWTP | MD0024694 | Minor | PAXTF | 0.013 | 0.02 |
| Tracey's Elementary School | MD0069582 | Minor | PAXTF | 0.001 | 0.001 |
| Waysons Mobile Court WWTP | MD0023647 | Minor | PAXTF | 0.049 | 0.06 |
| Federal Support Center WWTP | MD0025666 | Minor | PAXTF | 0.002 | 0.002 |
| Piney Orchard WWTP | MD0059145 | Minor | PAXTF | 0.605 | 0.76 |
| Southern Senior High School | MD0023728 | Minor | PAXTF | 0.006 | 0.01 |
| National Wildlife Visitor Center WWTP | MD0065358 | Minor | PAXTF | 0.007 | 0.01 |
| **Total WWTP Load (Minors)** | | | | | **1.08** |

*Million gallons per day
Note: Columns may not precisely add to totals due to rounding

**Table 14: Industrial Process Water tPCB Loads in the PAXMH, PAXOH, and PAXTF Watersheds**

| Facility Name | NPDES Permit | Tidal Segment | Average Flow (MGD) | Average tPCB Concentration (ng/L) | Industrial Process Water tPCB Load (g/year) |
|---|---|---|---|---|---|
| Genon Mid-Atlantic, LLC. - Chalk Point Generation Station | MD0002658 | PAXMH | 506.6 | 2.1 | 1,448.8 |

The facility is a coal-fired power plant which withdraws water directly from the PAXMH tidal segment for non-contact cooling processes. The water contains elevated levels of PCBs already present in the PAXMH tidal segment and simply re-circulates the contamination back to the tidal segment at the outfall discharge upstream of the facility. The average tidal water column tPCB concentrations at the nearest monitoring station upstream and downstream (LPR-5 & LPR-4) of the facility are 3.0 ng/L and 1.4 ng/L, respectively. The tPCB concentrations decrease as you move downstream from the power plant indicating that the facility does not contribute additional PCBs to the system. Since the tPCB load of 1,449 g/year is being re-circulated within the PAXMH tidal segment and does not represent an additional load into the system, it will not be assigned a baseline load or allocation within this TMDL.

**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:

1. 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);
2. Industrial facilities permitted for stormwater discharges; and
3. Small and large construction sites.

The lists of NPDES regulated stormwater permits within the PAXMH, PAXOH, and PAXTF watersheds that could potentially convey tPCB loads to the tidal segments is presented in Appendix F.

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 PAXOH, PAXTF and portions of the PAXMH watershed are located within of the following counties regulated under Phase I of the NPDES stormwater program: Anne Arundel, Charles, Frederick, Howard, Montgomery, and Prince George's County, Maryland. The NPDES stormwater permits within the watershed include: (i) the area covered under Phase I and 2 jurisdictional MS4 permit for these counties, (ii) the State Highway Administration's Phase I MS4 permit, (iii) industrial facilities permitted for stormwater discharges, and (iv) MDE general permit to construction sites (see Appendix F for a list of all NPDES regulated stormwater permits). The loads for all NPDES stormwater permittees are presented as an aggregate under the Phase I MS4 counties within the PAXMH, PAXOH, and PAXTF watersheds.

The NPDES regulated stormwater tPCB baseline loads were estimated by multiplying the percentage of regulated urban land use area within the regulated county portions of the PAXMH, PAXOH, and PAXTF watersheds by the corresponding county portions of the watershed tPCB baseline loads. The NPDES regulated stormwater tPCB baseline loads from the PAXMH, PAXOH, and PAXTF watersheds are presented in Table 15. The table includes the watershed, county, urban land use percentage, and NPDES regulated stormwater tPCB baseline loads.

**Table 15: Aggregate Regulated Stormwater tPCB Baseline Loads in the PAXMH, PAXOH, and PAXTF Watersheds**

| Watershed | County | Watershed tPCB Load (g/year) | County Portion of Watershed tPCB Load (g/year) | Regulated Urban Landuse (%) | NPDES Regulated Stormwater tPCB Load (g/year)[2] |
|---|---|---|---|---|---|
| PAXMH | Prince George's | 121.4 | 6.0 | 9.6% | 0.6 |
| | Calvert[1] | | 51.6 | 0.0% | 0.0 |
| | St. Mary's | | 45.3 | 0.1% | 0.1 |
| | Charles | | 18.5 | 8.3% | 1.5 |
| PAXOH | Anne Arundel | 75.2 | 3.2 | 9.5% | 0.3 |
| | Calvert[1] | | 46.6 | 0.0% | 0.0 |
| | Prince George's | | 25.4 | 5.5% | 1.4 |
| PAXTF | Anne Arundel | 1,680.7 | 338.0 | 30.9% | 104.4 |
| | Frederick | | 0.4 | 41.2% | 0.2 |
| | Howard | | 746.7 | 31.6% | 235.7 |
| | Montgomery | | 241.0 | 13.4% | 32.2 |
| | Prince George's | | 348.7 | 45.7% | 159.4 |

[1]Some figures appear as zero since their actual values are less than the number of significant decimal digits.
[2]NPDES regulated stormwater baseline loads are an aggregate of loadings from areas covered under the following permits: (i) Phase I & II jurisdictional MS4 permits, (ii) the State Highway Administration's Phase I MS4 permit, (iii) industrial facilities permitted for stormwater discharges, and (iv) MDE general permit to construction sites.

### 4.3 Source Assessment Summary

From this source assessment, all known point and nonpoint sources of PCBs in the PAXMH, PAXOH, and PAXTF watersheds and tidal segments have been identified and characterized. The following nonpoint sources of PCBs have been identified: 1) Chesapeake Bay mainstem tidal influence, 2) direct atmospheric deposition to the PAXMH, PAXOH, and PAXTF tidal segments, 3) one contaminated site, and 4) runoff from non-regulated watershed areas. Point sources include NPDES regulated municipal WWTP facilities, a NPDES regulated industrial process water facility and NPDES regulated stormwater. 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 PAXMH, PAXOH, and PAXTF tidal segments is presented in Table 16. As explained in Section 4.1, loads associated with re-suspension and diffusion from sediments, and tidal influences from the Chesapeake Bay mainstem are not considered to be directly controllable (reducible) within the framework of the TMDL and are thus not assigned baseline loads or allocations. Also, it was demonstrated that the industrial process water facility does not contribute additional PCBs to the system and is therefore not assigned a baseline load or allocation within this TMDL.

### Table 16: Summary of tPCB Baseline Loads in the PAXMH, PAXOH, and PAXTF Tidal Segments

| Tidal Segment | Source | Baseline Load (g/year) | Baseline Load (%) |
|---|---|---|---|
| PAXMH | Non-regulated Watershed Runoff | 119.2 | 40.62% |
| | Atmospheric Deposition | 172.1 | 58.64% |
| | ***Nonpoint Sources*** | ***291.4*** | ***99.26%*** |
| | NPDES Regulated Stormwater[3] | | |
| | Prince George's | 0.6 | 0.20% |
| | Calvert[1] | 0.0 | 0.01% |
| | St. Mary's | 0.1 | 0.02% |
| | Charles | 1.5 | 0.52% |
| | ***Point Sources*** | ***2.2*** | ***0.74%*** |
| | ***MOS (5%)*** | - | - |
| | ***Total*** | ***293.6*** | ***100.00%*** |
| PAXOH | Non-regulated Watershed Runoff | 73.5 | 74.93% |
| | Atmospheric Deposition | 22.9 | 23.30% |
| | ***Nonpoint Sources*** | ***96.4*** | ***98.23%*** |
| | NPDES Regulated Stormwater[3] | | |
| | Anne Arundel | 0.3 | 0.31% |
| | Calvert[1] | 0.0 | 0.01% |
| | Prince George's | 1.4 | 1.44% |
| | ***Point Sources*** | ***1.7*** | ***1.77%*** |
| | ***MOS (5%)*** | - | - |
| | ***Total*** | ***98.1*** | ***100.00%*** |
| PAXTF | Non-regulated Watershed Runoff[2] | 1,118.9 | 65.32% |
| | Atmospheric Deposition | 7.1 | 0.41% |
| | Contaminated Sites[1] | 0.0 | 0.00% |
| | ***Nonpoint Sources*** | ***1,126.0*** | ***65.74%*** |
| | NPDES Regulated Stormwater[2,3] | | |
| | Anne Arundel | 100.4 | 5.86% |
| | Frederick | 0.2 | 0.01% |
| | Howard | 228.6 | 13.35% |
| | Montgomery | 32.2 | 1.88% |
| | Prince George's | 154.6 | 9.03% |
| | WWTPs | 70.8 | 4.13% |
| | ***Point Sources*** | ***586.9*** | ***34.26%*** |
| | ***MOS (5%)*** | - | - |
| | ***Total*** | ***1,712.9*** | ***100.00%*** |

[1]Baseline load appear as zero since their actual values are less than the number of significant decimal digits.
[2]Baseline loads from WWTPs which discharge to the PAXTF watershed have been subtracted proportionally from the non-regulated watershed runoff and NPDES regulated stormwater baseline load to avoid double counting.
[3]NPDES regulated stormwater baseline loads are an aggregate of loadings from areas covered under the following permits: (i) Phase I & II jurisdictional MS4 permits, (ii) the State Highway Administration's Phase I MS4 permit, (iii) industrial facilities permitted for stormwater discharges, and (iv) MDE general permit to construction sites.
Note: Columns may not precisely add to totals due to rounding.

# 5.0 TOTAL MAXIMUM DAILY LOADS AND LOAD ALLOCATIONS

## 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 2016a):

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

This section describes how the tPCB TMDL and the corresponding LAs, WLAs, MOSs, and maximum daily loads (MDLs) have been developed for the PAXMH, PAXOH, and PAXTF tidal segments.

## 5.2 Analysis Framework

A tidally-averaged multi-segment one-dimensional transport model was applied to simulate the tPCB dynamic interactions between the water column and bottom sediments within the PAXMH, PAXOH, and PAXTF tidal segments and the Chesapeake Bay. The tidal system was divided into 14 segments and the watershed into 15 subwatersheds (See Figure C-1 in Appendix C). In general, tidal waters are exchanged through their connecting boundaries. Within the PAXMH, PAXOH, and PAXTF system, the dominant processes affecting the transport of PCBs throughout the water column include: dispersion induced by tide and concentration gradient between the Bay and the embayment, fresh water discharge from upstream rivers and adjacent watershed, atmospheric exchange due to volatilization and deposition, and exchange with the bottom sediments (through diffusion, re-suspension, and settling). Burial to deeper inactive layers and the exchange with the water column (through diffusion, resuspension, and settling) are the dominant processes affecting the transport of PCBs in the bottom sediments. A technical description of the model is presented in Appendix D.

**<u>Baseline Condition</u>**

The observed average tPCB concentrations in the sediment and water column (Table G-1 and G-3, in appendix G respectively) in each segment were used to characterize the initial (baseline) model conditions. If the segment did not have any PCB observations a linear interpolation of tPCB concentrations from the adjacent up- and down-stream segments was applied. 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 TMDL assumes a PCB attenuation rate of 5.0% per year at the boundary between the PAXMH tidal segment and the Chesapeake Bay mainstem (MDE 2011a). For establishing the TMDL, scenarios are run in which all other model inputs (i.e., fresh water discharge, dispersion coefficients, sediment and water column exchange rates, atmospheric deposition, and burial rate) were kept constant. Baseline tPCB loads for the PAXMH, PAXOH, and PAXTF watersheds were presented in Section 4.

The water quality model is initially run for a simulation period of 109.5 years (40,000 days) to determine whether the TMDL endpoints for the PAXMH, PAXOH, and PAXTF tidal segments can be achieved under baseline conditions and a rate of decline at the Chesapeake Bay boundary of 5%. After 109.5 year (40,000 days) and under baseline conditions the water column and sediment tPCB concentrations in the PAXOH and PAXTF tidal segments remain above the corresponding TMDL endpoints. The sediment TMDL endpoint in the PAXMH will be met within about 20 years (7,300 days) under baseline conditions as the boundary concentration declines at a rate of 5%. In order to meet TMDL endpoints in the PAXOH and PAXTF tidal segments a reduction to watershed loads will be required as the declining tPCB concentration at the Chesapeake Bay boundary alone is not sufficient to achieve the TMDL endpoints.

**TMDL Scenario**

To determine the TMDL in which the PAXMH, PAXOH, and PAXTF tidal segments will meet the corresponding water quality and sediment tPCB TMDL endpoints, model reduction scenarios were run with incremental increases in total load reduction. It was demonstrated that a minimum reduction of 95.3 % of the total baseline loads from all source categories of non-point and point sources to the PAXTF tidal segments was required in order to achieve the TMDL. The assigned reductions to the PAXTF tidal segments result in the water column and sediment tPCB TMDL endpoints being met for all tidal segments. Therefore no load reductions are required in the PAXMH and PAXOH tidal segments. The TMDL scenario time series for water column and sediment tPCB concentrations over the simulation period in the PAXMH, PAXOH, and PAXTF tidal segments (applying a 95.3% load reduction and accounting for the 5% boundary concentration decline to the PAXTF tidal segment) are presented in Figures 8, 9, and 10. It will take approximately 57.25 years (20,917 days) and 11.5 years (4,215 days) to meet both the water column and sediment TMDL endpoints in the PAXTF and PAXOH tidal segments, respectively, following implementation of load reductions necessary to support designated uses. For the PAXMH tidal segment, the water column and sediment TMDL endpoints are achieved under baseline conditions with a boundary concentration decline of 5%.

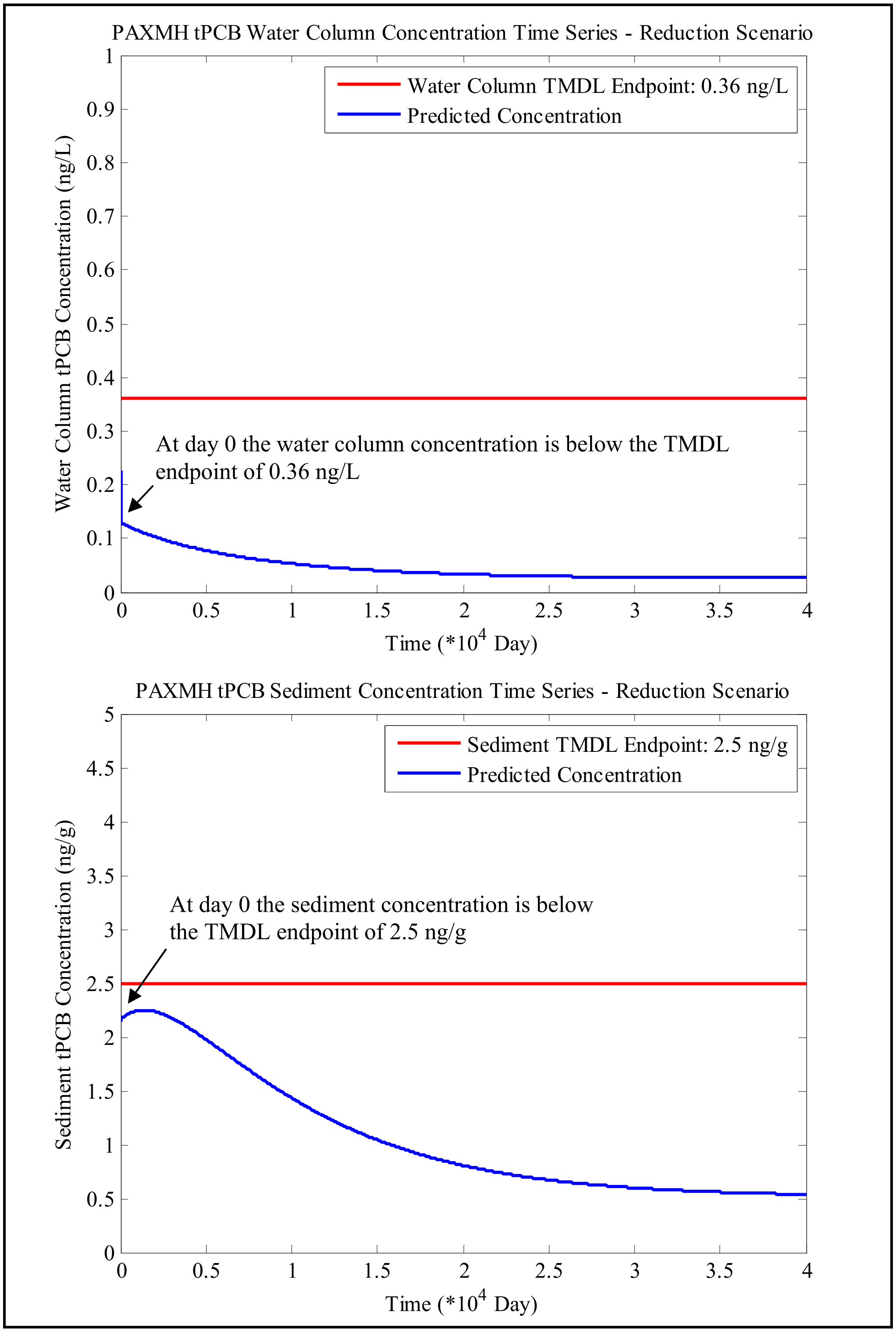


**Figure 8: Change in Water Column and Bottom Sediment tPCB Concentrations Over Time in the PAXMH Tidal Segment (TMDL Scenario)**

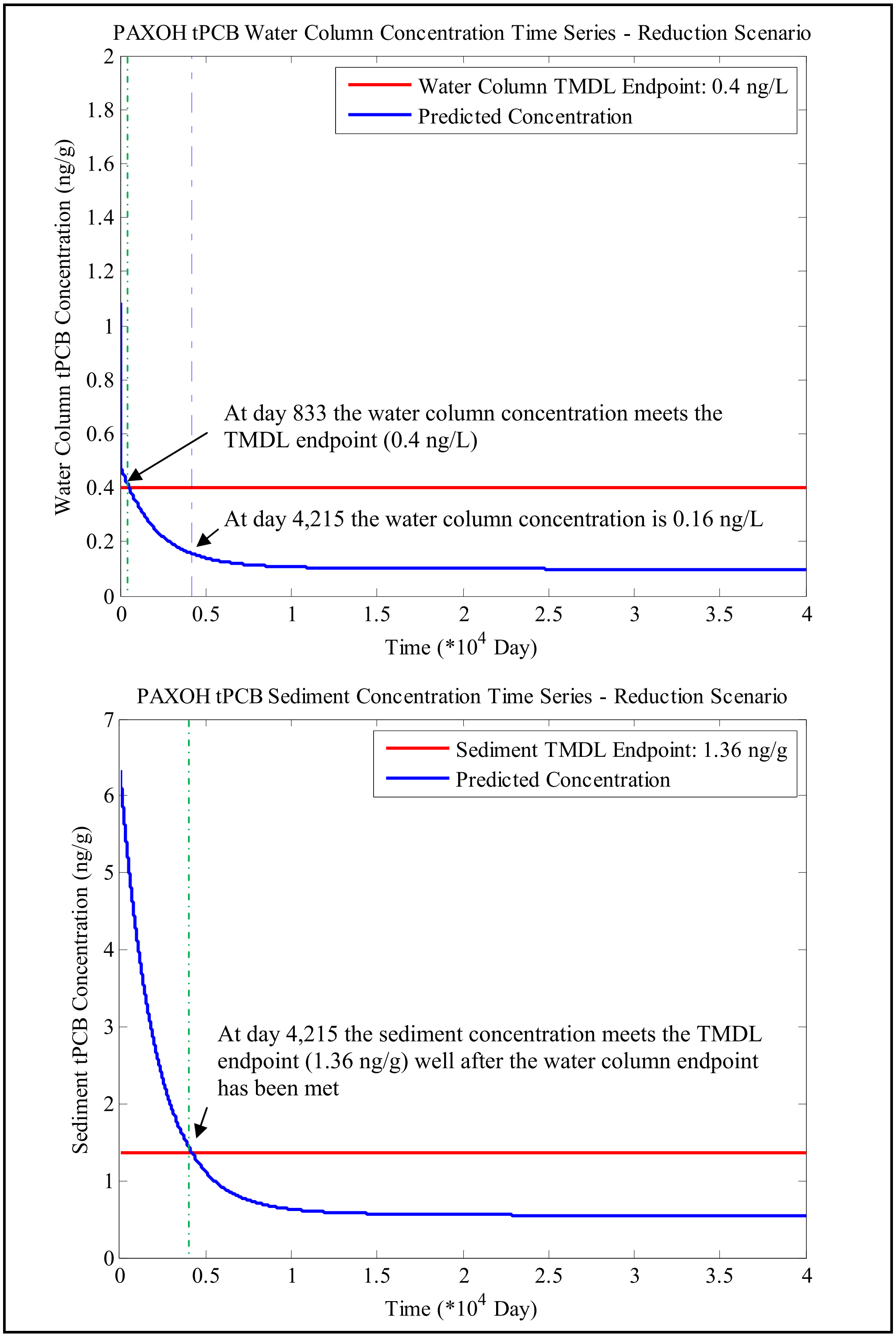


**Figure 9: Change in Water Column and Bottom Sediment tPCB Concentrations Over Time in the PAXOH Tidal Segment (TMDL Scenario)**

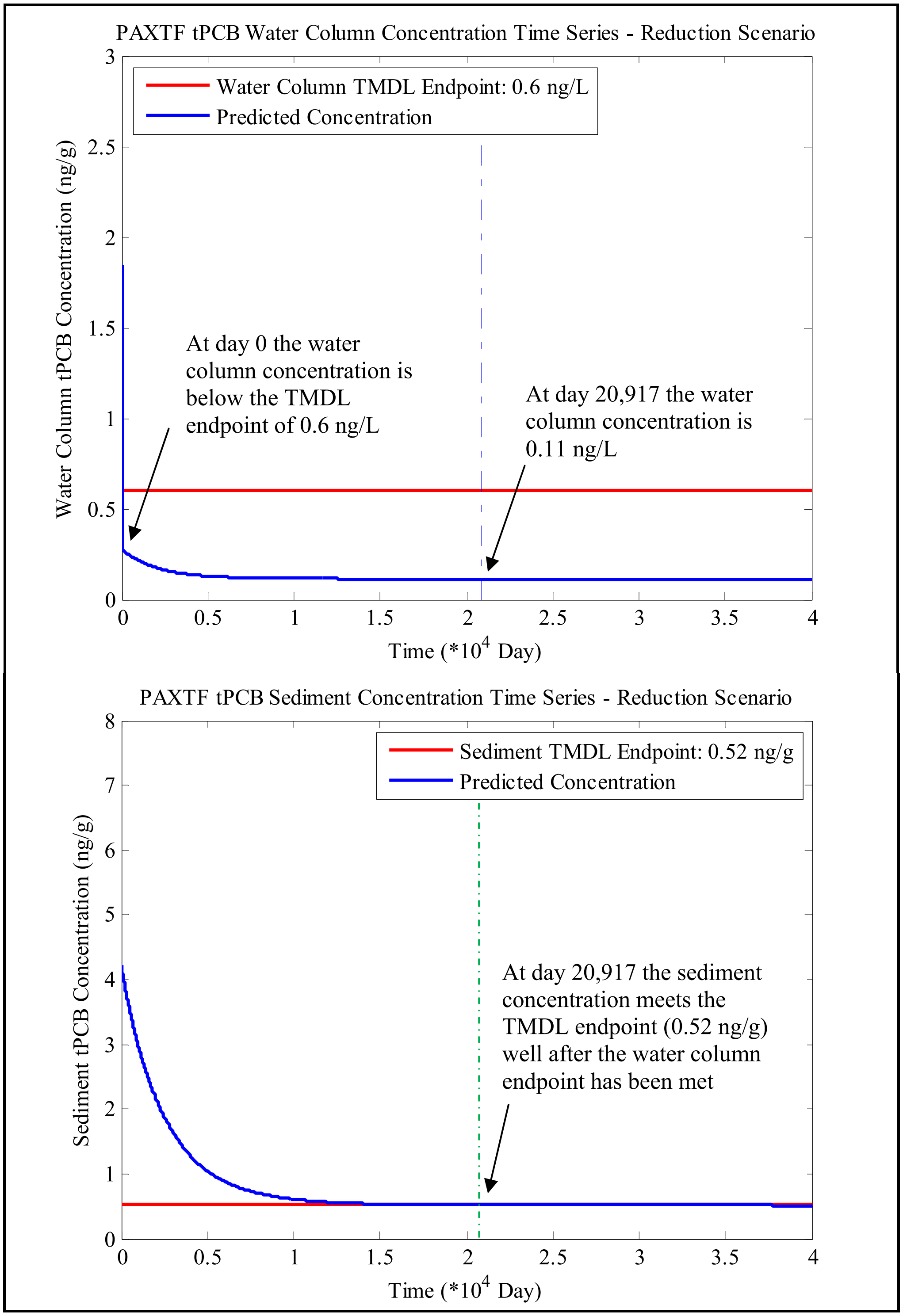


**Figure 10: Change in Water Column and Bottom Sediment tPCB Concentrations Over Time in the PAXTF Tidal Segment (TMDL Scenario)**

## 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 2016a). The intent of this requirement is to ensure that water quality is protected when it is most vulnerable.

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 PAXMH, PAXOH, and PAXTF tidal segments and estimation of watershed loads. 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 PAXMH, PAXOH, and PAXTF tidal segments. Furthermore, the water column tPCB TMDL endpoint is also supportive of the "protection of aquatic life" designated use at all times as it is more stringent than the freshwater and salt water chronic aquatic life tPCB criteria.

## 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 2016b). 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 PAXMH, PAXOH, and PAXTF tidal segments. These allocations are also supportive of the 'protection of aquatic life" designated use as explained in section 3.

### 5.4.1 Load Allocations

LAs have been assigned to the following nonpoint sources in order to support the "fishing" designated use: non-regulated watershed runoff from the PAXMH, PAXOH, and PAXTF watersheds, direct atmosphere deposition to the surface of the tidal segments, and a PCB contaminated site. The model demonstrates that in order to support the "fishing" designated use in the PAXMH, PAXOH, and PAXTF tidal segments, a tPCB load reduction of 95.5% from the total nonpoint source load in the PAXTF tidal segment is required to achieve the TMDL. The contaminated site did not require a reduction as it has already undergone remediation and accounts for a relatively small percentage of the total baseline load to the tidal segments (0.001%). The primary source of PCBs to the atmosphere is from volatilization of PCB contaminated land sources which will be reduced as these sources are remediated through implementation of the non-regulated watershed runoff LA and NPDES regulated stormwater WLA.

As explained in Section 4.1, loads associated with re-suspension and diffusion from sediments and tidal influences from the Chesapeake Bay mainstem are not considered to be directly controllable (reducible) within the framework of the TMDL and are thus not assigned baseline loads or allocations.

### 5.4.2 Wasteload Allocations

**Municipal WWTPs**

There are 21 municipal WWTPs located in the PAXMH, PAXOH and PAXTF watersheds. Eight of the municipal WWTPs are major facilities and 13 are minor facilities. As discussed in Section 4.2, the tPCB baseline loads were calculated based on their DMR average discharge flows and the average tPCB effluent concentration. As no tPCB effluent concentration data was available for the WWTP facilities, the median tPCB effluent concentration (0.91 ng/L) from 13 WWTPs monitored by MDE in the Chesapeake Bay watershed in 2006 was applied (MDE 2006). Loads from the minor WWTP facilities are considered insigificant as they account for a relatively small percentage of the total baseline loads and are not assigned a baseline load or allocation. No appreciable environmental benefit would be gained from reducing these loads. The major WWTP facilities are all located within the PAXTF watershed. The WLAs are calculated based on the water column tPCB TMDL endpoint concentration of 0.60 ng/L for the PAXTF tidal segment and current design flows for the WWTPs. The WLAs are presented in Table 17.

**Table 17: Municipal WWTP tPCB WLAs in the PAXMH, PAXOH, and PAXTF Watersheds**

| Facility Name | NPDES Permit | Tidal Segment | WWTP tPCB Baseline Load (g/year) | tPCB Water Column TMDL Endpoint (ng/L) | Design Flow (MGD) | WWTP tPCB WLA (g/year) |
|---|---|---|---|---|---|---|
| WSSC - Western Branch WWTP | MD0021741 | PAXTF | 25.11 | 0.6 | 30.6 | 25.37 |
| Little Patuxent Water Reclamation Plant | MD0055174 | PAXTF | 22.47 | 0.6 | 29 | 24.04 |
| Patuxent River Water Reclamation Plant | MD0021652 | PAXTF | 6.63 | 0.6 | 10.5 | 8.70 |
| WSSC - Parkway WWTP | MD0021725 | PAXTF | 8.14 | 0.6 | 7.5 | 6.22 |
| Fort Meade WWTP | MD0021717 | PAXTF | 3.02 | 0.6 | 4.5 | 3.73 |
| Bowie WWTP | MD0021628 | PAXTF | 2.33 | 0.6 | 3.3 | 2.74 |
| Maryland City Water Reclamation Facility | MD0062596 | PAXTF | 1.39 | 0.6 | 3.3 | 2.76 |
| Dorsey Run Advanced WWTP | MD0063207 | PAXTF | 1.68 | 0.6 | 2 | 1.66 |

Further characterization of the municipal WWTP baseline loads will need to be conducted through the NPDES permitting implementation process as tPCB effluent data was not available for these facilities in order to accurately estimate the loads. Characterization of the individual WWTP facility baseline loads may result in a change to the overall reduction.

**Industrial Process Water Facility**

Within the PAXMH, PAXOH, and PAXTF watershed, one industrial process water facility was identified as having the potential to discharge PCBs. As was discussed in Section 4.2, the tPCB load from this facility was calculated based on the average discharge flow and average tPCB effluent concentration.

The facility is a coal-fired power plant which withdrawals water directly from the PAXMH tidal segment for non-contact cooling processes. The water contains elevated levels of PCBs already present in the PAXMH tidal segment and simply re-circulates the contamination back to the tidal segment at the outfall discharge upstream of the facility. Since the tPCB load is being re-circulated within the PAXMH tidal segment and does not represent an additional load into the system, it will not be assigned a baseline load or allocation within this TMDL.

**NPDES Regulated Stormwater**

The NPDES Regulated Stormwater WLA was established by reducing the NPDES regulated stormwater baseline loads the same percentages as to the non-regulated watershed runoff baseline loads in the watershed. For more information on methods used to calculate the NPDES regulated stormwater PCB baseline load, please see Section 4.2. The NPDES regulated stormwater WLA may include any or all of the NPDES stormwater discharges listed in Section 4.2 (see Appendix F for a complete list of stormwater permits). As stormwater assessment or other program monitoring efforts result in a more refined source assessment, MDE reserves the right to revise the current NPDES regulated stormwater WLA provided the revisions are protective of the "fishing" designated use in the PAXMH, PAXOH, and PAXTF tidal segments. The NPDES regulated stormwater baseline load requires a 95.5% reduction for the PAXTF tidal segment to achieve the TMDL. No reduction was applied to the Frederick County portion of the NPDES regulated stormwater baseline load within the PAXTF tidal segment as it only accounts for a relatively small percentage of the total baseline load (0.01%) and is considered insignificant.

### 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 and in order to provide an adequate and environmentally protective TMDL, MDE applied an explicit 5% MOS. The MOS was applied to the PAXTF tidal segment where load reductions were required in order to achieve the TMDL. An explicit MOS was not applied to the PAXOH and PAXMH tidal segments as no load reductions were necessary in order to achieve the TMDL. In addition, the load reductions assigned to the PAXTF tidal segment functions as an implicit MOS for the PAXOH and PAXMH tidal segments which reduces the tPCB water column and sediment concentrations within these tidal segments well below their respective TMDL endpoints, ensuring the achievement of the TMDLs.

### 5.6 Maximum Daily Loads

All TMDLs must include 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 described in Appendix E and the results are displayed in Table 18.

### 5.7 TMDL Summary

Table 18 summarizes the tPCB baseline loads, TMDL allocations, load reductions, and MDLs for the PAXMH, PAXOH, and PAXTF tidal segments.

**Table 18: Summary of tPCB Baseline Loads, TMDL Allocations, Associated Percent Reductions and MDLs in the PAXMH, PAXOH, and PAXTF Tidal Segments**

| Tidal Segment | Source | Baseline Load (g/year) | Baseline Load (%) | TMDL (g/year) | Load Reduction (%) | MDL (g/day) |
|---|---|---|---|---|---|---|
| PAXMH | Non-regulated Watershed Runoff | 119.2 | 40.62% | 119.2 | 0.0% | 2.453 |
| | Atmospheric Deposition | 172.1 | 58.64% | 172.1 | 0.0% | 3.541 |
| | ***Nonpoint Sources*** | ***291.4*** | ***99.26%*** | ***291.4*** | ***0.0%*** | ***5.993*** |
| | NPDES Regulated Stormwater[4] | | | | | |
| | Prince George's | 0.6 | 0.20% | 0.6 | 0.0% | 0.012 |
| | Calvert[2] | 0.0 | 0.01% | 0.0 | 0.0% | 0.000 |
| | St. Mary’s | 0.1 | 0.02% | 0.1 | 0.0% | 0.001 |
| | Charles | 1.5 | 0.52% | 1.5 | 0.0% | 0.031 |
| | ***Point Sources*** | ***2.2*** | ***0.74%*** | ***2.2*** | ***0.0%*** | ***0.045*** |
| | ***MOS (5%)*** | ***-*** | ***-*** | | | |
| | ***Total PAXMH*** | ***293.6*** | ***100.00%*** | ***293.6*** | ***0.0%*** | ***6.038*** |
| PAXOH | Non-regulated Watershed Runoff | 73.5 | 74.93% | 73.5 | 0.0% | 0.952 |
| | Atmospheric Deposition | 22.9 | 23.30% | 22.9 | 0.0% | 0.296 |
| | ***Nonpoint Sources*** | ***96.4*** | ***98.23%*** | ***96.4*** | ***0.0%*** | ***1.248*** |
| | NPDES Regulated Stormwater[4] | | | | | |
| | Anne Arundel | 0.3 | 0.31% | 0.3 | 0.0% | 0.004 |
| | Calvert[2] | 0.0 | 0.01% | 0.0 | 0.0% | 0.000 |
| | Prince George's | 1.4 | 1.44% | 1.4 | 0.0% | 0.018 |
| | ***Point Sources*** | ***1.7*** | ***1.77%*** | ***1.7*** | ***0.0%*** | ***0.022*** |
| | ***MOS (5%)*** | ***-*** | ***-*** | | | |
| | ***Total PAXOH*** | ***98.1*** | ***100.00%*** | ***98.1*** | ***0.0%*** | ***1.271*** |
| PAXTF | Non-regulated Watershed Runoff[3] | 1,118.9 | 65.32% | 1.0 | 99.9% | 0.011 |
| | Atmospheric Deposition | 7.1 | 0.41% | 0.0 | 99.9% | 0.000 |
| | Contaminated Sites[1,2] | 0.0 | 0.00% | 0.0 | 0.0% | 0.000 |
| | ***Nonpoint Sources*** | ***1,126.0*** | ***65.74%*** | ***1.0*** | ***99.9%*** | ***0.011*** |
| | NPDES Regulated Stormwater [3,4] | | | | | |
| | Anne Arundel | 100.4 | 5.86% | 0.1 | 99.9% | 0.001 |
| | Frederick[1] | 0.2 | 0.01% | 0.2 | 0.0% | 0.002 |
| | Howard | 228.6 | 13.35% | 0.1 | 99.9% | 0.001 |
| | Montgomery | 32.2 | 1.88% | 0.0 | 99.9% | 0.000 |
| | Prince George's | 154.6 | 9.03% | 0.1 | 99.9% | 0.001 |
| | WWTPs | 70.8 | 4.13% | 75.2 | -6.3% | 0.639 |
| | ***Point Sources*** | ***586.9*** | ***34.26%*** | ***75.7*** | ***87.1%*** | ***0.645*** |
| | ***MOS (5%)*** | ***-*** | ***-*** | ***4.0*** | ***-*** | ***0.035*** |
| | ***Total PAXTF*** | ***1,712.9*** | ***100.00%*** | ***80.7*** | ***95.3%*** | ***0.690*** |

[1]Contaminated sites, and Frederick NPDES regulated stormwater tPCB baseline loads are considered insignificant (less than 0.01% of the total baseline load) and no reductions are assigned.
[2]Baseline load, TMDLs and MDLs appear as zero since their actual values are less than the number of significant decimal digits.
[3]Baseline loads from WWTPs which discharge to the PAXTF watershed have been subtracted proportionally from the non-regulated watershed runoff and NPDES regulated stormwater baseline load to avoid double counting.
[4]NPDES regulated stormwater baseline loads and WLAs are an aggregate of loadings from areas covered under the following permits: (i) Phase I & II jurisdictional MS4 permits, (ii) the State Highway Administration’s Phase I MS4 permit, (iii) industrial facilities permitted for stormwater discharges, and (iv) MDE general permit to construction sites.
Note: Columns may not precisely add to totals due to rounding.

## 6.0 ASSURANCE OF IMPLEMENTATION.

This section provides the basis for reasonable assurance that the tPCB TMDL for the PAXMH, PAXOH, and PAXTF tidal segments will be achieved and maintained.

Given that PCBs are no longer manufactured, and their use has been substantially restricted, it is reasonable to expect that with time tPCB concentrations in the aquatic environment will decline. 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 TMDL assumes a PCB attenuation rate of 5.0% per year at the boundary between the PAXMH tidal segment and the Chesapeake Bay mainstem as applied in the Back River PCB TMDL (MDE 2011a). Given this rate of decline in the mainstem, the tPCB levels in the PAXMH, PAXOH, and PAXTF tidal segments are expected to decline over time. 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. Even though tidal influence from the Chesapeake Bay mainstem serves as a source of PCBs to the PAXMH, PAXOH, and PAXTF tidal segments, the load contribution is resultant from other point and nonpoint source inputs (both historic and current) from throughout the upper Chesapeake Bay watershed and is not considered to be a directly controllable (reducible) source. Therefore this load was not assigned a baseline load or allocation within the TMDL.

Model scenarios predict that with the natural attenuation of tPCB concentrations in the Chesapeake Bay mainstem, and a 95.3% load reduction of the total baseline load from the PAXTF watershed, from direct atmosphere deposition to the surface of the tidal segments, and from the municipal WWTPs, the tPCB TMDL endpoints in both the water column and the sediment of the PAXTF and PAXOH tidal segments will be met in approximately 57 and 11 years, respectively. For the PAXMH tidal segment, the water column and sediment TMDL endpoints are achieved under baseline conditions as the boundary concentration declines at a rate of 5%. The sediment TMDL endpoint for the PAXMH tidal segment will be achieved within about 20 years. Loads from the watershed include non-regulated watershed runoff and NPDES regulated stormwater.

A new Chesapeake Bay Watershed Agreement was signed on June 16, 2014 which includes goals and outcomes for toxic contaminants including PCBs (CBP 2014a). 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 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 its 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 PAXMH, PAXOH, and PAXTF tidal segments.

Aside from the processes of natural attenuation, there are other approaches can assist in reducing the tPCB concentrations in the water column, such as 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. If the PCB-contaminated sediments were removed, load reductions would still be required under the TMDL, since PCBs would continue to enter the PAXMH, PAXOH, and PAXTF tidal segments from the mainstem of the Chesapeake Bay and from the PAXMH, PAXOH, and PAXTF watershed. However, the removal of these sediments could also mean that water quality supportive of the "fishing" designated use could be achieved in a shorter time frame. 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 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 re-suspension of contaminated sediments causes additional exposure of PCBs to aquatic organisms.

PCBs are still being released to the environment via accidental fires, leaks, or spills from older PCB-containing equipment; potential leaks from hazardous waste sites that contain PCBs; illegal or improper dumping; 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. The success of any implementation measures depend in large part on the feasibility of locating and evaluating opportunities to control on-land PCB sources, such as unidentified contaminated sites, leaky equipment, and contaminated soil or sediment.

MDE also periodically 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. Any 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.

Impervious surface restoration efforts have been known to result in total suspended solids (TSS) reductions. Since PCBs are known to adsorb to sediments and their concentrations correlate with TSS concentrations, any significant restoration requirements, which will lead to a reduction in sediment loads entering the PAXMH, PAXOH, and PAXTF tidal segments, will also contribute toward tPCB load reductions and meeting PCB water quality goals.

Given the persistent nature of PCBs, the difficulty in removing them from the environment and the significant watershed load reductions necessary in order to achieve water quality goals in the PAXMH, PAXOH, and PAXTF tidal segments, effectiveness of the implementation effort will need to be reevaluated throughout the process to ensure progress is being made towards reaching the TMDLs.

# REFERENCES

Ayris, S., Currado, G. M., Smith, D., and Harrad, S. 1997. GC/MS Procedures for the Determination of PCBs in Environmental Matrices. *Chemosphere* 35(5): 905-917.

Ashley, J. T. F., and J. E. Baker. 1999. Hydrophobic Organic Contaminants in Surficial Sediments of Baltimore Harbor: Inventories and Sources. *Environmental Toxicology and Chemistry* 18(5): 838-849.

CBP (Chesapeake Bay Program). 2014a. Chesapeake Bay Watershed Agreement. http://www.chesapeakebay.net/documents/FINAL_Ches_Bay_Watershed_Agreement.withsignatures-HIres.pdf.

______________. 2014b. CBP Bathymetry GIS Dataset. ftp://ftp.chesapeakebay.net/pub/Geographic/ChesapeakeBay/Bathymetry/

CFR (Code of Federal Regulations). 2016a. 40 CFR 130.2. http://www.gpo.gov/fdsys/pkg/CFR-2002-title40-vol18/pdf/CFR-2002-title40-vol18-sec130-2.pdf.

_____________. 2016b. 40 CFR 130.7. http://www.gpo.gov/fdsys/pkg/CFR-2011-title40-vol22/pdf/CFR-2011-title40-vol22-sec130-7.pdf.

_____________. 2016c. 40 CFR 122.44(k). http://www.gpo.gov/fdsys/pkg/CFR-2011-title40-vol22/pdf/CFR-2011-title40-vol22-sec122-44.pdf.

Chapra, S.C. 1997. Surface Water-Quality Modeling. McGraw-Hill, New York, USA, pp. 844.

COMAR (Code of Maryland Regulations). 2016a. 26.08.02.07. http://www.dsd.state.md.us/comar/comarhtml/26/26.08.02.07.htm (Accessed September, 2016).

_____________. 2016b. 26.08.02.08 M. http://www.dsd.state.md.us/comar/comarhtml/26/26.08.02.08.htm (Accessed September, 2016).

_____________. 2016c. 26.08.02.04-1.

http://www.dsd.state.md.us/comar/comarhtml/26/26.08.02.04-1.htm (Accessed September, 2016).

_____________. 2016d. 26.08.02.03-2. http://www.dsd.state.md.us/comar/comarhtml/26/26.08.02.03-2.htm (Accessed September, 2016).

_____________. 2016e. 26.08.02.03-1 (B) (3) (l). http://www.dsd.state.md.us/comar/comarhtml/26/26.08.02.03-1.htm (Accessed September, 2016).

De Bruijn, J., Busser, F., Seinen, W. and Hermens, J. 1989. Determination of Octanol/Water Partition Coefficients for Hydrophobic Organic Chemicals with the "Slow-Stirring" Method. *Environmental Toxicology and Chemistry* 8(6): 499-512.

DRBC (Delaware River Basin Commission). 2003. PCB Water Quality Model for Delaware Estuary (DELPCB). West Trenton, NJ: Delaware River Basin Commission.

Haywood, H. C., and Buchanan, C. 2007. Total Maximum Daily Loads of Polychlorinated Biphenyls (PCBs) for Tidal Portions of the Potomac and Anacostia Rivers in the District of Columbia, Maryland, and Virginia. Rockville, MD: Interstate Commission on the Potomac River Basin.

Hoke, R. A., Ankley, G. T., Cotter, A. M., Goldstein, T., Kosian, P. A., Phipps, G. L. and VanderMeiden, F. M. 1994. Evaluation of Equilibrium Partitioning Theory for Predicting Acute Toxicity to Field Collected Sediments Contaminated with DDT, DDE and DDD to the Amphipod Hyalella Azteca. *Environmental Toxicology and Chemistry* 13(1): 157-166.

Ko F. C., and Baker, J. E. 2004. Seasonal and Annual Loads of Hydrophobic Organic Contaminants from the Susquehanna River Basin to the Chesapeake Bay. *Marine Pollution Bulletin* 48(9-10): 840–851.

Konieczka, P., and Namiesnik, J. 2008. Determination of PCBs in Marine Sediment Using Pressurised Liquid Extraction-Gas Chromatography-Isotope Dilution Mass Spectrometry-
Method Validation. *Chemical Analysis* 53(6): 785-796.

MDE (Maryland Department of the Environment). 2006. Maryland Wastewater Treatment Plant PCB Survey Dataset. Baltimore, MD: Maryland Department of the Environment.

____________. 2011a. Total Maximum Daily Loads of Polychlorinated Biphenyls in Back River Oligohaline Tidal Chesapeake Bay Segment, Maryland. Baltimore, MD: Maryland Department of the Environment.

____________. 2011b. Total Maximum Daily Loads of Polychlorinated Biphenyls in Baltimore Harbor, Curtis Creek/Bay, and Bear Creek Portions of Patapsco River Mesohaline Tidal Chesapeake Bay Segment, Maryland. Baltimore, MD: Maryland Department of the Environment.

____________. 2014a. The 2014 Integrated Report of Surface Water Quality in Maryland. Baltimore, MD: Maryland Department of the Environment. Also Available at: http://www.mde.state.md.us/programs/Water/TMDL/Integrated303dReports/Pages/2014IR.aspx (Accessed September, 2016).

____________. 2014b. Statewide Fish Consumption Guidelines for All Ages: Table. http://mde.maryland.gov/programs/Marylander/CitizensInfoCenterHome/Documents/Fish%20Consumption%20Docs/Maryland_Fish_Advisories_2014_Web_bluecatedit.pdf (Accessed September, 2016)

_____________. 2016. Land Restoration Program's Geospatial Database (LRP-MAP). Baltimore, MD: Maryland Department of the Environment. http://mdewin64.mde.state.md.us/LRP/index.html (Accessed September, 2016).

Mydlova-Memersheimerova, J., Tienpont, B., David, F., Krupcik, J., and Sandra, P. 2009. Gas Chromatography of 209 Polychlorinated Biphenyl Congeners on An Extremely Efficient Nonselective Capillary Column. *Journal of Chromatography A* 1216(32): 6043-6062.

QEA (Quantitative Environmental Analysis, LLC). 1999. PCBs in the Upper Hudson River – Volume I, Historical Perspective and Model Overview. Albany, NY: Quantitative Environmental Analysis, LLC.

RETEC (The RETEC Group, Inc.). 2002. Remedial Investigation Report Lower Fox River and Green Bay, Wisconsin - Prepared for Wisconsin Department of Natural Resources.

Thomann R. V., and Mueller, J. A. 1987. Principles of Surface Water Quality Modeling and Control. New York City, NY: Harper & Row.

Totten, L. A., Panangadan, M., Eisenreich, S. J., Cavallo, G. J. and Fikslin, T. J. 2006. Direct and Indirect Atmospheric Deposition of PCBs to the Delaware River Watershed. Environmental Science and Technology. 40(7): 2171-2176.

US EPA (US Environmental Protection Agency). 1991. Technical Support Document (TSD) for Water Quality-based Toxics Control. Washington, DC: U.S. Environmental Protection Agency. Also Available at http://www.epa.gov/npdes/pubs/owm0264.pdf.

_____________. 1999. Chesapeake Bay Basin Toxics Load and Release Inventory. Annapolis, MD: U.S. Environmental Protection Agency with Chesapeake Bay Program.

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

_____________. 2003. Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health. Washington, DC: U.S. Environmental Protection Agency.

_____________. 2004. The Incidence and Severity of Sediment Contamination in Surface Waters of the United States: National Sediment Quality Survey, 2nd Edition. Washington, D.C: US EPA, Office of Science and Technology.

_____________. 2007. *Options for Expressing Daily Loads in TMDLs*. U.S. Environmental Protection Agency, Office of Wetlands, Oceans & Watersheds. https://www.epa.gov/sites/production/files/2015-10/documents/2007_06_26_tmdl_draft_daily_loads_tech-2.pdf.

USGS (United States Geological Survey). 2006. 2006 National Land Cover Dataset Chesapeake Bay Area, Modified Version 2.0. Annapolis, MD: United States Geological Survey, Chesapeake Bay Program Office.

## 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. 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 PAXMH, PAXOH, and PAXTF tidal segments 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 in the PAXMH, PAXOH, and PAXTF Tidal Segments**

| Common Name | Scientific Name | Trophic Level (#) | Trophic Level (Description) | Home Range (miles) |
|---|---|---|---|---|
| White Perch | *Morone americana* | 4 | Predator | 10 |
| Channel Catfish | *Ictalurus punctatus* | 3 | Benthivore-Generalist | 5 |

### 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 (2003):

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

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):

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

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 showing in 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:

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

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:

$$\text{Adj-tBAF} = (\text{Baseline BAF} \times \text{Median \% Lipid} + 1) \times \text{Median \%fd} \quad \text{(B-5)}$$

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 PCBs in fish tissue (http://www.mde.state.md.us/programs/Water/TMDL/Integrated303dReports/Pages/Programs/WaterPrograms/TMDL/maryland%20303%20dlist/ir_listing_methodologies.aspx), the 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 75% of the total length of the largest fish). The lowest tPCB water column threshold concentration of all the fish species will be selected as the TMDL endpoint in order to be supportive of the "fishing" designated use. In the PAXMH, PAXOH, and PAXTF tidal segments, the lowest threshold concentrations are 0.36 (White Perch), 0.40 (channel catfish), and 0.60 (Channel Catfish), respectively (See Table B-3). These thresholds have been selected as the water column TMDL endpoint for their respective tidal segments. The length and weight for all fish tissue samples are shown in Table B-4.

**Table B-3: tBAF, Baseline BAF, Adj-tBAF, and Water Column tPCB Threshold Concentration by Fish Species in the PAXMH, PAXOH, and PAXTF Tidal Segments**

| Tidal Segment | Species Name | Composites (Individual Fish) | tBAF (L/kg) | Baseline BAF (L/kg) | Adj-tBAF (L/kg) | Water Column tPCB Threshold Concentration* (ng/L) |
|---|---|---|---|---|---|---|
| PAXMH | White Perch | 11 (55) | 131,528 | 195,162 | 108,659 | **0.36** |
| PAXOH | White Perch | 4 (20) | 16,630 | 44,131 | 16,003 | 2.44 |
| | Channel Catfish | 5 (23) | 96,866 | 97,105 | 96,365 | **0.40** |
| PAXTF | White Perch | 2 (10) | 19,577 | 36,364 | 27,625 | 1.41 |
| | Channel Catfish | 2 (10) | 59,025 | 42,798 | 65,457 | **0.60** |

*Water column tPCB threshold concentrations in bold are applied as the TMDL endpoints for water column

**Table B-4: Individual Fish Lengths and Weights in the PAXMH, PAXOH, and PAXTF Tidal Segments**

| Tidal Segment | Sample ID | Station ID | Sample Date | Fish Species | Fish/ Composite | Fish ID | Length (cm) | Weight (g) |
|---|---|---|---|---|---|---|---|---|
| PAXMH | PAXR-A | PaxR | 5/20/2014 | White Perch | 5 | PAXR_01 | 24 | 191 |
| | | | | | | PAXR_02 | 24 | 162 |
| | | | | | | PAXR_03 | 23 | 166 |
| | | | | | | PAXR_04 | 23 | 169 |
| | | | | | | PAXR_05 | 22.5 | 163 |
| PAXMH | PAXR-B | PaxR | 5/20/2014 | White Perch | 5 | PAXR_06 | 22.3 | 147 |
| | | | | | | PAXR_07 | 21.2 | 140 |
| | | | | | | PAXR_08 | 21.2 | 125 |
| | | | | | | PAXR_09 | 21 | 121 |
| | | | | | | PAXR_10 | 21 | 111 |
| PAXMH | PAXR-C | PaxR | 5/20/2014 | White Perch | 5 | PAXR_11 | 20.8 | 122 |
| | | | | | | PAXR_12 | 21 | 111 |
| | | | | | | PAXR_13 | 20.2 | 113 |
| | | | | | | PAXR_14 | 20 | 116 |
| | | | | | | PAXR_15 | 21 | 120 |
| PAXMH | PXTBEN-A | PXTBEN | 9/16/2015 | White Perch | 5 | PXTBEN-01 | 18.8 | 108 |
| | | | | | | PXTBEN-02 | 17.8 | 86 |
| | | | | | | PXTBEN-03 | 17.8 | 82 |
| | | | | | | PXTBEN-04 | 17.5 | 82 |
| | | | | | | PXTBEN-05 | 17.5 | 80 |
| PAXMH | PXTBEN-B | PXTBEN | 9/16/2015 | White Perch | 5 | PXTBEN-06 | 17.3 | 81 |
| | | | | | | PXTBEN-07 | 17.2 | 83 |
| | | | | | | PXTBEN-08 | 17.2 | 76 |

| Tidal Segment | Sample ID | Station ID | Sample Date | Fish Species | Fish/ Composite | Fish ID | Length (cm) | Weight (g) |
|---|---|---|---|---|---|---|---|---|
| | | | | | | PXTBEN-09 | 17 | 76 |
| | | | | | | PXTBEN-10 | 17.5 | 81 |
| PAXMH | PXTBEN-C | PXTBEN | 9/16/2015 | White Perch | 5 | PXTBEN-11 | 17.5 | 75 |
| | | | | | | PXTBEN-12 | 17 | 71 |
| | | | | | | PXTBEN-13 | 17 | 73 |
| | | | | | | PXTBEN-14 | 16.5 | 74 |
| | | | | | | PXTBEN-15 | 16.5 | 76 |
| PAXMH | PXTBEN-D | PXTBEN | 9/16/2015 | White Perch | 5 | PXTBEN-16 | 16.5 | 78 |
| | | | | | | PXTBEN-17 | 17 | 89 |
| | | | | | | PXTBEN-18 | 16.5 | 73 |
| | | | | | | PXTBEN-19 | 16.7 | 76 |
| | | | | | | PXTBEN-20 | 16.1 | 72 |
| PAXMH | PATBRM-A | PATBRM | 9/16/2015 | White Perch | 5 | PATBRM-01 | 21.5 | 149 |
| | | | | | | PATBRM-02 | 22 | 152 |
| | | | | | | PATBRM-03 | 21 | 143 |
| | | | | | | PATBRM-04 | 20.3 | 114 |
| | | | | | | PATBRM-05 | 19.5 | 118 |
| PAXMH | PATBRM-B | PATBRM | 9/16/2015 | White Perch | 5 | PATBRM-06 | 19.3 | 100 |
| | | | | | | PATBRM-07 | 19.1 | 108 |
| | | | | | | PATBRM-08 | 18.6 | 107 |
| | | | | | | PATBRM-09 | 18.5 | 102 |
| | | | | | | PATBRM-10 | 18 | 92 |
| PAXMH | PATBRM-C | PATBRM | 9/16/2015 | White Perch | 5 | PATBRM-11 | 18.5 | 94 |
| | | | | | | PATBRM-12 | 18.3 | 99 |
| | | | | | | PATBRM-13 | 18 | 99 |

| Tidal Segment | Sample ID | Station ID | Sample Date | Fish Species | Fish/ Composite | Fish ID | Length (cm) | Weight (g) |
|---|---|---|---|---|---|---|---|---|
| | | | | | | PATBRM-14 | 18 | 96 |
| | | | | | | PATBRM-15 | 18 | 93 |
| PAXMH | PATBRM-D | PATBRM | 9/16/2015 | White Perch | 5 | PATBRM-16 | 17.9 | 97 |
| | | | | | | PATBRM-17 | 18 | 90 |
| | | | | | | PATBRM-18 | 18.5 | 95 |
| | | | | | | PATBRM-19 | 18 | 97 |
| | | | | | | PATBRM-20 | 17.7 | 97 |
| PAXOH | PAXR2-D | PaxR2 | 5/14/2014 | White Perch | 5 | PAXR2_01 | 25.2 | 228 |
| | | | | | | PAXR2_02 | 23.6 | 219 |
| | | | | | | PAXR2_03 | 24.4 | 186 |
| | | | | | | PAXR2_04 | 22.5 | 135 |
| | | | | | | PAXR2_05 | 23.3 | 154 |
| PAXOH | PAXR2-E | PaxR2 | 5/14/2014 | White Perch | 5 | PAXR2_06 | 21.6 | 138 |
| | | | | | | PAXR2_07 | 22.1 | 144 |
| | | | | | | PAXR2_08 | 22 | 154 |
| | | | | | | PAXR2_09 | 22 | 152 |
| | | | | | | PAXR2_10 | 22 | 139 |
| PAXOH | PAXR2-F | PaxR2 | 5/14/2014 | White Perch | 5 | PAXR2_11 | 21.1 | 130 |
| | | | | | | PAXR2_12 | 21 | 127 |
| | | | | | | PAXR2_13 | 21.2 | 113 |
| | | | | | | PAXR2_14 | 21.6 | 137 |
| | | | | | | PAXR2_15 | 20.8 | 113 |
| PAXOH | PAXR2-G | PaxR2 | 5/14/2014 | Channel Catfish | 5 | PAXR2_16 | 57.5 | 2220 |
| | | | | | | PAXR2_17 | 55 | 1742 |
| | | | | | | PAXR2_18 | 53.4 | 1699 |

| Tidal Segment | Sample ID | Station ID | Sample Date | Fish Species | Fish/ Composite | Fish ID | Length (cm) | Weight (g) |
|---|---|---|---|---|---|---|---|---|
| | | | | | | PAXR2_19 | 53.5 | 1595 |
| | | | | | | PAXR2_20 | 54.5 | 2012 |
| PAXOH | PAXR2-H | PaxR2 | 5/14/2014 | Channel Catfish | 5 | PAXR2_21 | 51 | 1312 |
| | | | | | | PAXR2_22 | 52 | 1523 |
| | | | | | | PAXR2_23 | 50 | 1145 |
| | | | | | | PAXR2_24 | 49.7 | 1332 |
| | | | | | | PAXR2_25 | 46 | 893 |
| PAXOH | PAXR2-I | PaxR2 | 5/14/2014 | Channel Catfish | 5 | PAXR2_26 | 44 | 813 |
| | | | | | | PAXR2_27 | 45.2 | 916 |
| | | | | | | PAXR2_28 | 44.5 | 734 |
| | | | | | | PAXR2_29 | 39.5 | 522 |
| | | | | | | PAXR2_30 | 38 | 501 |
| PAXOH | PAXBEN-A | PAXBEN | 9/29/2009 | White Perch | 5 | PAXBEN-01 | 19 | 82 |
| | | | | | | PAXBEN-02 | 19 | 88 |
| | | | | | | PAXBEN-03 | 19 | 89 |
| | | | | | | PAXBEN-04 | 18 | 76 |
| | | | | | | PAXBEN-05 | 17.5 | 74 |
| PAXOH | PAXBEN-C | PAXBEN | 9/29/2009 | Channel Catfish | 3 | PAXBEN-11 | 45.5 | 399 |
| | | | | | | PAXBEN-12 | 34.4 | 301 |
| | | | | | | PAXBEN-13 | 34.5 | 332 |
| PAXOH | PAXBEN-D | PAXBEN | 9/29/2009 | Channel Catfish | 5 | PAXBEN-14 | 31 | 255 |
| | | | | | | PAXBEN-15 | 31 | 249 |
| | | | | | | PAXBEN-16 | 29 | 242 |
| | | | | | | PAXBEN-17 | 29 | 214 |
| | | | | | | PAXBEN-18 | 29.4 | 206 |

| Tidal Segment | Sample ID | Station ID | Sample Date | Fish Species | Fish/ Composite | Fish ID | Length (cm) | Weight (g) |
|---|---|---|---|---|---|---|---|---|
| PAXTF | PATRRB-A | PATRRB | 9/22/2015 | Channel Catfish | 5 | PATRRB-01 | 46 | 1075 |
| | | | | | | PATRRB-02 | 48 | 946 |
| | | | | | | PATRRB-03 | 45.5 | 1053 |
| | | | | | | PATRRB-04 | 43 | 668 |
| | | | | | | PATRRB-05 | 44.3 | 700 |
| PAXTF | PATRRB-B | PATRRB | 9/22/2015 | Channel Catfish | 5 | PATRRB-06 | 42.3 | 611 |
| | | | | | | PATRRB-07 | 42.6 | 639 |
| | | | | | | PATRRB-08 | 37.8 | 449 |
| | | | | | | PATRRB-09 | 39 | 509 |
| | | | | | | PATRRB-10 | 33.8 | 347 |
| PAXTF | PATRRB-C | PATRRB | 9/22/2015 | White Perch | 5 | PATRRB-11 | 21.6 | 155 |
| | | | | | | PATRRB-12 | 20.5 | 132 |
| | | | | | | PATRRB-13 | 19.3 | 122 |
| | | | | | | PATRRB-14 | 19 | 103 |
| | | | | | | PATRRB-15 | 18.7 | 108 |
| PAXTF | PATRRB-D | PATRRB | 9/22/2015 | White Perch | 5 | PATRRB-16 | 18.6 | 91 |
| | | | | | | PATRRB-17 | 18.5 | 97 |
| | | | | | | PATRRB-18 | 18 | 93 |
| | | | | | | PATRRB-19 | 18 | 88 |
| | | | | | | PATRRB-20 | 17 | 70 |

## V. Biota-Sediment Accumulation Factors and Adjusted Sediment BAFs

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

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

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:

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

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. In the PAXMH, PAXOH, and PAXTF tidal segments, the lowest threshold concentrations are 2.5 (White Perch), 1.36 (channel catfish), and 0.52 (Channel Catfish), respectively (See Table B-5). These thresholds have been selected as the sediment TMDL endpoint for their respective tidal segments.

**Table B-5: BSAF, Adj-SedBAF, and Sediment tPCB Threshold Concentration by Fish Species in the PAXMH, PAXOH, and PAXTF Tidal Segments**

| Tidal Segment | Species Name | BSAF | Adj-SedBAF | Sediment tPCB Threshold Concentration (ng/g) |
|---|---|---|---|---|
| PAXMH | White Perch | 5.10 | 15.61 | **2.50** |
| PAXOH | White Perch | 1.99 | 3.40 | 11.47 |
| | Channel Catfish | 5.66 | 28.76 | **1.36** |
| PAXTF | White Perch | 14.45 | 32.01 | 1.22 |
| | Channel Catfish | 16.97 | 75.68 | **0.52** |

*Sediment tPCB threshold concentrations in bold are applied as the TMDL endpoints for sediment

## Appendix C: Method Used to Estimate Watershed tPCB Load

The PAXMH, PAXOH, and PAXTF watersheds were divided into 15 subwatershed segments in order to estimate tPCB loads for the water quality model. The subwatershed segmentation is displayed in Figure C-1. The PAXMH watershed includes subwatershed segments SW-1 through SW-6, the PAXOH watershed includes subwatershed segments SW-7 through SW-9, and the PAXTF watershed includes subwatershed segments SW-10 through SW-15.

Flow information from three United States Geological Survey (USGS) gauge stations, 01594526 (Western Branch at Upper Marlboro, MD), 01661050 (St Clement Creek near Clements, MD), and 01594440 (Patuxent River near Bowie, MD) was used to calculate subwatershed flows. The USGS gauge station locations are displayed in Figure C-1. USGS gauge stations 01594526 and 01594440 are located in subwatershed segments SW-12 and SW-15, respectively. The average daily unit flow rates from these stations were used to calculate flow from the corresponding subwatersheds. There are no USGS gages stations located within the remaining subwatersheds which have sufficient flow data or similar land use characteristics. The land use distribution for the drainage area of the USGS gauge should be similar to that of the subwatershed segment in order to accurately approximate flow. The land use distributions for the subwatershed segments in the PAXMH, PAXOH, and PAXTF watersheds and USGS gauge drainage areas are displayed in Table C-1. The table includes the USGS gauge/subwatershed segment, tidal segment, and distribution of urban, forest, agriculture, and water/wetland land uses.

The drainage area for USGS gauge station 01661050 located in the vicinity of the Patuxent River watershed in St. Clement's Bay has a similar land use distribution to subwatershed segments SW-2 through SW-11, SW-13, and SW-14. The average daily unit flow rate from this station was used to calculate the flow from these subwatersheds. The drainage area for USGS gauge station 01594526 which was used to calculate flow from subwatershed segment SW-12 also has a similar land use distribution to subwatershed segment SW-1. Therefore the average daily unit flow rate from this station was used to calculate the flow from subwatershed segment SW-1.

The average daily unit flow rate for each USGS gauge station was calculated for the period January 2005 through November 2015. The flow rate for each subwatershed segment was calculated by multiplying the average daily unit flow rate from the corresponding USGS gauge station by the subwatershed area. The subwatershed segment flow rates for the PAXMH, PAXOH, and PAXTF watersheds are presented in Table C-2. The table includes the watershed, subwatershed segment, corresponding USGS gauge for calculating the subwatershed flow, USGS gauge average unit flow, subwatershed area, and subwatershed flow.

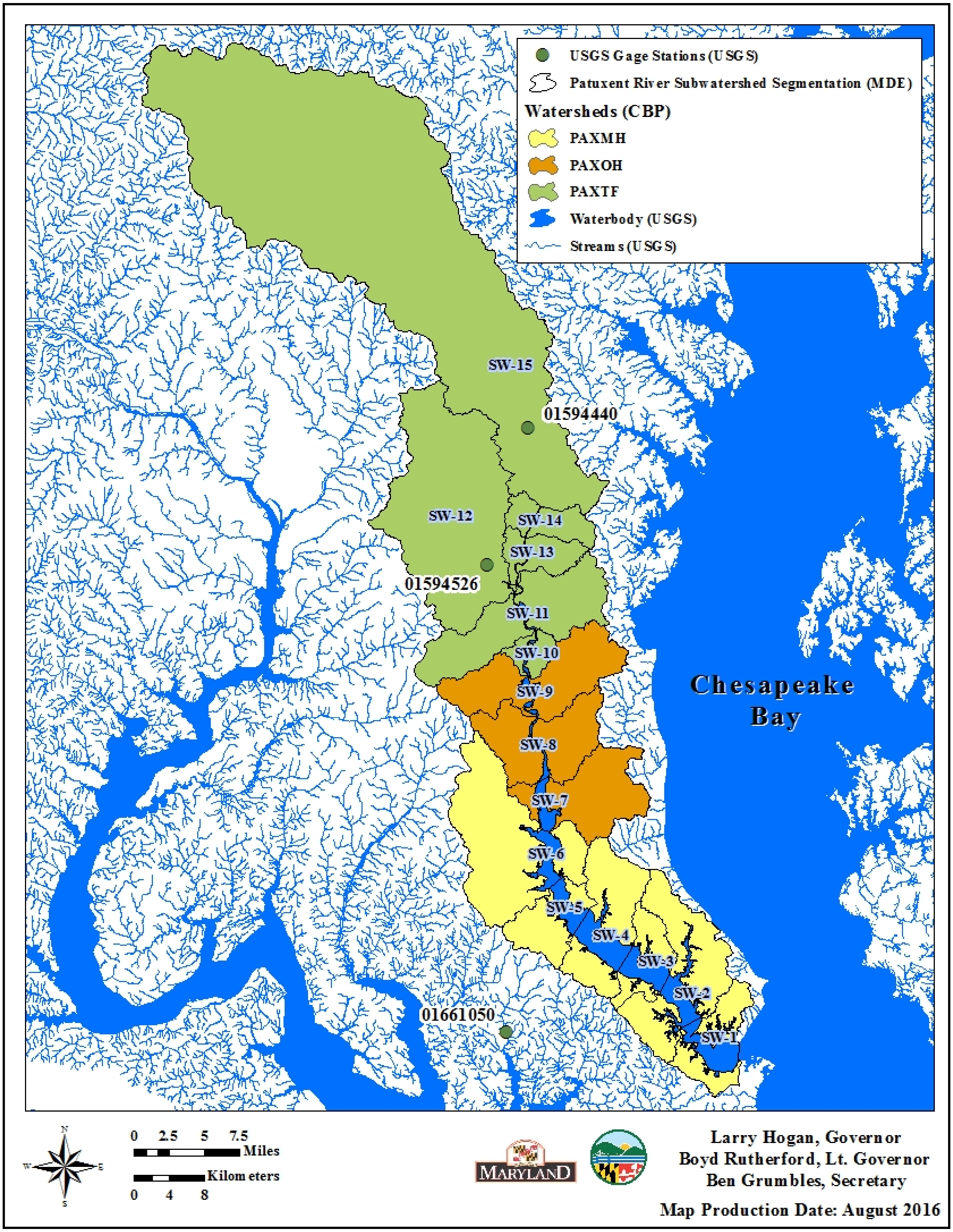


**Figure C-1: Subwatershed Segmentation in the PAXMH, PAXOH, and PAXTF Watersheds**

**Table C-1: Land Use Distribution for Subwatershed Segments in the PAXMH, PAXOH, and PAXTF Watersheds and USGS Gauge Drainage Areas**

| USGS gauge/ Subwatershed Segment | Watershed | Landuse Area (%) | | | |
|---|---|---|---|---|---|
| | | Urban | Forest | Agriculture | Water/Wetland |
| 01661050 | - | 9% | 54% | 29% | 7% |
| 01594526 | | 46% | 36% | 12% | 6% |
| 01594440 | | 31% | 35% | 27% | 6% |
| 1 | PAXMH | 51% | 34% | 1% | 14% |
| 2 | | 16% | 57% | 14% | 14% |
| 3 | | 8% | 51% | 27% | 15% |
| 4 | | 7% | 65% | 17% | 12% |
| 5 | | 6% | 59% | 25% | 11% |
| 6 | | 12% | 59% | 19% | 10% |
| 7 | PAXOH | 15% | 57% | 17% | 11% |
| 8 | | 10% | 53% | 24% | 12% |
| 9 | | 12% | 49% | 30% | 10% |
| 10 | PAXTF | 13% | 38% | 27% | 22% |
| 11 | | 10% | 49% | 29% | 12% |
| 12 | | 46% | 36% | 12% | 6% |
| 13 | | 16% | 39% | 30% | 14% |
| 14 | | 7% | 53% | 33% | 7% |
| 15 | | 31% | 35% | 27% | 6% |

**Table C-2: Subwatershed Segments Flows Rates in the PAXMH, PAXOH, and PAXTF Watersheds**

| Watershed | Subwatershed Segment | USGS Gage | USGS Gauge Average Unit Flow ($cfs/mi^2$) | Subwatershed Area ($mi^2$) | Subwatershed Flow Rate ($m^3$/day)* |
|---|---|---|---|---|---|
| PAXMH | SW-1 | 01594526 | 1.25 | 16.7 | 51,148 |
| | SW-2 | 01661050 | 0.99 | 41.0 | 99,476 |
| | SW-3 | 01661050 | 0.99 | 11.6 | 28,034 |
| | SW-4 | 01661050 | 0.99 | 30.8 | 74,674 |
| | SW-5 | 01661050 | 0.99 | 16.8 | 40,769 |
| | SW-6 | 01661050 | 0.99 | 64.9 | 157,404 |
| PAXOH | SW-7 | 01661050 | 0.99 | 34.1 | 82,674 |
| | SW-8 | 01661050 | 0.99 | 37.3 | 90,361 |
| | SW-9 | 01661050 | 0.99 | 44.0 | 106,759 |
| PAXTF | SW-10 | 01661050 | 0.99 | 7.3 | 17,750 |
| | SW-11 | 01661050 | 0.99 | 50.8 | 123,089 |
| | SW-12 | 01594526 | 1.25 | 111.6 | 342,266 |
| | SW-13 | 01661050 | 0.99 | 14.0 | 33,984 |
| | SW-14 | 01661050 | 0.99 | 14.2 | 34,413 |
| | SW-15 | 01594440 | 1.17 | 383.1 | 1,099,512 |

*2005 – 2015 average.

MDE collected water column samples for tPCB analysis at six non-tidal monitoring stations throughout the PAXMH, PAXOH, and PAXTF watersheds. The non-tidal water quality monitoring stations are displayed in Figure C-1. Stations LPR-11 and LPR-13 are located in subwatershed segments SW-15 and SW-12, respectively. PCB water quality data from these stations was used to calculate tPCB loads for the corresponding subwatersheds. PCB water quality data from stations LPR-10, 12, 14 & 15 was used to calculate tPCB loads for subwatersheds SW-1 through SW-11, SW-13, and SW-14.

Two methods have been developed for estimating subwatershed loads in tPCB TMDLs: 1) a regression method and 2) an averaging method. The regression method was first developed for the Back River tPCB TMDL (MDE 2011a). If the criteria for selecting the regression method are not met, the averaging method is applied to estimate watershed loads for the tPCB TMDL.

Under the regression method, a tPCB load is calculated for each non-tidal water column sample by multiplying the non-tidal water column tPCB concentration, USGS daily unit flow rate for that sampling date, and drainage area of the non-tidal water quality monitoring station. A regression is then calculated for all individual sample watershed loads and associated flows rates. The tPCB load from the regression equation associated with the average flow rate for a subwatershed is then applied as the subwatershed tPCB load in a TMDL. In order to apply the regression method: 1) the flow rates for all non-tidal water column samples must cover the entire flow regime (low to high flows), 2) the sample size must be greater than 10 samples, and 3) the coefficient of determination ($R^2$) from the regression analysis must be greater than 90%.

Flow duration curves for the three USGS gauge stations (01594526, 01661050, and 01594440) selected to estimate subwatershed flow rates for the PAXMH, PAXOH, and PAXTF watersheds are displayed in Figures C-2, C-3, and C-4. The flow duration curves plot the average daily unit flow rates for the period January 2005 through November 2015. The flow rates for each non-tidal water column sampling date are also identified on the flow duration curves.

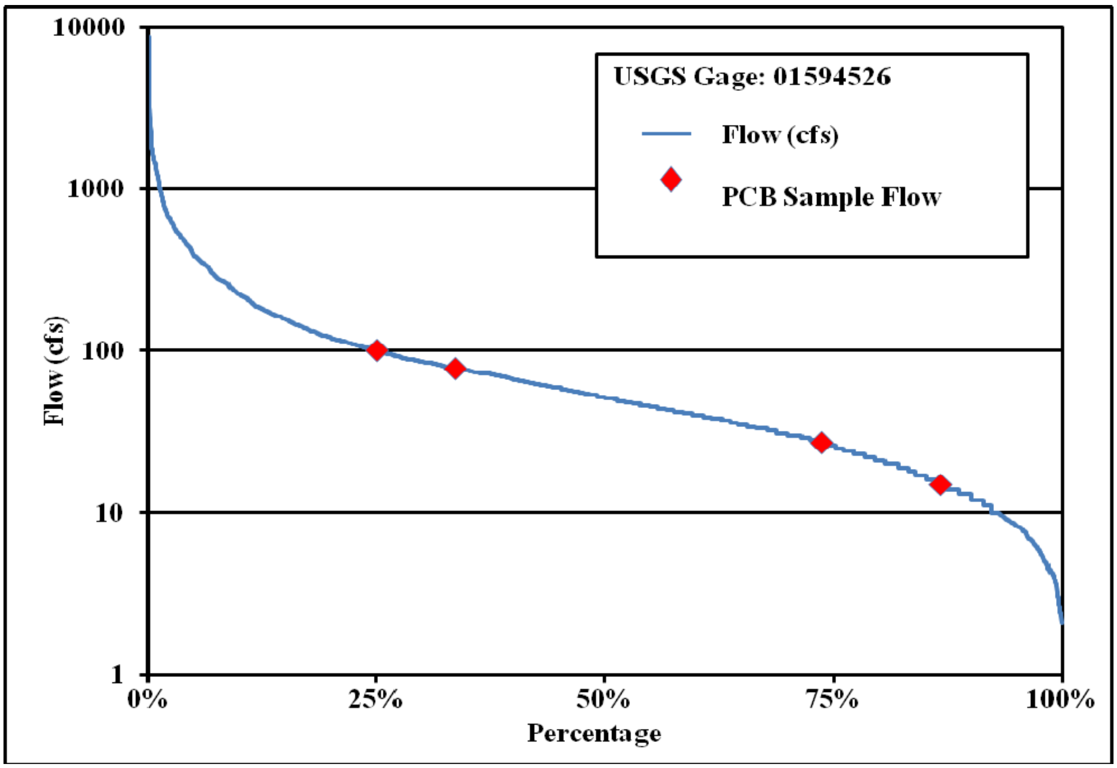


**Figure C-2: Flow Duration Curve for USGS Gauge Station 01594526**

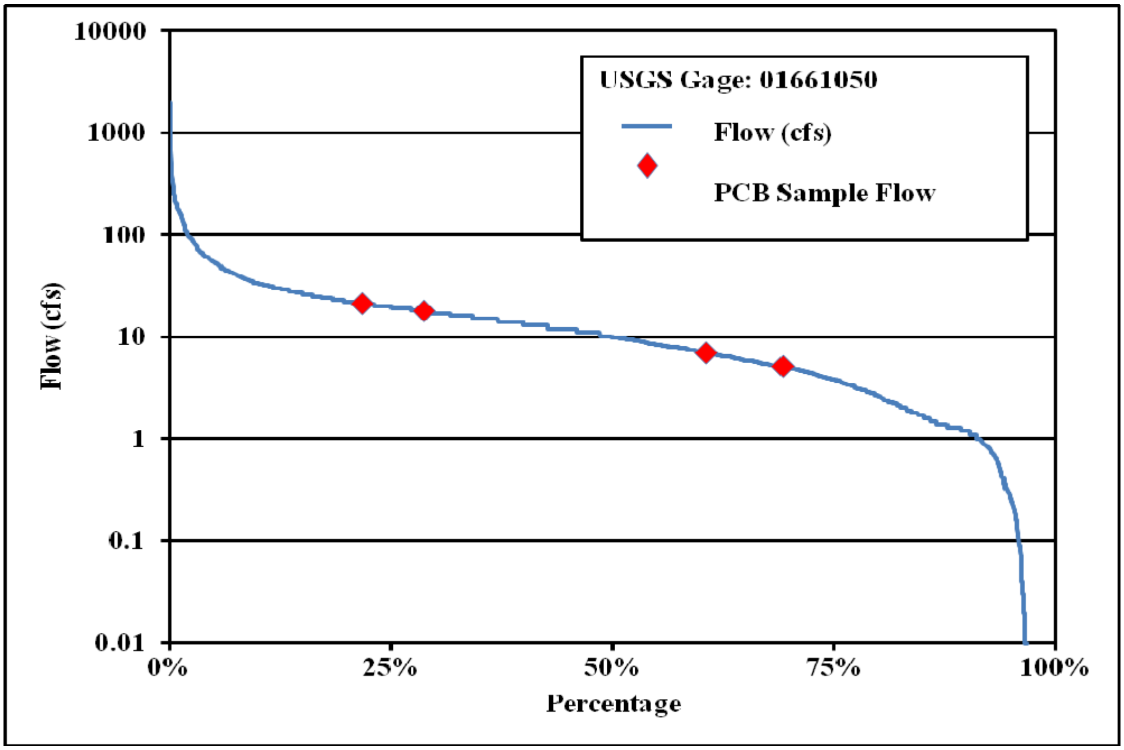


**Figure C-3: Flow Duration Curve for USGS Gauge Station 01661050**

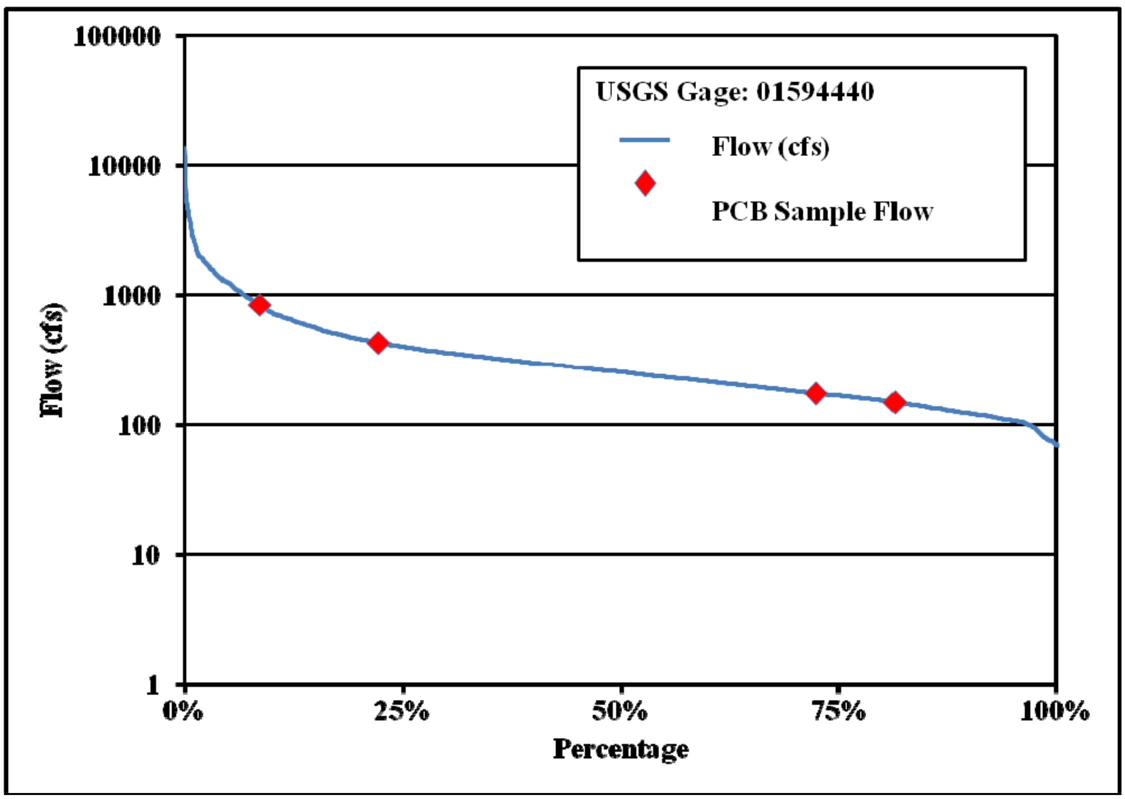


**Figure C-4: Flow Duration Curve for USGS Gauge Station 01594440**

Flow rates for non-tidal water column samples on the flow duration curve for USGS gauge station 01594526 cover the mid to low range flows but do not characterize the high flow; and for USGS gauge station 01661050 cover the mid range flows but do not characterize the high and low flow regimes. Therefore it not justifiable to apply the regression method for these USGS gauge stations which applies to subwatershed segments SW-1 through SW-14. Flow rates for non-tidal water column samples on the flow duration curve for USGS gauge station 01594440 cover the entire flow regime, however only four non-tidal water column samples are available for this regression analysis which applies to subwatershed segment SW-15. Therefore the sample size is insufficient and it is not justifiable to apply the regression method for this subwatershed segment. The averaging method will be applied to estimate tPCB loads for all subwatershed segments in the PAXMH, PAXOH, and PAXTF watersheds.

Under the averaging method, the tPCB baseline load from each subwatershed was calculated by multiply the average flow rate and average non-tidal water column tPCB concentration from the selected monitoring stations for each subwatershed. The subwatershed tPCB baseline loads for the PAXMH, PAXOH, and PAXTF watersheds are presented in Table C-3. The table includes the watershed, subwatershed segment, average non-tidal tPCB concentration, flow, and subwatershed segment tPCB load.

**Table C-3: Subwatershed tPCB Baseline Loads in the PAXMH, PAXOH, and PAXTF Watersheds**

| Watershed | Subwatershed Segment | Average tPCB Concentration (ng/L) | Flow ($m^3$/day) | Subwatershed Segment tPCB Load (g/year) [1] |
|---|---|---|---|---|
| PAXMH | SW-1 | 0.74 | 51,148 | 13.8 |
| | SW-2 | 0.74 | 99,476 | 26.8 |
| | SW-3 | 0.74 | 28,034 | 7.5 |
| | SW-4 | 0.74 | 74,674 | 20.1 |
| | SW-5 | 0.74 | 40,769 | 11.0 |
| | SW-6 | 0.74 | 157,404 | 42.3 |
| PAXOH | SW-7 | 0.74 | 82,674 | 22.2 |
| | SW-8 | 0.74 | 90,361 | 24.3 |
| | SW-9 | 0.74 | 106,759 | 28.7 |
| PAXTF | SW-10 | 0.74 | 17,750 | 4.8 |
| | SW-11 | 0.74 | 123,089 | 33.1 |
| | SW-12 | 0.96 | 342,266 | 120.2 |
| | SW-13 | 0.74 | 33,984 | 9.1 |
| | SW-14 | 0.74 | 34,413 | 9.3 |
| | SW-15 | 3.75 | 1,099,512 | 1,504.2 |

[1]Long Term (2005-2015) average loading rate

## Appendix D: Multi-Segment Tidally-Averaged One-Dimensional Transport Model

A tidally averaged multi-segment one-dimensional transport model was used to simulate the total polychlorinated biphenyl (tPCB) dynamic interactions between the water column and bottom sediments within the PAXMH, PAXOH, and PAXTF tidal segments and the Chesapeake Bay. The model is based on one-dimensional tidally averaged model (Thomann and Mueller 1987) and adopts the basic assumptions and methodology of the Water Quality Analysis Simulation Program (WASP) (Di Toro *et al*. 1983, Chapra 1997). It is assumed that the pollutant is well mixed in each segment and there is no decay of PCBs. The average observed tPCB concentrations in each segment were used as the model input representing baseline conditions. If the segment did not have any PCB observation, the linear interpolation of the most adjacent up- and down-stream segments' tPCB concentrations was used. The model assumes that at the Chesapeake Bay and PAXMH tidal segment boundary, the water column tPCB concentration on average decreases with a rate of 5% per year, which is consistent with the Back River PCB TMDL (MDE 2011a) and other PCB TMDLs developed by MDE. All other inputs (*i.e.*, freshwater inputs, dispersion coefficients, sediment and water column exchange rates, atmosphere exchange rates, and burial rates) were kept constant.

The model domain for the PAXMH, PAXOH, and PAXTF tidal segments was divided into 14 segments (see Figure D-1) and the PAXMH, PAXOH, and PAXTF watersheds were divided into 15 corresponding subwatersheds (see Figure C-1). In each segment, PCBs can enter the water column via loads from adjacent watersheds and atmosphere ($W_n$), loads from upstream through flow ($Q_{n+1}Cw_{n+1}$), loads from upstream through dispersion ($D_{n+1}(Cw_{n+1}-Cw_n)CA_{n+1}/L_{n+1}$), resuspension from the sediment ($Vr_nSA_nCs_n$), and diffusion between sediment-water column interface ($VdSA_n(Fds_nCs_n - Fdw_nCw_n)$). PCBs leave the water column via loads to downstream segments through flow and dispersion ($Q_nCw_n$ and $D_n(Cw_n-Cw_{n-1})CA_n/L_n$), volatilization ($VvSA_nFdw_nCw_n$), and settling ($VsetSA_nFpw_nCw_n$).

In the sediment, the PCBs enter the system via settling ($VsetSA_nFpw_nCw_n$), and leave the system via diffusion ($VdSA_n(Fds_nCs_n - Fdw_nCw_n)$), resuspension ($Vr_nSA_nCs_n$) and burial to a deeper layer ($VbSA_nCs_n$).

Specifically, the mass balance for the tPCBs in the water column of segment *n* can be written as:

$$\frac{dVw_nCw_n}{dt} = W_n + Q_{n+1}Cw_{n+1} + D_{n+1}(Cw_{n+1} - Cw_n)CA_{n+1}/L_{n+1} + Vr_nSA_nCs_n + VdSA_n(Fds_nCs_n - Fdw_nCw_n) - Q_nCw_n - D_n(Cw_n - Cw_{n-1})CA_n/L_n - VvSA_nFdw_nCw_n - VsetSA_nFpw_nCw_n \quad \text{(D-1)}$$

and that in the sediment of segment *n* can be written as:

$$\frac{dVs_nCs_n}{dt} = VsetSA_nFpw_nCw_n - VdSA_n(Fds_nCs_n - Fdw_nCw_n) - Vr_nSA_nCs_n - VbSA_nCs_n \quad \text{(D-2)}$$

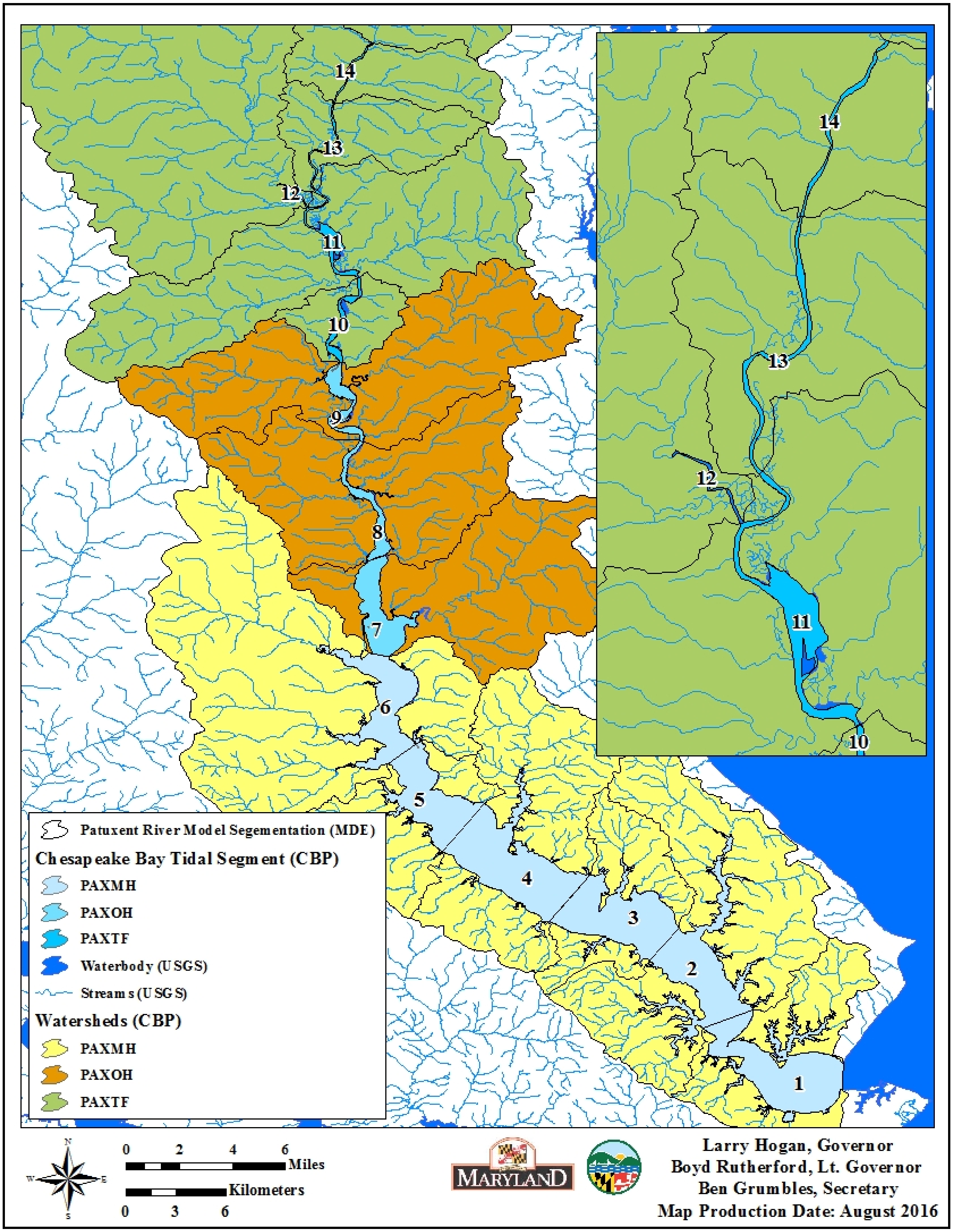


**Figure D-1: Water Quality Model Segmentation in the PAXMH, PAXOH, and PAXTF Tidal Segments**

Where:
$n$ = the n$^{th}$ river segment;
$Vw_n$ and $Vs_n$ = volume of the water and sediment (m$^3$);
$Cw_n$ *and* $Cs_n$ = tPCB concentration in water and sediment (ng/L);
$t$ = time (day);
$W_n$ = tPCB load from adjacent watershed (including tributaries) and atmosphere (ug/day);
$Q_n$ = quantity of water that flows from segment $n$ to $n\text{-}1$ (m$^3$/day);
$Q_{nb}$ = quantity of water that flows from adjacent branch to segment $n$ (m$^3$/day);
$D_n$ and $D_{nb}$ = dispersion coefficients (tidal averaged diffusivity) at the upstream and downstream sides of segment $n$ (m$^2$/day);
$CA_n$ and $CA_{nb}$ = cross sectional area between segment $n$ and $n\text{-}1$ and between its branch and segment $n$ (m2);
$L_n$ and $L_{nb}$ = distance between center of segment $n$ to $n\text{-}1$ and between center of its branch to segment $n$ (m);
$SA_n$ = surface area of segment $n$ (m$^2$);
$Vr_n$ = rate of resuspension (m/day);
$Vd$ = diffusive mixing velocity (m/day), which is same for all the segments;
$Vv$ = volatilization coefficient (m/day), which is same for all the segments;
$Vset$ = rate of settling (m/day);
$Vb$ = burial rate (m/day), which is same for all the segments;
$Fdw_n$ = fraction of truly dissolved and dissolved organic carbon (DOC) associated PCBs in the water column;
$Fds_n$ = fraction of truly dissolved and DOC associated PCBs in the sediment;
$Fpw_n$ = fraction of particular associated PCBs in the water column.

The values of the parameters for the water quality model are as follows:

$n$ = 14. It was delineated in consideration of the locations of the water quality monitoring stations and the bathymetry.
$Vw_n$ = mean water depth of segment $n$ × surface area of segment $n$. The mean water depth was obtained from the CBP GIS bathymetry dataset (CBP 2014b)
$Vs_n$ = active sediment layer thickness (10 cm) × surface area of segment $n$.
$Cw_n$ = measured tPCB water column concentration of segment $n$. If the measurement was not available, the linear interpolation of the most adjacent segments' concentrations was used.
$Cs_n$ = Measured tPCB concentration on a dry sediment base × Sediment density × (1-porosity) ÷ Fraction of particulate associated PCBs in the sediment, and the porosity (water content on a volume base) of 0.8 is selected based on reference (Thomann and Mueller 1987);

$W_n$ = tPCB load from the adjacent watershed of segment $n$ and atmospheric deposition. As showed in Figure C-1, the watershed was divided into 15 subwatersheds (See Appendix C for detailed information on subwatershed load estimation). The direct atmospheric deposition load to the surface water of each model segment was calculated

by multiplying the surface water area and the deposition rate of 1.6 μg/m$^2$/year (USEPA 1999).
$Q_n$ = total flow from all the upstream subwatersheds of segment n-1 (See Appendix C for detailed information on subwatershed flow estimation)
$D_n$ = dispersion coefficient of each segment. Estimation based on salinity data in the PAXMH, PAXOH, PAXTF tidal segments. Salinity is a conservative constituent. It has no loss due to reaction, volatilization, or settling in the water and no source from the watershed. The deposition from the atmosphere is minimal and can be ignored. Therefore, the only source of salinity in the system is from the Chesapeake Bay water at the mouth. Consequently, in Equation (C1), all the terms $W_n$, $Vr_nSA_nCs_n$, $VdSA_n(Fds_nCs_n – Fdw_nCw_n)$, $VvSA_nFdw_nCw_n$, and $VsetSA_nFpw_nCw_n$ become zero. Dispersion coefficient can be obtained by solving the steady state, Equation (C1) providing know parameters of flow and measured salinity. $D_n$ can be estimated for segment 14, using the equation $0 = -Q_{14}Cw_{14} - D_{14} (Cw_{14} - Cw_{13})CA_{14}/L_{14}$. Then the $D_n$ of Segments 13 through 1 can be estimated in sequence.
$CA_n$ = depth × length of the cross section.
$L_n$ = distance between segments directly measured using ArcView GIS.
$SA_n$ = surface area calculated from ArcView GIS.
$Vd$ = 69.35 × Porosity × (Molecular weight of PCBs)$^{-2/3}$÷ 365 = 69.35 × 0.85 × (305.6)$^{-2/3}$ ÷ 365= 0.00356 (m/day, Thomann and Mueller 1987).
$Vv$ = 0.251 m/day, which was derived from empirical method of Chapra (1997).
$Vset$ = 0.25 - 1 (m/d), a default value of settling rate used in literature (DRBC 2003).
$Vb$ = 3.935×10$^{-6}$ (m/day, average of the measured sedimentation rates through $_{210}$Pb technology for Corsica River, Northeast River, Bohemia River, and Sassafras River).
$V_{rn}$ can be calculated via mass balance of the sediment in the active sediment layer at steady state.

$$\frac{d\rho(1-\varphi)}{dt} = V_s \times TSS - V_r \times \rho \times (1-\varphi) - V_b \times \rho \times (1-\varphi) = 0 \qquad \text{(D-3)}$$

Where: $TSS$ is the total suspended solid concentration (g/m$^3$, measured)
$\rho$ is the sediment density (g/m$^3$; Thomann and Mueller, 1987)
$\varphi$ is the porosity (Thomann and Mueller, 1987)

Rearrange Equation D-3:

$$V_r = \frac{V_s \times TSS}{\rho \times (1-\varphi)} - V_b \qquad \text{(D-4)}$$

Physical parameters of each segment can be found in Table D-1.

**Table D-1: Physical Parameters of the Model for Each Segment**

| n | *SA* ($m^2$) | *Vw* ($m^3$) | *CA* ($m^2$) | L (m) | $Fdw_n$ | $Fpw_n$ | $Fds_n$ |
|---|---|---|---|---|---|---|---|
| 1 | 21,811,453 | 201,225,162 | 18,954 | 7,038 | 0.7541 | 0.2459 | 0.0017 |
| 2 | 19,619,195 | 113,914,912 | 23,322 | 6,510 | 0.7468 | 0.2532 | 0.0017 |
| 3 | 17,682,371 | 92,459,739 | 16,976 | 5,657 | 0.7419 | 0.2581 | 0.0017 |
| 4 | 22,157,679 | 94,414,537 | 15,808 | 6,486 | 0.7371 | 0.2629 | 0.0017 |
| 5 | 12,888,374 | 44,175,184 | 14,933 | 5,960 | 0.6790 | 0.3210 | 0.0017 |
| 6 | 13,427,417 | 28,125,740 | 6,382 | 6,100 | 0.6295 | 0.3705 | 0.0017 |
| 7 | 8,055,165 | 11,536,527 | 2,663 | 5,843 | 0.4676 | 0.5324 | 0.0017 |
| 8 | 3,181,872 | 6,881,269 | 1,236 | 6,499 | 0.4785 | 0.5215 | 0.0017 |
| 9 | 3,049,528 | 5,353,382 | 706 | 8,727 | 0.4897 | 0.5103 | 0.0017 |
| 10 | 1,477,264 | 4,623,835 | 599 | 5,280 | 0.4934 | 0.5066 | 0.0017 |
| 11 | 2,027,962 | 6,712,554 | 482 | 6,885 | 0.4975 | 0.5025 | 0.0017 |
| 12 | 131,531 | 44,720 | 66 | 3,790 | 0.5927 | 0.4073 | 0.0017 |
| 13 | 589,626 | 1,179,252 | 141 | 6,848 | 0.6457 | 0.3543 | 0.0017 |
| 14 | 314,511 | 314,511 | 51 | 5,830 | 0.6507 | 0.3493 | 0.0017 |

The $Fdw_n$, $Fds_n$, and $Fpw_n$ values from Table D-1 were calculated as follows:

$$Fpw_n = \frac{TSS \times 10^{-6} K_{oc} \times f_{oc1}}{1 + (K_{oc} \times 10^{-6})(TSS \times f_{oc1} + DOC_1)} \qquad \text{(D-5)}$$

$$Fdw_n = \frac{1 + (K_{oc} \times 10^{-6}) DOC_1}{1 + (K_{oc} \times 10^{-6})(TSS \times f_{oc1} + DOC_1)} \qquad \text{(D-6)}$$

$$Fds_n = \frac{\phi + \phi(K_{oc} \times 10^{-6}) DOC_2}{\phi + (K_{oc} \times 10^{-6})(f_{oc2} \times \rho \times (1-\phi) + \phi DOC_2)} \qquad \text{(D-7)}$$

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 (measured) and pore water (DRBC 2003), respectively.
$\varphi$ = the porosity of the sediment (Thomann and Mueller, 1987).

## Appendix E: 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 PAXMH, PAXOH, and PAXTF tidal segments. 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.

## IV. 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 PAXMH, PAXOH, and PAXTF tidal segments.

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 PAXMH, PAXOH, and PAXTF tidal segments:

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 95$^{th}$ percentile value would result in a MDL that would be exceeded 5% of the time.

## V. Selected Approach

The approach selected for defining PAXMH, PAXOH, and PAXTF MDLs 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 PAXMH, PAXOH, and PAXTF MDLs 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.

MDLs were 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 tidal water column tPCB concentrations in the PAXMH, PAXOH, and PAXTF tidal segments. 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 99$^{th}$ percentile of the log-normal probability distribution should be used.

CVs were calculated for the PAXMH, PAXOH, and PAXTF tidal segments using the arithmetic mean and standard deviation of the tidal water column tPCB concentrations from each individual tidal segment (Equation E-1).

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

Where,
CV = coefficient of variation
$\alpha$ = mean (arithmetic)
$\beta$ = 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 (99th percentile)
$\sigma = \ln(CV^2+1)$
CV = Coefficient of variation based on arithmetic mean and standard deviation
MDL conversion factor = $e^{(z\sigma - 0.5\sigma^2)}$

The MDL conversion factors and associated parameters are presented in Table E-1. Average annual tPCB TMDLs for the PAXMH, PAXOH, and PAXTF tidal segments are reported in g/year, and the MDL conversion factor is divided by 365 in order to convert the annual load (g/year) to a maximum daily load (g/day).

**Table E-1: MDL Conversion Factors for PAXMH, PAXOH, and PAXTF Tidal Segments**

| Tidal Segment | α | β | CV | z-score | σ | MDL Conversion Factor |
|---|---|---|---|---|---|---|
| PAXMH | 0.879 | 1.289 | 1.467 | 2.33 | 1.148 | 0.021 |
| PAXOH | 3.337 | 3.715 | 1.113 | 2.33 | 0.806 | 0.013 |
| PAXTF | 4.445 | 4.606 | 1.036 | 2.33 | 0.729 | 0.011 |

## VII. Approach for Municipal WWTPs

The TMDL also considers contributions from NPDES permitted municipal WWTPs that discharge quantifiable concentrations of tPCBs to the PAXMH, PAXOH, and PAXTF tidal segments. The MDLs were calculated for these facilities 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 tPCB TMDL was converted to maximum daily limits using Table 5-2 of the TSD assuming a coefficient of variation of 0.6 and a 99th percentile probability. This results in a dimensionless multiplication factor of 3.11. The average annual tPCB TMDLs for the PAXMH, PAXOH, and PAXTF tidal segments are 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).

## VIII. Results of Approach

Table E-2 lists the results of the selected approach to define the PAXMH, PAXOH, and PAXTF MDLs.

**Table E-2: Summary of tPCB Maximum Daily Loads in the PAXMH, PAXOH, and PAXTF Tidal Segments**

| Tidal Segment | Source | TMDL (g/year) | MDL (g/day) |
|---|---|---|---|
| PAXMH | Non-regulated Watershed Runoff | 119.2 | 2.453 |
| | Atmospheric Deposition | 172.1 | 3.541 |
| | ***Nonpoint Sources*** | ***291.4*** | ***5.993*** |
| | NPDES Regulated Stormwater | | |
| | Prince George's | 0.6 | 0.012 |
| | Calvert[1] | 0.0 | 0.000 |
| | St. Mary's | 0.1 | 0.001 |
| | Charles | 1.5 | 0.031 |
| | ***Point Sources*** | ***2.2*** | ***0.045*** |
| | ***MOS (5%)*** | | |
| | ***Total PAXMH*** | ***293.6*** | ***6.038*** |
| PAXOH | Non-regulated Watershed Runoff | 73.5 | 0.952 |
| | Atmospheric Deposition | 22.9 | 0.296 |
| | ***Nonpoint Sources*** | ***96.4*** | ***1.248*** |
| | NPDES Regulated Stormwater | | |
| | Anne Arundel | 0.3 | 0.004 |
| | Calvert[1] | 0.0 | 0.000 |
| | Prince George's | 1.4 | 0.018 |
| | ***Point Sources*** | ***1.7*** | ***0.022*** |
| | ***MOS (5%)*** | | |
| | ***Total PAXOH*** | ***98.1*** | ***1.271*** |
| PAXTF | Non-regulated Watershed Runoff | 1.0 | 0.011 |
| | Atmospheric Deposition | 0.0 | 0.000 |
| | Contaminated Sites[2] | 0.0 | 0.000 |
| | ***Nonpoint Sources*** | ***1.0*** | ***0.011*** |
| | NPDES Regulated Stormwater | | |
| | Anne Arundel | 0.1 | 0.001 |
| | Frederick[2] | 0.2 | 0.002 |
| | Howard | 0.1 | 0.001 |
| | Montgomery | 0.0 | 0.000 |
| | Prince George's | 0.1 | 0.001 |
| | WWTPs | 75.2 | 0.639 |
| | ***Point Sources*** | ***75.7*** | ***0.645*** |
| | ***MOS (5%)*** | ***4.0*** | ***0.035*** |
| | ***Total PAXTF*** | ***80.7*** | ***0.690*** |

[1]TMDLs and MDLs appear as zero values due to number of significant decimal figures
Note: Columns may not precisely add to totals due to rounding.
[2]Contaminated sites, and Frederick NPDES regulated stormwater tPCB baseline loads are considered insignificant (less than 0.01% of the total baseline load) and no reductions are assigned.

## Appendix F: List of NPDES Regulated Stormwater Permits

**Table F-1: NPDES Regulated Stormwater Permit Summary in the PAXMH, PAXOH, and PAXTF Watersheds[1]**

| MDE Permit | NPDES Permit | Facility | County | Watershed |
|---|---|---|---|---|
| 11-DP-3313 | MD0068276 | State Highway Administration (MS4) | All Phase I | All |
| 09-GP-0000 | MDR100000 | MDE General Permit to Construct | All | All |
| 11-DP-3322 | MD0068365 | Charles County Phase I MS4 | Charles | PAXMH |
| 11-DP-3314 | MD0068284 | Prince George's County Phase I MS4 | Prince George's | PAXMH<br>PAXOH<br>PAXTF |
| 11-DP-3317 | MD0068314 | Anne Arundel County Phase I MS4 | Anne Arundel | PAXOH<br>PAXTF |
| 11-DP-3321 | MD0068357 | Frederick County Phase I MS4 | Frederick | PAXTF |
| 11-DP-3318 | MD0068322 | Howard County Phase I MS4 | Howard | PAXTF |
| 11-DP-3320 | MD0068349 | Montgomery County Phase I MS4 | Montgomery | PAXTF |
| 03-IM-5500 | MDR055500 | District Heights Phase II MS4 | Prince George's | PAXTF |
| 03-IM-5500 | MDR055500 | Laurel Phase II MS4 | Prince George's | PAXTF |
| 12SW0300 | MDR000300 | Naval Air Station Patuxent River - Solomons Annex | Calvert | PAXMH |
| 02SW2176 | MDR002176 | Solomons Island WWTP | Calvert | PAXMH |
| 02SW1117 | MDR001117 | Goad Lumber Company, Inc. | Charles | PAXMH |
| 12SW0448 | MDR000448 | Sailing Specialties, Inc. | St. Mary's | PAXMH |
| 12SW0842 | MDR000842 | Southern Maryland Auto Parts | St. Mary's | PAXMH |
| 12SW1089 | MDR001089 | Seymour Used Auto Parts | St. Mary's | PAXMH |
| 12SW1865 | MDR001865 | Rolling Frito-Lay Sales - Charlotte Hall DC | St. Mary's | PAXMH |

| MDE Permit | NPDES Permit | Facility | County | Watershed |
|---|---|---|---|---|
| 02SW2200 | MDR002200 | Southern States Cooperative, Inc – Charlotte Hall Service | St. Mary's | PAXMH |
| 12SW2452 | MDR002452 | U.S. Navy - Patuxent River Naval Air Station | St. Mary's | PAXMH |
| 12SW1702 | MDR001702 | Baystar Precast Corporation | Calvert | PAXOH |
| 12SW1713 | MDR001713 | Hance Land Clearing Debris Landfill | Calvert | PAXOH |
| 02SW0171 | MDR000171 | Ford/Rooney Pit - Percontee Inc. | Prince George's | PAXOH |
| 02SW0173 | MDR000173 | Benfield Tract | Prince George's | PAXOH |
| 02SW1572 | MDR001572 | Glory Days Auto Salvage | Anne Arundel | PAXTF |
| 02SW0331 | MDR000331 | Dorsey Run Advanced Wastewater Treatment Plant | Anne Arundel | PAXTF |
| 12SW0700 | MDR000700 | U.S. Army - Fort George G. Meade | Anne Arundel | PAXTF |
| 02SW0727 | MDR000727 | Piney Orchard WWTP | Anne Arundel | PAXTF |
| 02SW0759 | MDR000759 | Patuxent River Water Reclamation Facility | Anne Arundel | PAXTF |
| 02SW1164 | MDR001164 | Amtrak - Odenton Maintenance of Way Base | Anne Arundel | PAXTF |
| 12SW1177 | MDR001177 | Anne Arundel County - Odenton | Anne Arundel | PAXTF |
| 12SW1697 | MDR001697 | Tipton Airport | Anne Arundel | PAXTF |
| 02SW1706 | MDR001706 | Waste Management of Maryland – Annapolis Junction Transfer Station | Anne Arundel | PAXTF |
| 12SW0761 | MDR000761 | Anne Arundel County - Maryland City Water Reclamation Facility | Anne Arundel | PAXTF |
| 02SW0951 | MDR000951 | Balcon | Anne Arundel | PAXTF |
| 02SW1049X | MDR001049 | Federal Express - Crofton | Anne Arundel | PAXTF |
| 02SW1125 | MDR001125 | Ashwell Bus Service, inc | Howard | PAXTF |
| 02SW3008 | MDR003008 | Clements & Steed, Inc. | Howard | PAXTF |
| 12SW0123 | MDR000123 | ISP Pharma Systems | Howard | PAXTF |

| MDE Permit | NPDES Permit | Facility | County | Watershed |
|---|---|---|---|---|
| 12SW0260 | MDR000260 | Little Patuxent Water Reclamation Plant | Howard | PAXTF |
| 02SW0544 | MDR000544 | Giant of Maryland, LLC. - Jessup | Howard | PAXTF |
| 02SW0735 | MDR000735 | Cinder & Concrete Block Corp. - Jessup | Howard | PAXTF |
| 12SW0744 | MDR000744 | U.S. Postal Service - Columbia VMF | Howard | PAXTF |
| 02SW0751 | MDR000751 | INX International Ink Company | Howard | PAXTF |
| 02SW0773 | MDR000773 | Flint Group North America Limited | Howard | PAXTF |
| 02SW0776 | MDR000776 | FedEx Freight, Inc. - WBA | Howard | PAXTF |
| 02SW0833 | MDR000833 | Allied Systems, LTD. | Howard | PAXTF |
| 02SW0947 | MDR000947 | Total Distribution Services, Inc | Howard | PAXTF |
| 12SW0966 | MDR000966 | Aggregate Industries - Annapolis Junction Asphalt Plant | Howard | PAXTF |
| 02SW0975 | MDR000975 | Kohl & Madden Printing Ink Company | Howard | PAXTF |
| 02SW1160 | MDR001160 | General Electric Company | Howard | PAXTF |
| 02SW1168 | MDR001168 | United Parcel Service | Howard | PAXTF |
| 02SW1197 | MDR001197 | Corman Construction, Inc | Howard | PAXTF |
| 02SW1203 | MDR001203 | Con-way Central Express - XJP | Howard | PAXTF |
| 02SW1259 | MDR001259 | Dreyer's Grand Ice Cream Inc | Howard | PAXTF |
| 02SW1268 | MDR001268 | Tate Access Floors | Howard | PAXTF |
| 02SW1269 | MDR001269 | National Distributing Company | Howard | PAXTF |
| 12SW1436 | MDR001436 | Howard County Central Fleet/Guilford Shop | Howard | PAXTF |
| 12SW1439 | MDR001439 | Howard County Central Fleet Utilities Shop | Howard | PAXTF |
| 02SW1503 | MDR001503 | Laurel Block Corporation | Howard | PAXTF |
| 02SW1615 | MDR001615 | ThorLabs - Quantum Electronics | Howard | PAXTF |
| 02SW1639 | MDR001639 | Penske Logistics, LLC | Howard | PAXTF |

| MDE Permit | NPDES Permit | Facility | County | Watershed |
|---|---|---|---|---|
| 12SW1682 | MDR001682 | Cookies 'n Milk | Howard | PAXTF |
| 02SW1807 | MDR001807 | Maryland Paving & Sealant, Inc. | Howard | PAXTF |
| 02SW1974 | MDR001974 | D.B. Concrete Construction, Inc. | Howard | PAXTF |
| 02SW2110 | MDR002110 | American Infrastructure - MD, Inc. | Howard | PAXTF |
| 12SW2175 | MDR002175 | First Transit, Inc. | Howard | PAXTF |
| 02SW2193 | MDR002193 | Centennial Park Maintenance Center | Howard | PAXTF |
| 02SW2247 | MDR002247 | Howard County - Cedar Lane Park Maintenance Shop | Howard | PAXTF |
| 02SW2248 | MDR002248 | Howard County - Rockburn Branch Park | Howard | PAXTF |
| 02SW2249 | MDR002249 | Howard County - Savage Park Maintenance Shop | Howard | PAXTF |
| 02SW2250 | MDR002250 | Howard County - Schooley Mill Park Maintenance Shop | Howard | PAXTF |
| 02SW2251 | MDR002251 | Howard County - Western Regional Park Maintenance Shop | Howard | PAXTF |
| 02SW2262 | MDR002262 | Pick Your Part | Howard | PAXTF |
| 12SW1435 | MDR001435 | Howard County Central Fleet - Cookesville Shop | Howard | PAXTF |
| 12SW1437 | MDR001437 | Howard County Central Fleet - Dayton Shop | Howard | PAXTF |
| 02SW2067 | MDR002067 | Forest Recycling Project (FRP) Inc. | Howard | PAXTF |
| 12SW2456 | MDR002456 | SHA - Dayton Shop | Howard | PAXTF |
| 02SW0882 | MDR000882 | Washington Wilbert Vault Works | Howard | PAXTF |
| 12SW0264 | MDR000264 | Oaks Landfill | Montgomery | PAXTF |
| 02SW0121 | MDR000121 | WSSC - Western Branch WWTP | Prince George's | PAXTF |
| 02SW0153 | MDR000153 | Brandywine Enterprises - North Keys Pit | Prince George's | PAXTF |
| 02SW0167 | MDR000167 | Rockhill Sand & Gravel Corp./ Gudelsky Materials | Prince George's | PAXTF |
| 02SW1750 | MDR001750 | Insurance Auto Auctions, Inc. | Prince George's | PAXTF |

| MDE Permit | NPDES Permit | Facility | County | Watershed |
|---|---|---|---|---|
| 12SW1841 | MDR001841 | City of Laurel DPW Maintenance Facility | Prince George's | PAXTF |
| 02SW0238 | MDR000238 | Oceaneering Technologies, Inc. | Prince George's | PAXTF |
| 12SW0312 | MDR000312 | Prince George's County Vehicle Audit Unit | Prince George's | PAXTF |
| 12SW0401 | MDR000401 | Brown Station Road Sanitary Landfill | Prince George's | PAXTF |
| 12SW0521 | MDR000521 | Prince George's County DPW & Transportation | Prince George's | PAXTF |
| 02SW0560 | MDR000560 | ABF Freight Systems, Inc | Prince George's | PAXTF |
| 02SW0649 | MDR000649 | Murry's, Inc. | Prince George's | PAXTF |
| 12SW0844 | MDR000844 | Foreign Car Parts, Inc. | Prince George's | PAXTF |
| 12SW0937 | MDR000937 | United States Postal Service - Souther VMP | Prince George's | PAXTF |
| 12SW1064 | MDR001064 | Ripples Service, Inc. | Prince George's | PAXTF |
| 12SW1092 | MDR001092 | Republic Services of Washington Metro | Prince George's | PAXTF |
| 12SW1224 | MDR001224 | Prince George's County - Recycling Facility | Prince George's | PAXTF |
| 12SW1325 | MDR001325 | SHA - Marlboro Shop | Prince George's | PAXTF |
| 12SW1933 | MDR001933 | Marlboro Auto Parts | Prince George's | PAXTF |
| 12SW2141 | MDR002141 | City of District Heights Public Works | Prince George's | PAXTF |
| 03-IM-5500 | MDR055500 | Bowie Phase II MS4 | Prince George's | PAXTF |
| 03-IM-5500 | MDR055500 | Glenarden Phase II MS4 | Prince George's | PAXTF |
| 12SW2246 | MDR002246 | QTG CDSD - Landover | Prince George's | PAXTF |
| 02SW0118 | MDR000118 | WSSC - Parkway Wastewater Treatment Plant | Prince George's | PAXTF |
| 12SW0314 | MDR000314 | Sandy Hill Muncipal Landfill | Prince George's | PAXTF |
| 02SW0511 | MDR000511 | The Bechdon Company, Inc. | Prince George's | PAXTF |
| 02SW0596 | MDR000596 | First Transit, Inc. | Prince George's | PAXTF |
| 02SW0841 | MDR000841 | Central Small Car Salvage | Prince George's | PAXTF |

| MDE Permit | NPDES Permit | Facility | County | Watershed |
|---|---|---|---|---|
| 02SW0846 | MDR000846 | Bowie Used Auto Parts, Inc. | Prince George's | PAXTF |
| 12SW0857 | MDR000857 | United Parcel Service | Prince George's | PAXTF |
| 02SW0859 | MDR000859 | United Parcel Service - Burtonsville | Prince George's | PAXTF |
| 02SW1120 | MDR001120 | B&B Auto Salvage, LTD. | Prince George's | PAXTF |
| 02SW1324 | MDR001324 | SHA - Laurel Shop | Prince George's | PAXTF |
| 02SW1738 | MDR001738 | WSSC - Laurel Garage | Prince George's | PAXTF |

[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 G: Total PCB Concentrations and Locations of the PCB Monitoring Stations

Tables G-1 through G-3 list the tPCB concentrations for sediment, fish tissue, and water column samples collected in the PAXMH, PAXOH, PAXTF tidal segments.

**Table G-1: Sediment tPCB Concentrations in the PAXMH, PAXOH, and PAXTF Tidal Segments**

| Tidal Segment | Station | Station Type | Date | tPCBs (ng/g) |
|---|---|---|---|---|
| PAXMH | 2 | 11/7/2013 | Tidal | 2.5 |
| PAXMH | 2 | 5/15/2014 | Tidal | 3.9 |
| PAXMH | 3 | 11/7/2013 | Tidal | 1.5 |
| PAXMH | 3 | 5/15/2014 | Tidal | 1.2 |
| PAXMH | 4 | 11/7/2013 | Tidal | 2.6 |
| PAXMH | 4 | 5/15/2014 | Tidal | 1.7 |
| PAXOH | 5 | 11/7/2013 | Tidal | 7.8 |
| PAXOH | 5 | 11/7/2013 | Tidal | 2.9 |
| PAXOH | 5 | 5/15/2014 | Tidal | 3.6 |
| PAXOH | 6 | 11/7/2013 | Tidal | 5.3 |
| PAXOH | 6 | 5/15/2014 | Tidal | 8.6 |
| PAXTF | 7 | 11/7/2013 | Tidal | 0.4 |
| PAXTF | 7 | 5/15/2014 | Tidal | 6.2 |

**Table G-2: Fish Tissue tPCB Concentrations in the PAXMH, PAXOH, and PAXTF Tidal Segments**

| Tidal Segment | Station | Sample ID | Date | Fish Species | Mean Length (cm) | Mean Weight (g) | tPCBs (ng/g) | Lipid Content (%) |
|---|---|---|---|---|---|---|---|---|
| PAXMH | PaxR | PAXR-A | 5/20/2014 | White perch | 23.3 | 170.2 | 15.7 | 2.66 |
| PAXMH | PaxR | PAXR-B | 5/20/2014 | White perch | 21.3 | 128.8 | 9.5 | 1.78 |
| PAXMH | PaxR | PAXR-C | 5/20/2014 | White perch | 20.6 | 116.4 | 60.1 | 1.95 |
| PAXMH | PATBRM | PATBRM-A | 9/16/2015 | White perch | 20.86 | 135.2 | 43.8 | 4.33 |
| PAXMH | PATBRM | PATBRM-B | 9/16/2015 | White perch | 18.7 | 101.8 | 105.5 | 3.01 |
| PAXMH | PATBRM | PATBRM-C | 9/16/2015 | White perch | 18.16 | 96.2 | 59.2 | 3.24 |
| PAXMH | PATBRM | PATBRM-D | 9/16/2015 | White perch | 18.02 | 95.2 | 35.5 | 4.10 |
| PAXMH | PXTBEN | PXTBEN-A | 9/16/2015 | White perch | 17.5 | 80 | 19.1 | 2.66 |
| PAXMH | PXTBEN | PXTBEN-B | 9/16/2015 | White perch | 17.24 | 79.4 | 67 | 4.39 |
| PAXMH | PXTBEN | PXTBEN-C | 9/16/2015 | White perch | 16.9 | 73.8 | 49.1 | 3.06 |
| PAXMH | PXTBEN | PXTBEN-D | 9/16/2015 | White perch | 16.56 | 77.6 | 63 | 5.21 |
| PAXOH | PaxR2 | PAXR2-D | 5/14/2014 | White perch | 23.8 | 184.4 | 12.1 | 3.43 |
| PAXOH | PaxR2 | PAXR2-E | 5/14/2014 | White perch | 21.9 | 145.4 | 15.8 | 0.99 |
| PAXOH | PaxR2 | PAXR2-F | 5/14/2014 | White perch | 21.1 | 124.0 | 9.6 | 1.38 |
| PAXOH | PaxR2 | PAXR2-G | 5/14/2014 | Channel Catfish | 54.8 | 1853.6 | 268.9 | 5.51 |
| PAXOH | PaxR2 | PAXR2-H | 5/14/2014 | Channel Catfish | 49.7 | 1241.0 | 177.6 | 6.06 |
| PAXOH | PaxR2 | PAXR2-I | 5/14/2014 | Channel Catfish | 42.2 | 697.2 | 138.6 | 3.67 |
| PAXOH | PAXBEN | PAXBEN-C | 9/29/2009 | Channel Catfish | 38.1 | 344.0 | 57.47 | 5.08 |
| PAXOH | PAXBEN | PAXBEN-D | 9/29/2009 | Channel Catfish | 29.9 | 233.2 | 48.87 | 5.08 |
| PAXOH | PAXBEN | PAXBEN-A | 9/29/2009 | White Perch | 18.5 | 81.8 | 18.42 | 2.03 |
| PAXTF | PATRRB | PATRRB-A | 9/22/2015 | Channel Catfish | 45.36 | 888.4 | 125.5 | 4.64 |
| PAXTF | PATRRB | PATRRB-B | 9/22/2015 | Channel Catfish | 39.1 | 511 | 115.1 | 4.28 |
| PAXTF | PATRRB | PATRRB-C | 9/22/2015 | White perch | 19.82 | 124 | 33.1 | 1.03 |
| PAXTF | PATRRB | PATRRB-D | 9/22/2015 | White perch | 18.02 | 87.8 | 46.7 | 3.40 |

**Table G-3: Water Column tPCB Concentrations in the PAXMH, PAXOH, and PAXTF Tidal Segments**

| Tidal Segment | Station | Station Type | Date | tPCBs (ng/L) |
|---|---|---|---|---|
| Chesapeake Bay | LPR-1 | Tidal (Boundary) | 8/20/13 | 0.02 |
| Chesapeake Bay | LPR-1 | Tidal (Boundary) | 11/7/13 | 0.01 |
| Chesapeake Bay | LPR-1 | Tidal (Boundary) | 3/11/14 | 0.72 |
| Chesapeake Bay | LPR-1 | Tidal (Boundary) | 5/15/14 | 10.99 |
| PAXMH | LPR-2 | Tidal | 8/20/13 | 0.03 |
| PAXMH | LPR-2 | Tidal | 11/7/13 | 0.01 |
| PAXMH | LPR-2 | Tidal | 3/11/14 | 0.55 |
| PAXMH | LPR-2 | Tidal | 5/15/14 | 1.61 |
| PAXMH | LPR-3 | Tidal | 8/20/13 | 0.02 |
| PAXMH | LPR-3 | Tidal | 3/11/14 | 0.68 |
| PAXMH | LPR-3 | Tidal | 5/15/14 | 2.20 |
| PAXMH | LPR-4 | Tidal | 8/20/13 | 0.03 |
| PAXMH | LPR-4 | Tidal | 11/7/13 | 0.05 |
| PAXMH | LPR-4 | Tidal | 3/11/14 | 1.12 |
| PAXMH | LPR-4 | Tidal | 5/15/14 | 4.26 |
| PAXOH | LPR-5 | Tidal | 8/20/13 | 0.28 |
| PAXOH | LPR-5 | Tidal | 11/7/13 | 0.40 |
| PAXOH | LPR-5 | Tidal | 3/11/14 | 3.03 |
| PAXOH | LPR-5 | Tidal | 5/15/14 | 8.21 |
| PAXOH | LPR-6 | Tidal | 8/20/13 | 0.46 |
| PAXOH | LPR-6 | Tidal | 11/7/13 | 0.31 |
| PAXOH | LPR-6 | Tidal | 3/11/14 | 4.71 |
| PAXOH | LPR-6 | Tidal | 5/15/14 | 9.30 |
| PAXTF | LPR-7 | Tidal | 8/20/13 | 0.77 |
| PAXTF | LPR-7 | Tidal | 11/7/13 | 0.33 |
| PAXTF | LPR-7 | Tidal | 3/11/14 | 5.27 |
| PAXTF | LPR-7 | Tidal | 5/15/14 | 7.78 |
| PAXTF | LPR-8 | Tidal | 5/15/14 | 12.43 |
| PAXTF | LPR-8 | Tidal | 8/20/13 | 0.56 |
| PAXTF | LPR-8 | Tidal | 11/7/13 | 0.51 |
| PAXTF | LPR-8 | Tidal | 3/11/14 | 7.90 |

| Tidal Segment | Station | Station Type | Date | tPCBs (ng/L) |
|---|---|---|---|---|
| PAXMH | LPR-10 | Non-Tidal | 8/20/13 | 0.01 |
| PAXMH | LPR-10 | Non-Tidal | 11/7/13 | 0.04 |
| PAXMH | LPR-10 | Non-Tidal | 3/11/14 | 0.65 |
| PAXMH | LPR-10 | Non-Tidal | 5/15/14 | 2.01 |
| PAXMH | LPR-12 | Non-Tidal | 8/20/13 | 0.01 |
| PAXMH | LPR-12 | Non-Tidal | 11/7/13 | 0.01 |
| PAXMH | LPR-12 | Non-Tidal | 3/11/14 | 4.27 |
| PAXMH | LPR-12 | Non-Tidal | 5/15/14 | 0.96 |
| PAXOH | LPR-14 | Non-Tidal | 8/20/13 | 0.02 |
| PAXOH | LPR-14 | Non-Tidal | 11/7/13 | 0.05 |
| PAXOH | LPR-14 | Non-Tidal | 3/11/14 | 2.16 |
| PAXOH | LPR-14 | Non-Tidal | 5/15/14 | 1.31 |
| PAXOH | LPR-15 | Non-Tidal | 8/20/13 | 0.05 |
| PAXOH | LPR-15 | Non-Tidal | 11/7/13 | 0.02 |
| PAXOH | LPR-15 | Non-Tidal | 3/11/14 | 0.47 |
| PAXOH | LPR-15 | Non-Tidal | 5/15/14 | 8.62 |
| PAXTF | LPR-13 | Non-Tidal | 8/20/13 | 0.18 |
| PAXTF | LPR-13 | Non-Tidal | 11/7/13 | 0.05 |
| PAXTF | LPR-13 | Non-Tidal | 3/11/14 | 2.59 |
| PAXTF | LPR-13 | Non-Tidal | 5/15/14 | 2.81 |
| PAXTF | LPR-11 | Non-Tidal | 8/20/13 | 0.26 |
| PAXTF | LPR-11 | Non-Tidal | 11/7/13 | 0.16 |
| PAXTF | LPR-11 | Non-Tidal | 3/11/14 | 10.63 |
| PAXTF | LPR-11 | Non-Tidal | 5/15/14 | 12.77 |

## Appendix H: Contaminated Site Load Calculation Methodology

The term PCB contaminated site used throughout this report refers to areas with known PCB soil contamination, as documented by state or federal hazardous waste cleanup programs (i.e., state or federal Superfund programs). When compared against the human health screening criteria for soil and groundwater exposure pathways, PCBs are not necessarily a contaminant of concern at these sites, but they have been screened for, reported, and detected during formal site investigations. Within the PAXMH, PAXOH, and PAXTF watersheds, only one site, MD-267 (Patuxent Wildlife Research Center), has been identified with PCB soil concentrations at or above method detection levels. Figure 6 depicts its location. This site (see Table H-1) was identified based on information gathered from MDE's Land Restoration Program Geospatial Database (LRP-MAP) database (MDE 2016), and has tPCB soil concentrations at or above method detection levels, as determined via soil sample results contained within MDE-LMA's records of contaminated site surveys and investigations.

The tPCB EOF load from the site has been calculated, and subsequently, the EOF load would usually be converted to EOS load using methods applied within Maryland's non-tidal sediment TMDLs, thirteen of which have been approved by the EPA since 2006. The modeling assumption behind the conversion to EOS load is that not all of the contaminated site tPCB loads are expected to reach the impaired waterbody. Thus, EOS load is thought to be a more accurate representation of tPCB loads from the site. Various delivery factors were applied.

The purpose of this appendix is to describe the detailed procedures used to calculate the Contaminated Site tPCB Baseline Load.

### I. tPCB Soil Concentration Data Processing

The Contaminated Site tPCB Baseline Load was only characterized for the site (contained within MDE's LRP-MAP database and located within the PAXTF watershed) with samples where tPCB concentrations were found to be at or above the method detection limits used in the soil sampling analyses conducted as part of site investigations. Only one property (See Table H-1) was identified as PCB contaminated site. For the most part, these soil sampling analyses employed an Aroclor based analytical method. Thus, when a given sample was analyzed for multiple Aroclors and more than one mixture was detected (e.g., 1232, 1248, 1262, etc.), the results were added together to represent tPCB concentrations. Next, the median values of the tPCB concentrations from these sites were calculated.

### II. Revised Universal Soil Loss Equation Version II Soil Loss Calculation Procedures

The Revised Universal Soil Loss Equation Version II (RUSLE2)[1] was run for the site with the use of the Maryland state climate database, county soil databases, and management databases

[1] RUSLE2 is an advanced, user-friendly software model developed by the University of Tennessee Biosystems Engineering & Soil Science Department, in cooperation with the United States Department of Agriculture (USDA) – Agricultural Research Service (ARS), the National Sedimentation Laboratory, USDA – Natural Resources Conservation Service (NRCS), and the Bureau of Land Management.

that can be downloaded from the following website: http://fargo.nserl.purdue.edu/rusle2_dataweb/RUSLE2_Index.htm. The site characteristics (e.g., soil types, land cover, slope, etc.) were selected from drop down menus provided in the RUSLE2 worksheet. Input parameters were selected via the following decision rules:

1. **Location:** The appropriate county name was selected from the Maryland state climate database in the RUSLE2 *location* field. This resulted in an automatic selection of the appropriate climatic factors.

2. **Soil:** Soil types were identified per site via Geographic Information System (GIS) analysis using a digitized site area and soils data acquired from the USDA-NRCS. The soil types were then subsequently selected from the appropriate county's soils database in the RUSLE2 worksheet.

3. **Slope Length:** Slope length (length of the site), which was identified via GIS analysis using flow direction grids generated from Digital Elevation Models (DEMs) from the USGS, and/or digital USGS quadrangles (i.e., topographic maps), was manually inserted into the *slope length* field. The maximum slope length permitted by the soil loss equation was 2000 feet. If the site has a length greater than 2000 feet, 2000 feet was used.

4. **Percent Slope:** Percent slope, or slope steepness (the difference between maximum and minimum site elevations/slope length), which was identified via GIS analysis, was manually inserted into the *percent slope* field. Percent slope was calculated using GIS analysis by calculating the slope per DEM grid cell within the digitized site area and subsequently taking the average of the cell values.

5. **Management:** The *management option* field was used to represent a site's land cover (i.e., forest, grass, barren, etc.), which was identified via GIS analysis (i.e., agricultural management options were used to approximate the soil loss characteristics of the land covers present at these non-agricultural sites). For example, for sites covered by grass, the warm season grass – not harvested management option was selected; for wooded sites, the established orchard - full cover option was selected; and for sites with bare soil, the bare ground management option was selected. Land cover classification areas were estimated using GIS analysis by digitizing the various land cover areas within the site's boundaries using the State of Maryland's 2007 6-inch resolution orthophotography. This includes impervious areas of the site; however, these areas were left out of the soil loss calculations, since there is no potential for soil runoff. Please see Section III below for more information on how impervious areas were removed from the total site soil loss calculation.

For sites with multiple soil types and land cover classifications present, soil loss was first calculated for each unique soil type-land cover combination based on the entire site's parameters (e.g. slope and slope length). Then, the soil loss values for each soil type-land cover combination were weighted based on the percentage of the site that the unique combination occupied (determined by the GIS intersection between the soil type data layer and digitized land cover data layer). Finally, the summation of the weighted soil loss values was calculated to produce a total soil loss for the entire site.

### III. Calculating EOF tPCB loads

The RUSLE2 generated soil loss values, reported in tons/acre/year, were used in conjunction with adjusted pervious area estimates and median tPCB soil concentrations to determine the EOF contaminated site PCB loads. As discussed previously, the various land cover types per site were digitized. The land cover types include: impervious, barren, grass, and forest classifications. Barren, grass, and forest all constitute pervious areas. The area of these pervious land covers were calculated and summed to produce a total pervious area. Then, the total pervious area estimates were adjusted for at each site based on the percent of samples that were above the method detection limit (e.g., if only 25% of the samples had tPCB concentrations above the method detection limit, only 25% of the previous area of the site was used in the calculations). These total adjusted pervious areas were then used in conjunction with the RUSLE2 generated soil loss values to produce a total soil loss value for each site in tons/year. To be consistent with the RUSLE2 soil loss units, the median tPCB soil concentration of the identified site was converted to pounds of tPCBs per pound of soil (lbs/lb). The EOF contaminated site tPCB load is reported in Table H-1 in g/year.

### IV. Calculating EOS tPCB loads

The EOF load is expected to be delivered to the system with some losses expected to occur over land. The identified contaminated site is located immediately adjacent to a stream segment within the PAXTF watershed. Therefore, the entire edge of field load is expected to be delivered directly to the system, with no losses expected to occur over land, and a delivery factor of one is consequently applied to the EOF loads. The resultant EOS load is therefore equivalent to the initial EOF load (Table H-1).

**Table H-1: Summary of Contaminated Site Soil Loss Value and EOS tPCB Loads**

| Site Name | MDE LRP Site ID | Median tPCB (ng/g) | Soil Loss (lbs/year) | EOF Load (g/year) | Delivery Factor | EOS Load (g/year) |
|---|---|---|---|---|---|---|
| Patuxent Wildlife Research Center | MD-267 | 1312.4 | 20.9 | 0.012 | 1 | 0.012 |

### V. Contaminated Site Baseline Load Summary

The total Contaminated Site tPCB Baseline Load from the identified site in the PAXTF watershed is estimated to be 0.012 g/year.