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

FINAL

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Adj-SediBAF	Sediment Bioaccumulation Factor
Adj-tBAF	Adjusted Total Bioaccumulation Factor
ARS	Agricultural Research Service
BCF	Bioconcentration Factor
BIBI	Benthic Index of Biotic Integrity
BMP	Best Management Practice
BSAF	Biota-Sediment Accumulation Factor
CBP	Chesapeake Bay Program
CHARM	Comprehensive Harbor Assessment and Regional Modeling Study
CI	Confidence Interval
COMAR	Code of Maryland Regulations
CSF	Cancer Slope Factor
CV	Coefficient of Variation
CWA	Clean Water Act
DEM	Digital Elevation Model
DL	Detection Limit
DMCF	Dredged Material Containment Facility
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
DRBC	Delaware River Basin Commission
EFDC	Environmental Fluid Dynamic Computer Code
ENR	Enhanced Nutrient Removal
EOF	Edge of Field
EOS	Edge of Stream
EPA	U.S. Environmental Protection Agency
ERRP	Environmental Restoration and Redevelopment Program
ERM	Effects Range Median
FIBI	Fish Index of Biotic Integrity

Ft	Feet
GIS	Geographic Information System
HOC	Hydrophobic Organic Chemical
Kg	Kilogram
Km	Kilometer
Kow	PCB Octanol-Water Partition Coefficient
L	Liters
LA	Load Allocation
Lbs	Pounds
LMA	Land Management Administration
LRP-MAP	Land Restoration Program Internet Mapping Site
M	Meters
MD 8-Digit	Maryland 8-Digit Watershed
MDE	Maryland Department of the Environment
MDL	Maximum Daily Load
Mg	Milligram
MGD	Million Gallons Per Day
MOS	Margin of Safety
MS4	Municipal Separate Storm Sewer Systems
Ng	Nanograms
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
OC	Organic Carbon
PCB	Polychlorinated Biphenyl
POC	Particulate Organic Carbon
Pg	Picogram
Ppb	Parts per Billion
Ppt	Parts per Trillion

RUSLE2	Revised Universal Soil Loss Equation Version II
SediBAF	Sediment Bioaccumulation Factor
SHA	State Highway Administration
SIC	Standard Industrial Classification
SQG	Sediment Quality Guideline
TMDL	Total Maximum Daily Load
tBAF	Total Bioaccumulation Factor
tPCB	Total PCB
TEL	Threshold Effects Level
TSD	Technical Support Document
TSS	Total Suspended Solids
VCP	Voluntary Cleanup Program
UMCES	University of Maryland Center for Environmental Science
USDA	United States Department of Agriculture
USGS	United States Geological Survey
VA	Virginia
WAS	Waste Management Administration
WLA	Waste Load Allocation
WQA	Water Quality Analysis
WQBELs	Water Quality Based Effluent Limitations
WQLS	Water Quality Limited Segment
WQS	Water Quality Standard
WWTP	Waste Water Treatment Plant
µg	Micrograms

EXECUTIVE SUMMARY

This document, upon approval by the U.S. Environmental Protection Agency (EPA), establishes Total Maximum Daily Loads (TMDLs) of Polychlorinated Biphenyls (PCBs) in the Baltimore Harbor, Curtis Creek/Bay, and Bear Creek portions of the Patapsco River Mesohaline Tidal Chesapeake Bay Segment. Section 303(d) of the federal Clean Water Act (CWA) and the EPA's implementing regulations direct each State to identify and list waters, known as water quality limited segments (WQLSs), in which current required controls of a specified substance are inadequate to achieve water quality standards (WQSs). For each WQLS, the State is to either establish a TMDL of the specified substance that the waterbody can receive without violating WQSs, or demonstrate that WQSs are being met (CFR 2011b).

Maryland WQSs specify that all surface waters of the State shall be protected for water contact recreation, fishing, and the protection of aquatic life (COMAR 2011a). Additionally, the specific designated use of the Baltimore Harbor, Curtis Creek/Bay, and Bear Creek portions of the Patapsco River Mesohaline Tidal Chesapeake Bay Segment is Use II – Support of Estuarine and Marine Aquatic Life and Shellfish Harvesting (COMAR 2011b). The Maryland Department of the Environment (MDE) has identified the Patapsco River Mesohaline Tidal Chesapeake Bay Segment (Integrated Report Assessment Unit ID: PATMH) on the State's 2010 Integrated Report as impaired by nutrients – nitrogen and phosphorus (1996), sediments (1996), trash and debris (2008), and impacts to biological communities (2004). The Baltimore Harbor portion of the Patapsco River Mesohaline Tidal Chesapeake Bay Segment (Integrated Report assessment unit ID: MD-PATMH-02130903) has been individually identified on the State's 2010 Integrated Report as impaired by: PCBs in fish tissue (1998), chlordane (1998), bacteria – Furnace Creek, Marley Creek, Rock Creek, and all tidal waters upstream of the harbor tunnel (1998), zinc – Middle and Northwest Branches (1998), chromium – Northwest Branch (1998), and lead - Northwest Branch (1998). In addition, the Curtis Creek/Bay portion of the Patapsco River Mesohaline Tidal Chesapeake Bay Segment (Integrated Report assessment unit ID: MD-PATMH-CURTIS_BAY_CREEK) has been individually identified on the State's 2010 Integrated Report as impaired by PCBs in both fish tissue and sediment (1998) and zinc (1998), and the Bear Creek portion of the Bay Segment has been individually identified on the State's 2010 Integrated Report (Integrated Report assessment unit ID: MD-PATMH-BEAR_CREEK) as impaired by PCBs in both fish tissue and sediment (1998), zinc (1998), and chromium (1998) (MDE 2011a).

The entire Patapsco River Mesohaline Tidal Chesapeake Bay Segment, also referred to as an embayment, includes more than the individual segments identified within this report as impaired for PCBs, for which TMDLs have been developed. This includes areas such as Bodkin Creek. It should also be noted that the Baltimore Harbor portion of the Patapsco River Mesohaline Tidal Chesapeake Bay Segment encompasses both Curtis Creek/Bay and Bear Creek. Thus, since the Curtis Creek/Bay and Bear Creek segments were individually identified as impaired for PCBs due to sediment data, in addition to the impairment listing for the entire Baltimore Harbor portion of the Bay Segment (based on PCB fish tissue concentrations), there is a spatial overlap between the various PCB impairment listings for the Bay Segment. As a result, the baseline and TMDL loads for the Baltimore Harbor portion of the Bay Segment described within this report include the baseline and TMDL loads for the Curtis Creek/Bay and Bear Creek segments. For the purposes of this report, the spatial unit defined as the Baltimore Harbor embayment will refer solely to the Baltimore Harbor portion of the Patapsco River Mesohaline Tidal Chesapeake Bay Segment (i.e., the portion of the Bay Segment impaired for PCBs in fish tissue), which encompasses the Curtis Creek/Bay and Bear Creek segments. The spatial units defined as Curtis Creek/Bay and Bear Creek will refer solely to these individual segments of the Baltimore Harbor embayment, which are specifically impaired for PCBs in sediment, in addition to fish tissue. Figure 1 on page 6 of the main report depicts the spatial relationship between the areas of the Patapsco River Mesohaline Tidal Chesapeake Bay Segment that are identified as impaired for PCBs in both fish tissue and sediments and the remaining area of the Bay Segment that is not identified as impaired for PCBs, as well as the watershed areas draining to each.

The TMDLs established herein by MDE will address the total PCB (tPCB) listings for the Baltimore Harbor embayment, Curtis Creek/Bay, and Bear Creek, for which a data solicitation was conducted, and all readily available data from the past 5 years have been considered. Bacteria TMDLs for Marley and Furnace Creeks of the Baltimore Harbor embayment were submitted to the EPA in 2010. The bacteria impairment for Rock Creek of the Baltimore Harbor embayment was delisted in 2004. Chlordane and nutrient (nitrogen and phosphorus) TMDLs for the Baltimore Harbor embayment were approved by the EPA in 2001 and 2007, respectively. Then, in 2010, the Chesapeake Bay nutrient and sediment TMDLs were developed by the EPA, which addressed the nutrient and sediment impairment listings for the entirety of the Patapsco River Mesohaline Tidal Chesapeake Bay Segment. WQAs for the chromium, lead, and zinc impairment listings in the Northwest Branch of the Baltimore Harbor embayment, the zinc impairment listing in the Middle Branch of the Baltimore Harbor embayment, the zinc impairment listing in Curtis Creek/Bay, and the zinc and chromium impairment listings in Bear Creek were developed by MDE in 2004; however, they were not approved by EPA, as the information to support the delisting was insufficient at the time. Studies are currently underway to determine whether these metals listings will require TMDLs to be developed in the future. The listing for impacts to biological communities, trash, and bacteria upstream of the harbor tunnel will be addressed at a future date.

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

Since the Baltimore Harbor embayment was 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, in the embayment is supported; however, these TMDLs will also ensure the protection of all other applicable designated uses within the embayment. This objective is achieved via the use of extensive field observations and a three-dimensional numeric model that simulates hydrodynamics, organic carbon (OC) species, and PCB homologs. In the model, the transport and fate processes of PCBs are associated with OCs and include mechanisms of adsorption/desorption, surface volatilization, exchanges with bottom sediments from settling/resuspension, and exchanges between the Baltimore Harbor embayment and the open waters of the Chesapeake Bay mainstem. The conceptual basis of the model is that the transport and fate of toxic chemicals, especially hydrophobic organic chemicals (HOCs), such as PCBs, is strongly influenced by their adsorption to OCs and exchanges between the water column and bottom sediments (Haywood and Buchanan 2007). The tPCB fish tissue listing threshold of 39 nanograms/gram (ng/g, ppb) (wet weight) is used to derive the water column and sediment TMDL endpoints (MDE 2011a). The model incorporates the long term influences of freshwater tributary inputs, full estuarine dynamics, and exchanges between the water column and bottom sediments, thereby representing realistic dynamic transport within the Baltimore Harbor embayment. The model is used to:

1. Estimate and predict PCB transport and fate based on PCB adsorption and associated OC transport, settling/resuspension, and air-water exchanges.
2. Validate predicted PCB concentrations via comparison to 1996-1998 observed concentrations.
3. Simulate long-term PCB homolog concentrations in the water column and bottom sediments.
4. 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).
5. Estimate the amount of time necessary for tPCB concentrations within the embayment to reach the water column and sediment TMDL 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 embayment and the Chesapeake Bay mainstem.

The CWA, as recently interpreted by the United States District Court, requires TMDLs to be protective of all the designated uses applicable to a particular waterbody (US District Court for the District of Columbia 2011). Within the Baltimore Harbor embayment, these designated uses, as described previously, include “water contact recreation”, “fishing”, “the protection of aquatic life”, and “marine and estuarine aquatic life and shellfish harvesting”. The TMDLs presented herein were developed specifically to be protective of the “fishing” designated use, which is protective of human health related to the consumption of fish, since each segment of the embayment was identified as impaired for “PCBs in fish tissue” on the Integrated Report. Additionally, Curtis Creek/Bay and Bear Creek were also identified on the Integrated Report as impaired for PCBs in sediment. These PCB sediment impairment listings were assessed based on sediment concentrations exceeding the sediment quality guideline (SQG) effects-range median (ERM) for PCBs (Buchman 1999). Concentrations above the ERM are likely to result in toxicological impacts to sediment dwelling organisms. Though the ERM is sufficient for providing an official assessment (i.e., Integrated Report listing purposes) of PCB sediment impairments, since it provides reasonable certainty that concentrations above this threshold do in fact result in toxicity, concentrations below this threshold may still be representative of conditions that adversely impact benthic life, in some instances. Conversely, the SQG Threshold Effects Level (TEL) for PCBs in marine sediments indicates that concentrations below this threshold are highly unlikely to result in toxicity and will therefore be protective of benthic life. Thus, the TEL will be used as a reference for comparison, rather than the ERM, when evaluating the sediment TMDL endpoint tPCB concentration for Cutis Creek/Bay and Bear Creek.

The water column and sediment TMDL endpoint tPCB concentrations applied within this analysis, which are derived from Maryland's Integrated Report fish tissue listing threshold tPCB concentration and site specific tBAFs, are lower than 1) EPA's human health criterion tPCB water column concentration relative to fish consumption, 2) both Maryland's freshwater and saltwater aquatic life chronic criteria tPCB water column concentrations, and 3) the SQG |TEL for PCBs (see Section 3 for further details). This indicates that these TMDLs are not only protective of the "fishing" designated use but also the "aquatic life" designated use, specifically the protection of "marine and estuarine aquatic life and shellfish harvesting" (i.e., water column TMDL endpoint tPCB concentration < saltwater aquatic life chronic criteria), and in particular, they are also protective of benthic aquatic life (i.e., sediment TMDL endpoint tPCB concentration < SQG TEL). Since the sediment TMDL endpoint tPCB concentration applied within the analysis is less than the SQG TEL, this indicates that that the impairment listings for PCBs in sediment for Curtis Creek/Bay and Bear Creek will be addressed as well. Lastly, the designated use for "water contact recreation" is not associated with any potential human health risks due to PCB exposure. Dermal contact and consumption of water from activities associated with "water contact recreation" are not a significant pathway for the uptake of PCBs. The EPA human health criterion was developed solely based on organism consumption, as drinking water consumption does not pose any risk for cancer development at environmentally relevant levels. The only human health risk associated with PCB exposure is through the consumption of aquatic organisms, which is addressed by the water column and sediment tPCB endpoint concentrations applied within these TMDLs developed to be supportive of the "fishing" designated use for the embayment.

As part of this analysis, both point and non-point sources of PCBs have been identified throughout the Baltimore Harbor embayment's watershed. Nonpoint sources include loads from direct atmospheric deposition to the embayment, identified contaminated sites, resuspension and diffusion from bottom sediments, tidal influence from the Chesapeake Bay mainstem, tributaries outside of the embayment's direct drainage, and runoff from non-regulated watershed areas within the embayment's direct drainage. Point sources include loads from two municipal wastewater treatment plants (WWTPs), five industrial process water facilities, two dredged material containment facilities (DMCFs), and National Pollutant Discharge Elimination System (NPDES) regulated stormwater runoff from watershed areas within the embayment's direct drainage. Model estimated tPCB loads from these point and nonpoint sources represent the baseline conditions to the embayment.

Although the transport of PCBs to the embayment from bottom sediments via resuspension and diffusion is currently estimated to be a major source of PCBs to the embayment (net transport of 9,107.3 grams/year (g/year)), this load contribution is resultant from other point and nonpoint source inputs (both historic and current) within the embayment's watershed. Thus, this source is not considered to be directly controllable and will not be considered for reductions within the scope of this TMDL. Also, the transport of PCBs into the embayment due to tidal influxes from the Chesapeake Bay mainstem could be a major source of PCBs to the system; however, under current conditions, due to the high water column concentration of PCBs within the embayment, there is a net transport of PCBs out of the embayment into the Bay's mainstem (1,112.9 g/year). Thus, through tidal influences, PCBs are being removed from the Baltimore Harbor embayment. Even if the Bay mainstem served as a source of PCBs to the water column, the load contribution is resultant from other point and nonpoint source inputs throughout the Upper Chesapeake Bay watershed. Thus, this source is also not considered to be directly controllable and will not be considered for reductions within the scope of this TMDL.

The objective of the TMDLs established herein is to reduce current PCB loads to the Baltimore Harbor embayment, Curtis Creek/Bay, and Bear Creek 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 and 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 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) (CFR 2011b). 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 this analysis to account for such uncertainty.

A summary of the baseline conditions and TMDLs for the Baltimore Harbor embayment, Curtis Creek/Bay, and Bear Creek are presented in Tables ES-1 through ES-3. The baseline loads and TMDL allocations for the Baltimore Harbor embayment include loads from Curtis Creek/Bay and Bear Creek. Additionally, the baseline loads and TMDL allocations only consider current sources of PCBs to the embayment that are considered to be directly controllable, positive net loads (reducible loads), and therefore do not include resuspension and diffusion from bottom sediments and the tidal influence of the Chesapeake Bay mainstem. When implemented, these TMDLs, will ensure that the resulting tPCB loads are at levels supportive of the "fishing" designated use in these segments.

The water quality model developed for simulating ambient sediment and water column tPCB concentrations within the Baltimore Harbor embayment was used to determine the specific load reductions for each reducible source category that would result in simulated tPCB concentrations in the sediment and water column that meet the TMDL endpoints. The results of this scenario establish the load reductions per reducible source category and the associated WLAs and LAs necessary to achieve the TMDL, except for certain reducible source sector loads, described as follows. Loads from contaminated sites were not reduced from their baseline loads, since they have already undergone some degree of remediation and their baseline loads constitute a relatively small percentage of the Total Baseline Load to the embayment (0.2% - Baltimore Harbor Embayment; 1.3% - Curtis Creek/Bay). The WLAs for the industrial process water facilities and municipal WWTPs were assigned based on the water column TMDL endpoint and the facility design flow for municipal WWTPs/average observed flow for industrial process water facilities. Loads from DMCFs will not be reduced from their baseline as these facilities are not capable of treating their discharge for PCBs. Furthermore, any PCBs in their discharge are due to PCBs in the bottom sediments that were dredged, thus indicating a pass through condition (i.e., no additional PCBs are generated during the containment process), and at this time, there are no alternative options for the disposal of dredged material from the embayment. The TMDL modeling scenario was used to develop the load reductions, WLAs, and LAs for the tributary, non-regulated watershed runoff, NPDES regulated stormwater, and atmospheric deposition source categories. The resultant TMDL scenario requires a 91.5 % reduction for all watershed sources (i.e., tributaries, non-regulated watershed runoff, and NPDES regulated stormwater), with slight variations in the regulated stormwater sector due to the locations of the contaminated sites, and a 57.6% reduction for atmospheric deposition, in order to achieve the sediment and water column TMDL endpoint tPCB concentrations. A smaller reduction for atmospheric deposition is required since it has less of an impact on water quality than the watershed land sources. The atmospherically deposited load is evenly distributed over the surface water of the entire embayment. However, watershed sources will vary relative to their impact on water quality throughout the embayment, thus resulting in higher tPCB concentrations in specific portions of the embayment, thereby requiring a greater reduction to achieve the TMDL condition.

Table ES-1: Summary of tPCB Baseline Loads, TMDL Allocations, Load Reductions, and Maximum Daily Loads (MDLs) in the Baltimore Harbor Embayment

PCB Source	Baseline Load (g/year)	Percent of Total Baseline Load (%)	TMDL (g/year)	Load Reduction (%)	MDL (g/day)
Direct Atmospheric Deposition (to the Surface of the Embayment)	1,360.88	22%	576.47	57.6	5.30
Tributaries[1]					
Jones Fall	299.34	4.8	25.59	91.5	0.24
Gwynns Fall	541.42	8.7	46.29	91.5	0.43
Patapsco River Lower North Branch	688.85	11.1	58.90	91.5	0.54
Non-regulated Watershed Runoff[2]	362.49	5.9	30.99	91.5	0.29
Contaminated Sites	14.51	0.2	14.51	0.0	0.13
Nonpoint Sources/LAs	***3,267.49***	***52.7***	***752.75***	***77.0***	***6.93***
Industrial Process Water[4]	859.38	13.9	498.60	42.0	4.24
WWTPs	366.81	5.9	32.83	91.1	0.28
DMCFs	77.60	1.3	77.60	0.0	0.66
NPDES Regulated Stormwater[2,3]					
Anne Arundel County	850.74	13.7	66.97	92.1	0.62
Baltimore County	338.50	5.5	28.94	91.5	0.27
Baltimore City	435.27	7.0	30.44	93.0	0.28
Point Sources/WLAs	***2,928.31***	***47.3***	***735.22***	***74.9***	***6.34***
MOS (5%)	**-**	**-**	**78.31**	**-**	**0.70**
Total	**6,195.79**	**100.0**	**1,566.29**	**74.7**	**13.96**

Notes: [1] Although the tributary loads are reported here as a single nonpoint source value, they could include both point and nonpoint source loads.

[2] Load applies to the direct drainage portion of the applicable watershed only.

[3] Load per jurisdiction applies to all NPDES stormwater dischargers within the direct drainage area of the jurisdiction to the Baltimore Harbor embayment. These dischargers are identified in Appendix H.

[4] 18.66 g/year of the 498.6 g/year allocated to industrial process water point sources is assigned to the Back River WWTP Outfall 002, since the effluent from the outfall is routed to RG Steel for use in their industrial processes. The allocation to the Back River WWTP Outfall 002 is calculated as the part of the WWTP design flow allocated to the outfall, which is 50 Million Gallons per Day (MGD), multiplied by the water column TMDL endpoint, which is 0.27 ng/L.

Table ES-2: Summary of tPCB Baseline Loads, TMDL Allocations, Load Reductions, and MDLs in the Curtis Creek/Bay

PCB Source[1]	Baseline Load (g/year)	Percent of Total Baseline Load (%)	TMDL (g/year)	Load Reduction (%)	MDL (g/day)
Direct Atmospheric Deposition (to the Surface of the Embayment)	121.26	20.5	51.37	57.6	0.47
Non-regulated Watershed Runoff[2]	77.19	13.1	6.60	91.5	0.06
Contaminated Sites	7.84	1.3	7.84	0.0	0.07
Nonpoint Sources/LAs	***206.29***	***35.0***	***65.81***	***68.1***	***0.61***
Industrial Process Water[3]	-	-	-	-	-
WWTPs[3]	-	-	-	-	-
DMCFs[3]	-	-	-	-	-
NPDES Regulated Stormwater[2,4]					
Anne Arundel County	357.68	60.6	23.13	93.5	0.21
Baltimore City	26.22	4.4	2.91	88.9	0.03
Point Sources/WLAs	***383.89***	***65.0***	***26.05***	***93.2***	***0.24***
MOS (5%)	**-**	**-**	**4.83**	**-**	**0.04**
Total	**590.18**	**100.0**	**96.68**	**83.6**	**0.89**

Notes: [1] None of the upstream tributaries (i.e., Jones Falls, Gwynns Falls, and the Patapsco River Lower North Branch) drain directly into the Curtis Creek/Bay portion of the embayment.
[2] Load applies to the direct drainage portion of the applicable watershed only.
[3] No industrial process water facilities, WWTPs, or DMCFs have been identified in the applicable watershed.
[4] Load per jurisdiction applies to all NPDES stormwater dischargers within the direct drainage area of the jurisdiction to Curtis Creek/Bay. These dischargers are identified in Appendix H.

Table ES-3: Summary of tPCB Baseline Loads, TMDL Allocations, Load Reductions, and MDLs in the Bear Creek

PCB Source[1]	Baseline Load (g/year)	Percent of Total Baseline Load (%)	TMDL (g/year)	Load Reduction (%)	MDL (g/day)
Direct Atmospheric Deposition (to the Surface of the Embayment)	79.32	18.5	33.60	57.6	0.31
Non-regulated Watershed Runoff[2]	26.33	6.1	2.25	91.5	0.02
Contaminated Sites[4]	-	-	-	-	-
Nonpoint Sources/LAs	***105.65***	***24.7***	***35.85***	***66.1***	***0.33***
Industrial Process Water[3]	-	-	-	-	-
WWTPs[4]	-	-	-	-	-
DMCFs[4]	-	-	-	-	-
NPDES Regulated Stormwater[2]					
Baltimore County[5]	322.85	75.3	27.60	91.5	0.25
Point Sources/WLAs	***322.85***	***75.3***	***27.60***	***91.5***	***0.25***
MOS (5%)	**-**	**-**	***3.34***	**-**	**0.03**
Total	**428.50**	**100.0**	***66.80***	***84.4***	**0.61**

Notes: [1] None of the upstream tributaries (i.e., Jones Falls, Gwynns Falls, and the Patapsco River Lower North Branch) drain directly into the Bear Creek portion of the embayment.
[2] Load applies to the direct drainage portion of the applicable watershed only.
[3] One outfall from the RG Steel facility discharges to Bear Creek. However, this facility falls under an aggregate WLA for all industrial process water discharges, which is accounted for in the TMDL for the Baltimore Harbor embayment. An individual baseline load and WLA for this outfall will therefore not be presented in this table.
[4] No WWTPs, DMCFs, or contaminated sites have been identified in the applicable watershed.
[5] Load applies to all NPDES stormwater dischargers within the direct drainage area of the jurisdiction to Bear Creek. These dischargers are identified in Appendix H.

Federal regulations require that TMDL analysis take into account the impact of critical conditions and seasonality on water quality (CFR 2011b). The intent of these requirements is to ensure that load reductions under this TMDL when implemented will produce water quality conditions supportive of the designated use at all times. Given that 1) at the observed concentrations, acute conditions are not a concern, and 2) since PCB levels in fish tissue become elevated due to long-term exposure, the selection of the average annual 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. Thus, the TMDLs for the Baltimore Harbor embayment, Curtis Creek/Bay, and Bear Creek implicitly account for seasonal variations as well as critical conditions.

Resuspension and diffusion of PCBs from the bottom sediments largely dictates the recovery time of the Baltimore Harbor embayment. However, despite the fact that PCB loads from resuspension and diffusion are not considered to be directly controllable, these load contributions are still expected to decrease over time as the result of 1) the implementation of directly controllable point and nonpoint source reductions within the embayment’s watershed and 2) the natural attenuation of PCBs in the environment.

After the initial decline in PCB water column concentrations within the embayment, due to the natural attenuation of PCBs in the environment, in addition to the expected decrease of point and nonpoint source inputs within the embayment's watershed, the net exchange of PCBs at the tidal boundary between the embayment and the Chesapeake Bay mainstem may shift as well. As a result, instead of loads being exported from the embayment into the Bay's mainstem, loads may be imported from the Bay's mainstem into the embayment, meaning that this boundary condition may start to dominate the recovery time of the impaired embayment. Should this occur, however, observations show that the average tPCB concentration in the Upper Chesapeake Bay is decreasing at a rate of 6.5% per year (MDE 2009). Thus, as a conservative estimate, a 5% per year decrease of tPCB concentrations can be expected at the tidal boundary between the embayment and the Bay mainstem, which is equivalent to a 91% reduction of tPCB concentrations over a 45 year period. Given this natural rate of decline in the boundary concentrations, tPCB levels in the embayment are expected to continue to decline over time. Thus, discovering and remediating any existing PCB land sources throughout the upper Chesapeake Bay watershed via future TMDL development and implementation will further aid in the decline of the boundary condition tPCB concentrations and meeting water quality goals in the Baltimore Harbor embayment.

Once EPA has approved this TMDL, MDE will begin an iterative process of implementation that will first identify specific sources, or areas of PCB contamination, within the embayment's watershed, and second, target remedial action to those sources with the largest impact on water quality, while giving consideration to the relative cost and ease of implementation. The implementation efforts will be periodically evaluated, and if necessary, improved, in order to further progress toward achieving the water quality goals. Given that a number of contaminated sites have already undergone some degree of remediation and their baseline loads constitute a relatively small percentage of the Total Baseline Loads (i.e., 0.2% - Baltimore Harbor Embayment; 1.3% - Curtis Creek/Bay Portion of the Baltimore Harbor Embayment), these sites are not intended to be targeted during the initial stages of implementation and thus at this point were not subjected to any reductions (as discussed previously). However, if in the future it becomes clear that the TMDL goals cannot be achieved without load reductions from these sites, additional reduction measures might need to be considered. As part of Maryland's Watershed Cycling Strategy, follow-up monitoring and assessment will be routinely conducted to evaluate the implementation status in the Baltimore Harbor embayment. 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 embayment.

1. INTRODUCTION

This document, upon approval by the U.S. Environmental Protection Agency (EPA), establishes Total Maximum Daily Loads (TMDLs) of Polychlorinated Biphenyls (PCBs) in the Baltimore Harbor, Curtis Creek/Bay, and Bear Creek portions of the Patapsco River Mesohaline Tidal Chesapeake Bay Segment. Section 303(d) of the federal Clean Water Act (CWA) and the EPA's implementing regulations direct each State to identify and list waters, known as water quality limited segments (WQLSs), in which current required controls of a specified substance are inadequate to achieve water quality standards (WQSs). For each WQLS, the State is to either establish a TMDL of the specified substance that the waterbody can receive without violating WQSs, or demonstrate that WQSs are being met (CFR 2011b).

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

Maryland WQSs specify that all surface waters of the State shall be protected for water contact recreation, fishing, and the protection of aquatic life (COMAR 2011a). Additionally, the specific designated use of the Baltimore Harbor, Curtis Creek/Bay, and Bear Creek portions of the Patapsco River Mesohaline Tidal Chesapeake Bay Segment is Use II – Support of Estuarine and Marine Aquatic Life and Shellfish Harvesting (COMAR 2011b). The Maryland Department of the Environment (MDE) has identified the Patapsco River Mesohaline Tidal Chesapeake Bay Segment (Integrated Report Assessment Unit ID: PATMH) on the State's 2010 Integrated Report as impaired by nutrients – nitrogen and phosphorus (1996), sediments (1996), trash and debris (2008), and impacts to biological communities (2004). The Baltimore Harbor portion of the Patapsco River Mesohaline Tidal Chesapeake Bay Segment (Integrated Report assessment unit ID: MD-PATMH-02130903) has been individually identified on the State's 2010 Integrated Report as impaired by PCBs in fish tissue (1998), chlordane (1998), bacteria – Furnace Creek, Marley Creek, Rock Creek, and all tidal waters upstream of the harbor tunnel (1998), zinc – Middle and Northwest Branches (1998), chromium – Northwest Branch (1998), and lead - Northwest Branch (1998). In addition, the Curtis Creek/Bay portion of the Patapsco River Mesohaline Tidal Chesapeake Bay Segment (Integrated Report assessment unit ID: MD-PATMH-CURTIS_BAY_CREEK) has been individually identified on the State's 2010 Integrated Report as impaired by PCBs in both fish tissue and sediment (1998) and zinc (1998), and the Bear Creek portion of the Bay Segment has been individually identified on the State's 2010 Integrated Report (Integrated Report assessment unit ID: MD-PATMH-BEAR_CREEK) as impaired by PCBs in both fish tissue and sediment (1998), zinc (1998), and chromium (1998) (MDE 2011a).

The entire Patapsco River Mesohaline Tidal Chesapeake Bay Segment, also referred to as an embayment, includes more than the individual segments identified within this report as impaired for PCBs, for which TMDLs have been developed. This includes areas such as Bodkin Creek. It should also be noted that the Baltimore Harbor portion of the Patapsco River Mesohaline Tidal

Chesapeake Bay Segment encompasses both Curtis Creek/Bay and Bear Creek. Thus, since the Curtis Creek/Bay and Bear Creek segments were individually identified as impaired for PCBs due to sediment data, in addition to the impairment listing for the entire Baltimore Harbor portion of the Bay Segment (based on PCB fish tissue concentrations), there is a spatial overlap between the various PCB impairment listings for the Bay Segment. As a result, the baseline and TMDL loads for the Baltimore Harbor portion of the Bay Segment described within this report include the baseline and TMDL loads for the Curtis Creek/Bay and Bear Creek segments. For the purposes of this report, the spatial unit defined as the Baltimore Harbor embayment will refer solely to the Baltimore Harbor portion of the Patapsco River Mesohaline Tidal Chesapeake Bay Segment (i.e., the portion of the Bay Segment impaired for PCBs in fish tissue), which encompasses the Curtis Creek/Bay and Bear Creek segments. The spatial units defined as Curtis Creek/Bay and Bear Creek will refer solely to these individual segments of the Baltimore Harbor embayment, which are specifically impaired for PCBs in sediment, in addition to fish tissue. Table 1 provides further details regarding the 2010 Integrated Report PCB impairments listings, and Figure 1 on page 6 of the main report depicts the spatial relationship between the areas of the Patapsco River Mesohaline Tidal Chesapeake Bay Segment that are identified as impaired for PCBs in both fish tissue and sediments and the remaining area of the Bay Segment that is not identified as impaired for PCBs, as well as the watershed areas draining to each.

Table 1: Maryland's 2010 Integrated Report PCB Impairment Listings for the Patapsco River Mesohaline Tidal Chesapeake Bay Segment

Listing Year	Basin Name	Assessment Unit ID	County	Specific PCB Impairment
1998	Patapsco River Mesohaline Chesapeake Bay Segment - Baltimore Harbor	MD-PATMH-02130903	Anne Arundel, Baltimore, Baltimore City	PCBs in Fish Tissue
1998	Patapsco River Mesohaline Chesapeake Bay Segment - Bear Creek	MD-PATMH-BEAR_CREEK	Baltimore	PCBs in Fish Tissue and Sediment
1998	Patapsco River Mesohaline Chesapeake Bay Segment - Curtis Creek/Bay	MD-PATMH-CURTIS _BAY_CREEK	Anne Arundel, Baltimore City	PCBs in Fish Tissue and Sediment

The TMDLs established herein by MDE will address the total PCB (tPCB) listings for the Baltimore Harbor embayment, Curtis Creek/Bay, and Bear Creek, for which a data solicitation was conducted, and all readily available data from the past 5 years have been considered. Bacteria TMDLs for Marley and Furnace Creeks of the Baltimore Harbor embayment were submitted to the EPA in 2010. The bacteria impairment for Rock Creek of the Baltimore Harbor embayment was delisted in 2004. Chlordane and nutrient (nitrogen and phosphorus) TMDLs for the Baltimore Harbor embayment were approved by the EPA in 2001 and 2007, respectively. Then, in 2010, the Chesapeake Bay nutrient and sediment TMDLs were developed by the EPA, which addressed the nutrient and sediment impairment listings for the entirety of the Patapsco River Mesohaline Tidal Chesapeake Bay Segment. WQAs for the chromium, lead, and zinc impairment listings in the Northwest Branch of the Baltimore Harbor embayment, the zinc impairment listing in the Middle Branch of the Baltimore Harbor embayment, the zinc impairment listing in Curtis Creek/Bay, and the zinc and chromium impairment listings in Bear Creek were developed by MDE in 2004; however, they were not approved by EPA, as the information to support the delisting was insufficient at the time. Studies are currently underway to determine whether these metals listings will require TMDLs to be developed in the future. The listing for impacts to biological communities, trash, and bacteria upstream of the harbor tunnel will be addressed at a future date.

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

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

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

The Baltimore Harbor embayment, Curtis Creek/Bay, and Bear Creek were first identified as impaired by PCBs on Maryland’s 1998 Integrated Report based on fish tissue PCB data from MDE’s monitoring program that exceeded the tPCB fish tissue listing threshold of 39 nanograms/gram (ng/g), or parts per billion (ppb) (wet weight) (MDE 2011a). In addition to identifying impaired waterbodies on the State’s Integrated Report, MDE also issues statewide and site specific fish consumption advisories (ranging from 0 to 4 meals per month) and recommendations (ranging from 4 to 8 meals per month). Current recreational fish consumption advisories suggest limiting the consumption of the following fish species caught in the Baltimore Harbor, Curtis Creek/Bay, and Bear Creek: American Eel, Brown Bullhead, Channel Catfish, White Perch, Striped Bass, and White Catfish (MDE 2011b). Additionally, Curtis Creek/Bay and Bear Creek were listed as impaired for PCBs in sediment, as well as fish tissue, in 1998. The PCB sediment concentrations exceeded the sediment quality guideline (SQG) effects range median (ERM) concentration of 180 ng/g, or ppb, thus indicating toxicological impacts to benthic organisms (Buchman 1999).

2. SETTING AND WATER QUALITY DESCRIPTION

2.1 General Setting

Location

The Patapsco River Mesohaline Chesapeake Bay Segment is a tidal estuary, or embayment, located on the western shore of the Chesapeake Bay. The total watershed draining to the Bay Segment covers 1,514 square kilometers (km^2) (374,040 acres) and spans Baltimore City, Carroll, Howard, Anne Arundel, and Baltimore Counties. The Baltimore Harbor Maryland 8-Digit (MD 8-Digit) watershed comprises the majority of the Patapsco River Mesohaline Chesapeake Bay Segment. Curtis Creek/Bay and Bear Creek are specific segments within the Baltimore Harbor portion of the Bay Segment, which have been specifically identified as impaired for PCBs in sediments, in addition to fish tissue. Curtis Creek/Bay is located on the southwest shore of the Harbor within both Baltimore City and Anne Arundel County, while Bear Creek is located on the northwest shore of the Harbor within solely Baltimore County. The total watershed area draining to the Baltimore Harbor portion of the Bay Segment covers 1,491 km^2 (368,388 acres) and spans Baltimore City, Carroll, Howard, Anne Arundel, and Baltimore Counties; however, the direct drainage portion of this watershed area only covers 219 km^2 (53,994 acres) and spans Baltimore City, Anne Arundel County, and Baltimore County. As stated within the introduction, throughout this report, for simplicity, the spatial unit defined as the Baltimore Harbor embayment will refer solely to the Baltimore Harbor portion of the Patapsco River Mesohaline Tidal Chesapeake Bay Segment (i.e., the portion of the Bay Segment impaired for PCBs in fish tissue), which encompasses the Curtis Creek/Bay and Bear Creek segments. The spatial units defined as Curtis Creek/Bay and Bear Creek will refer solely to these individual segments of the Baltimore Harbor embayment, which are specifically impaired for PCBs in sediment, in addition to fish tissue. The location of the Patapsco River Mesohaline Tidal Chesapeake Bay Segment and the various portions of the Bay Segment impaired for PCBs in fish tissue and sediment (i.e., the Baltimore Harbor embayment, Curtis Creek/Bay, Bear Creek) are shown in Figure 1.

It is estimated that 60 percent of the total freshwater entering the Baltimore Harbor embayment comes from the nontidal Patapsco River (Quirk, Lawler, and Matusky Engineers 1973). The two other major tributaries entering the embayment are the Gwynns Falls and Jones Falls (see Figure 1). The tidal range of the embayment is 0.3 meters (m) based on the United States National Oceanic and Atmospheric Administration (NOAA) tidal station at in the Middle Branch Patapsco River. There are several "high quality," or Tier II, stream segments (Benthic Index of Biotic Integrity (BIBI) and Fish Index of Biotic Integrity (FIBI) aquatic life assessment scores > 4 (scale 1-5)) located within the embayment's watershed (none within the direct drainage portion however) requiring the implementation of Maryland's anti-degradation policy including at least portions of: Beaver Run, Cooks Branch, Gillis Falls, Joe Branch, Keyser's Run, Morgan Run, Little Morgan Run, an unnamed tributary to Morgan Run, Middle Run, Red Run, the North Branch Patapsco River, an unnamed tributary to the North Branch Patapsco River, and an unnamed tributary to the South Branch Patapsco River (COMAR 2011d; MDE 2010). Approximately 0.9% percent of the embayment's drainage area is covered by water (i.e., streams, ponds, etc). The total population in the embayment's watershed is approximately 1,351,190 (US Census Bureau 2000).

Land Use

According to the United States Geological Survey's (USGS) 2006 land cover data (USGS 2011), which was specifically developed to be applied within the Chesapeake Bay Program's (CBP) Phase 5.3.2 watershed model, land use in the Baltimore Harbor embayment's watershed is predominantly urban. Urban land occupies approximately 45.1% of the watershed, while 29.0% is forested and 21.8% is agricultural. The remaining 4.1% is classified as barren, natural grassland, water, or wetland. The land use distribution is displayed and summarized in Figures 2 and 3 as well as Table 2.

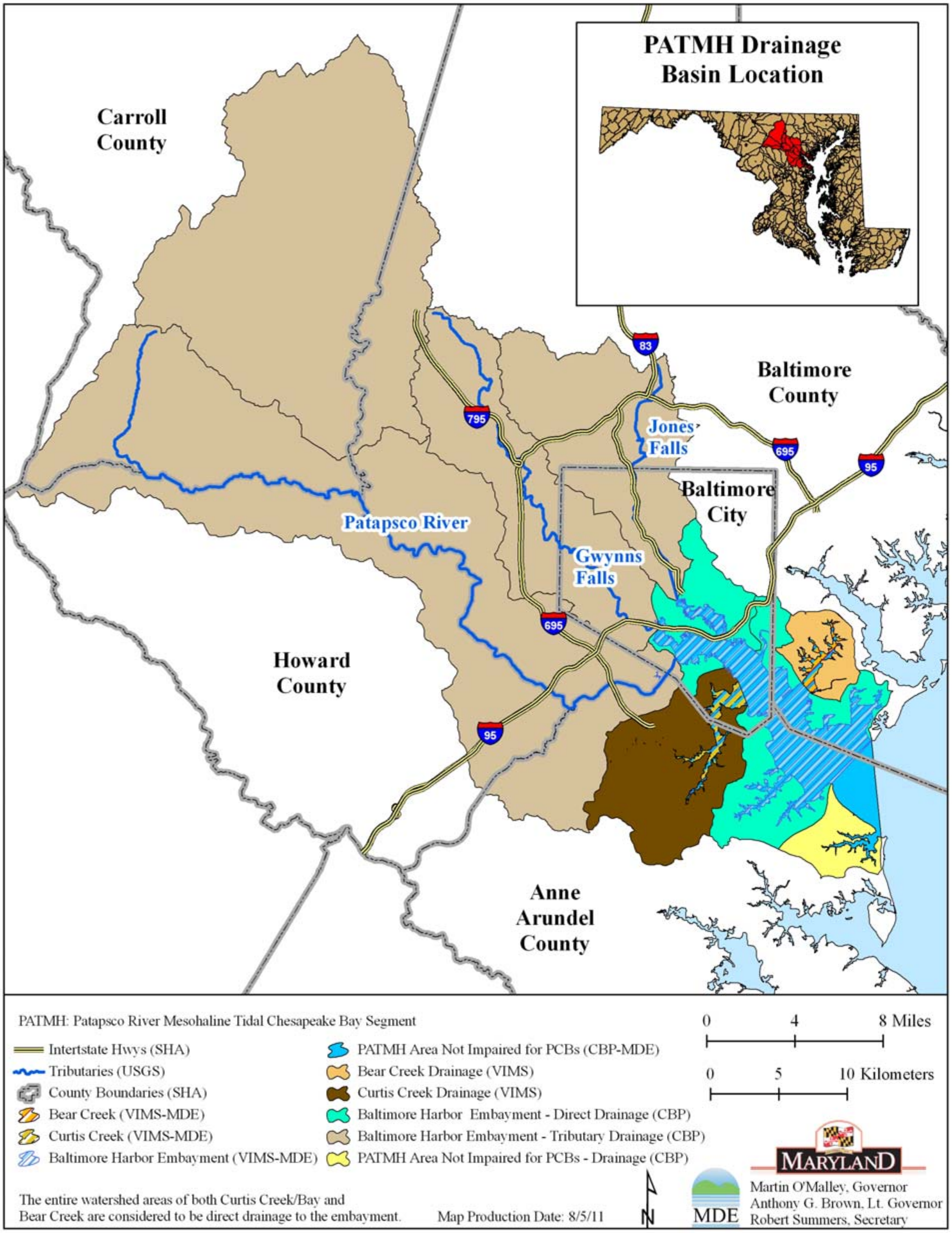


Figure 1: Location Map of the Patapsco River Mesohaline Tidal Chesapeake Bay Segment with Specific PCB Impaired Areas and Associated Watersheds

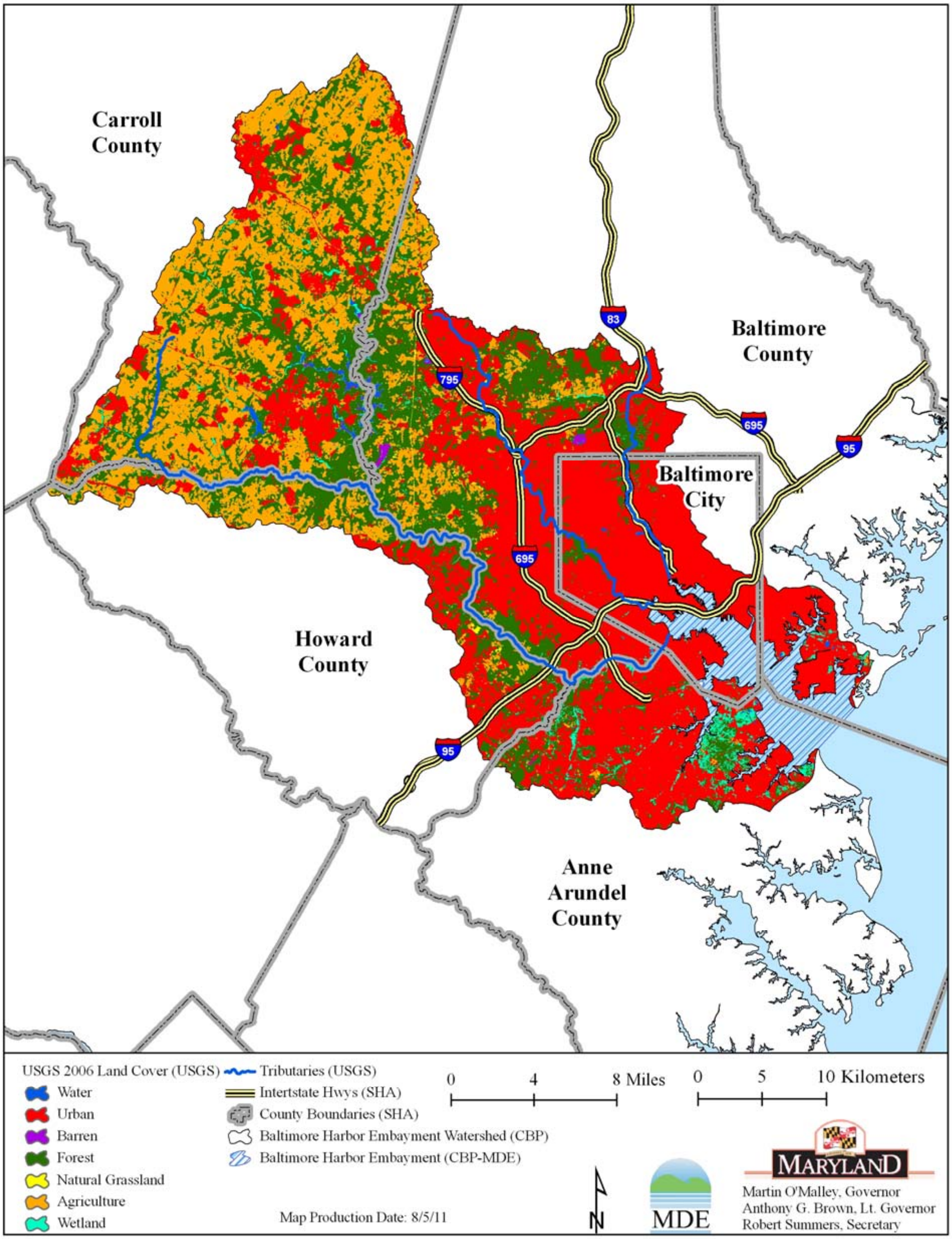
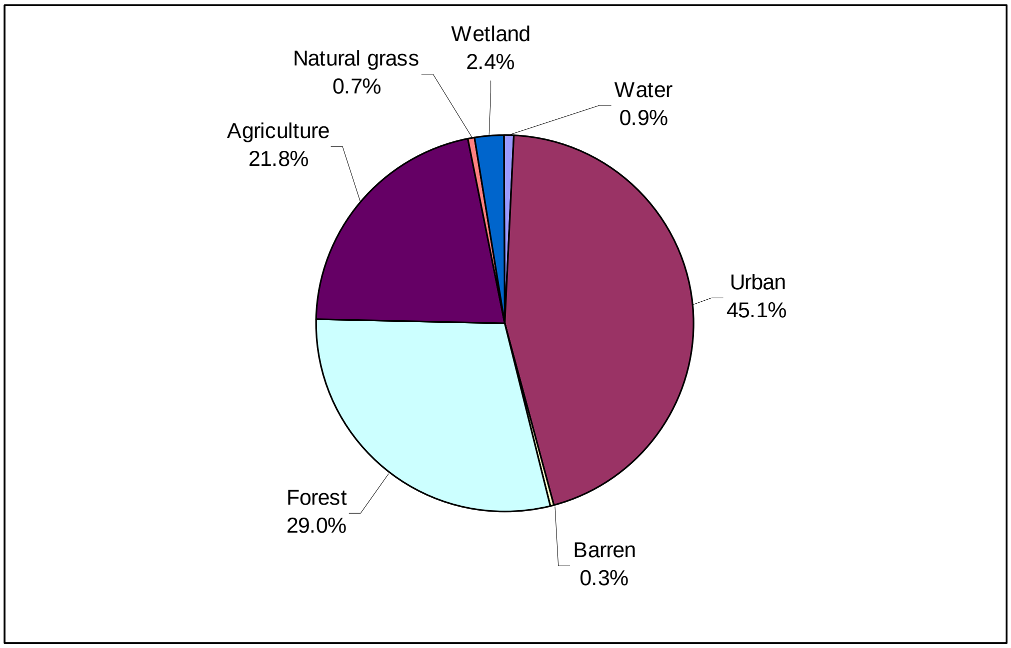


Figure 2: Land Use in the Baltimore Harbor Embayment's Watershed

Table 2: Land Use Distribution in the Baltimore Harbor Embayment's Watershed

Segment	Land Use	Area (km^2)	Percent of Total (%)
Baltimore Harbor[1]	Water	12.7	0.9
	Urban	673.0	45.1
	Barren	3.9	0.3
	Forest	431.9	29.0
	Agriculture	324.8	21.8
	Natural grass	10.1	0.7
	Wetland	35.3	2.4
	Total	**1,491.7**	**100.0**
Curtis Creek/Bay	Water	0.2	0.2
	Urban	80.6	84.7
	Barren	0.8	0.8
	Forest	10.8	11.3
	Agriculture	0.7	0.7
	Natural grass	0.1	0.1
	Wetland	2.0	2.1
	Total	**95.2**	**100.0**
Bear Creek	Water	0.3	1.3
	Urban	21.3	92.6
	Barren	0.1	0.4
	Forest	0.4	1.7
	Agriculture	0.0	0.0
	Natural grass	0.0	0.0
	Wetland	0.9	3.9
	Total	**23.0**	**100.0**

Note: [1] Includes Curtis Creek/Bay and Bear Creek acres due to spatial overlap.



Note: Land use distribution matches the Baltimore Harbor distribution in Table 2, since the Curtis Creek/Bay and Bear Creek acres are incorporated in the Baltimore Harbor acres.

Figure 3: Land Use Distribution in the Baltimore Harbor Embayment's Watershed

2.2 Water Quality Characterization and Impairment

Maryland WQSs specify that all surface waters of the State shall be protected for water contact recreation, fishing, and the protection of aquatic life (COMAR 2011a). The specific designated use of the Baltimore Harbor embayment, Curtis Creek/Bay, and Bear Creek is Use II – Support of Estuarine and Marine Aquatic Life and Shellfish Harvesting (COMAR 2011b). The State of Maryland has adopted three separate water column tPCB criteria: criterion for protection of human health associated with the consumption of PCB contaminated fish, as well as fresh and saltwater chronic tPCB criteria for protection of aquatic life. The Maryland human health tPCB criterion is set at 0.64 nanograms/liter (ng/L), or parts per trillion (ppt), (COMAR 2011c; US EPA 2006). This 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), cancer risk level of 10^{-5}, a lifetime risk level and exposure duration of 70 years, and a fish intake of 17.5 g/day. A cancer risk level provides an estimate of the additional incidence of cancer that may be expected in an exposed population. A risk level of 10^{-5} indicates a probability of one additional case of cancer for every 100,000 people exposed. The Maryland fresh and saltwater aquatic life chronic tPCB criterion are set at 14 ng/L and 30 ng/L, respectively (COMAR 2011c; US EPA 2006). The water column mean tPCB concentration within the embayment exceeds the human health criteria of 0.64 ng/L; however, only a single water column sample exceeds the saltwater aquatic life tPCB criterion of 30 ng/L.

A sediment tPCB criterion has not yet been established in Maryland; however, in order to assess waters of the State for toxic impairments in sediment, an Integrated Report assessment methodology has been established. If toxicity and a degraded benthic community are present within the sediment, and the sediment concentration of a given toxic substance exceeds the ERM, the waterbody will be listed as impaired on the Integrated Report for that substance (MDE 2011a). The Curtis Creek/Bay and Bear Creek segments were listed as impaired for PCBs in sediment due to the presence of toxicity, a degraded benthic community, and exceedances of the sediment tPCB ERM concentration of 180 ng/g, or ppb. The sediment tPCB concentration data for these listings are presented in Appendix K.

In addition to the water column and sediment criteria described above, fish tissue monitoring can serve as an indicator of PCB water quality conditions. The Maryland fish tissue monitoring data is used to issue fish consumption advisories/recommendations and determine whether Maryland waterbodies are meeting the “fishing” designated use. Only data results from the analysis of skinless fillets, the edible portion of fish typically consumed by humans, is used for assessment purposes and development of this TMDL. Currently Maryland applies 39 ng/g as the tPCB fish tissue listing threshold (MDE 2011a). MDE collected fish tissue samples for PCB analysis in the Baltimore Harbor embayment, including Curtis Creek/Bay and Bear Creek, from 2001 to 2003. In 2008, additional fish tissue samples were collected in support of these TMDLs. The tPCB concentrations for all of the fish samples (several species of fish including channel catfish, white perch, etc. were collected) exceed the listing threshold, demonstrating that a PCB impairment exists within the Baltimore Harbor embayment. The PCB fish tissue concentration data is presented in Appendix K.

From 1996 to 2003, monitoring surveys were conducted under the Comprehensive Harbor Assessment and Regional Modeling Study (CHARM) (Baker et al. 2002) to measure tidal and non-tidal water column tPCB concentrations at stations throughout the Baltimore Harbor embayment and watershed. Sediment samples were collected in 1996 under the Baltimore Harbor Sediment Mapping Study to characterize tPCB sediment concentrations throughout the embayment. From 2008 to 2009, MDE collected additional fish tissue, water column (non-tidal and tidal), and stormwater samples for PCB analysis to further support TMDL development. Table 3 summarizes the tPCB data for fish tissue, water column (embayment only – nontidal data not included), and sediment samples (Curtis Creek/Bay and Bear Creek only) that were applied in this analysis. Appendix K contains figures of the sampling locations and tables containing all of the PCB water quality data.

Table 3: Summary of Fish Tissue, Water Column, and Sediment tPCB Data

tPCB Data	Units	Sampling Years	Sample Size	tPCB Concentration		
				Mean	Maximum	Minimum
Fish Tissue	ng/g	2001-2003, 2008	41	494.3	1,774.1	77.4
Water Column[1]	ng/L	1996-2003, 2008-2009	189	4.17	31.5	0.54
Sediment (Curtis Creek/Bay)	ng/g	1995-1996, 2008	12	326.1	827.1	1.6
Sediment (Bear Creek)		1996, 2008	11	255.1	1,175.9	0.1

Note: [1] Water column data presented here is for the embayment (i.e., tidal areas) only and does not include the nontidal or stormwater sampling data that was collected, since this data does not actually characterize the PCB impairment in the actual embayment. Additionally, the sediment data presented here is for Curtis Creek/Bay and Bear Creek only and does not include the sediment data that was collected in the other portions of the embayment, since this data does not actually characterize the specific areas of the embayment identified as impaired for PCBs in sediments.

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 electron capture detection. 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). Based on this method, 86 chromatographic peaks can be quantified. Some of the peaks contain one PCB congener, while many are comprised of two or more co-eluting congeners. 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. A list of the congeners detected under this analytical method is presented in Appendix A.

3. WATER COLUMN AND SEDIMENT TMDL ENDPOINTS

As described in Section 2.2, MDE evaluates whether a waterbody meets PCB related WQSs via 1) the use of the tPCB Integrated Report fish tissue listing threshold (39 ng/g, or ppb), 2) for PCBs in the water column, the human health tPCB water column criterion (0.64 ng/L, or ppt) and the fresh and saltwater chronic tPCB criteria for protection of aquatic life (14 ng/L and 30 ng/L, or ppt, respectively), or 3) for PCBs in sediments, the tPCB ERM (180 ng/g, or ppb), if there is toxicity present and a degraded benthic community in the sediment. Since the Baltimore Harbor embayment, Curtis Creek/Bay, and Bear Creek 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, in the embayment is supported; however, these TMDLs will also ensure the protection of all other applicable designated uses within the embayment.

Since the overall objective of the tPCB TMDLs for the Baltimore Harbor embayment, Curtis Creek/Bay, and Bear Creek is to ensure the support of the "fishing" designated use, the tPCB fish tissue listing threshold was translated into an associated water column tPCB threshold concentration (see Equation 3.1 and Calculation 3.1) to apply within this analysis as the water column TMDL endpoint. This was done using the Adjusted Total Bioaccumulation Factor (Adj-tBAF) of 145,344 L/kg for the Baltimore Harbor embayment, the derivation of which follows the method applied within the Potomac River PCB TMDLs (Haywood and Buchanan 2007). A total Bioaccumulation Factor (tBAF) is calculated per fish species, and subsequently the tBAFs are normalized by the median species lipid content and median dissolved water column tPCB concentration in the species home range to produce the Adj-tBAF per species (see Appendix B for further details regarding the calculation of the Adj-tBAF). The most environmentally conservative of the Adj-tBAFs is then selected to calculate the water column TMDL endpoint tPCB concentration. This final water column tPCB concentration was then subsequently compared to the water column tPCB criteria concentrations, as described in Section 2.2, to ensure that all applicable criteria within the embayment would be attained (Calculation 3.1).

tPCB Water Column Concentration = (tPCB Fish Tissue Concentration/
(Adj-tBAF × Unit Conversion)) (Equation 3.1)

Substituting 39 ng/g into the equation results in:

tPCB Water Column Concentration =
(39 ng/g ÷ (145,344 L/kg × 1,000 g/kg)) = 0.27 ng/L,
which is < 0.64 ng/L (human health tPCB water column criterion); and
< 14 ng/L (freshwater aquatic life chronic tPCB water column criteria); and
< 30 ng/L (saltwater aquatic life chronic tPCB water column criteria) (Calculation 3.1)

Based on this analysis, the water column tPCB concentration and TMDL endpoint of 0.27 ng/L for the Baltimore Harbor embayment, derived from the tPCB fish tissue listing threshold, is less than both the human health water column tPCB criterion of 0.64 ng/L as well as the fresh and saltwater aquatic life chronic tPCB criteria of 14 ng/L and 30 ng/L, respectively.

Similarly, in order to establish a sediment tPCB concentration that is protective of the "fishing" designated use within the embayment, a tPCB sediment concentration was derived from the tPCB fish tissue listing threshold (see Equation 3.2 and Calculation 3.2) to apply within this analysis as the sediment TMDL endpoint concentration. This was done using the Adjusted Sediment Bioaccumulation Factor (Adj-SediBAF) of 12.4 (unitless) for the Baltimore Harbor embayment, the derivation of which follows the method applied within Potomac River PCB TMDLs (Haywood and Buchanan 2007). Similar to the calculation of the 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 TMDL endpoint tPCB concentration.

Though the ERM is sufficient for providing an official assessment (i.e., Integrated Report listing purposes) of PCB sediment impairments, since it provides reasonable certainty that concentrations above this threshold do in fact result in toxicity, concentrations below this threshold may still be representative of conditions that adversely impact benthic life, in some instances. Conversely, the SQG Threshold Effects Level (TEL) of 21.6 ng/g, or ppb, for PCBs in estuarine sediments indicates that concentrations below this threshold are highly unlikely to result in toxicity and will therefore be protective of benthic life. Thus, the final target sediment tPCB concentration was compared to the tPCB TEL of 21.6 ng/g, since the endpoint concentration must be protective of benthic life within Curtis Creek/Bay and Bear Creek, in order to address the specific sediment PCB impairment listings for these two segments (Calculation 3.2).

tPCB Sediment Concentration = (tPCB Fish Tissue Threshold/
Adj-SediBAF) (Equation 3.2)

Substituting 39 ng/g into the equation results in:

tPCB Sediment Concentration = (39 ng/g ÷ 12.4) = 3.1 ng/g,
Which is < 21.6 ng/g (tPCB sediment TEL) (Calculation 3.2)

Based on this analysis, the sediment tPCB concentration and TMDL endpoint of 3.1 ng/g for the Baltimore Harbor embayment, derived from the tPCB fish tissue listing threshold, is less than the TEL of 21.6 ng/g. By establishing a tPCB TMDL endpoint for sediments protective of the "fishing" designated use in the embayment, the benthic life in Curtis Creek/Bay and Bear Creek will also be protected when this endpoint is achieved (i.e., the impairment listings for PCBs in sediment for the Curtis Creek/Bay and Bear Creek portions of the embayment will be addressed).

The CWA, as recently interpreted by the United States District Court, requires TMDLs to be protective of all the designated uses applicable to a particular waterbody (US District Court for the District of Columbia 2011). In addition to the "fishing" designated use, the TMDLs presented herein are also supportive of the other applicable designated uses within the embayment, as described in the Introduction to this report and Section 2.2. These include "water contact recreation", "the protection of aquatic life", and "marine and estuarine aquatic life and shellfish harvesting". Specifically, the TMDLs are protective of the "aquatic life" designated use, in particular the protection of "marine and estuarine aquatic life and shellfish harvesting" and benthic aquatic life, since 1) the water column TMDL endpoint tPCB concentration is less than the saltwater aquatic life chronic criterion, and 2) the sediment TMDL endpoint tPCB concentration is less than the SQG TEL. Lastly, the designated use for "water contact recreation" is not associated with any potential human health risks due to PCB exposure. Dermal contact and consumption of water from activities associated with "water contact recreation" are not a significant pathway for the uptake of PCBs. The EPA human health criterion was developed solely based on organism consumption, as drinking water consumption does not pose any risk for cancer development at environmentally relevant levels. The only human health risk associated with PCB exposure is through the consumption of aquatic organisms, which is addressed by the water column and sediment endpoints applied within this TMDL developed to be supportive of the "fishing" designated use for the embayment.

4. SOURCE ASSESSMENT

PCBs do not occur naturally in the environment. Therefore, unless existing or historical anthropogenic sources are present, their natural background levels are expected to be zero. Although PCBs are no longer manufactured in the United States, they are still being released to the environment via accidental fires, leaks, or spills from PCB-containing equipment; 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 not designed to handle hazardous waste. Once in the environment, PCBs do not readily break down and tend to cycle between various environmental media such as air, water, and soil.

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

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

A simplified conceptual model of PCB fate and transport in the Baltimore Harbor embayment 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 point and nonpoint sources. This section provides a summary of these existing nonpoint and point sources that have been identified as contributing PCB loads to the Baltimore Harbor embayment.

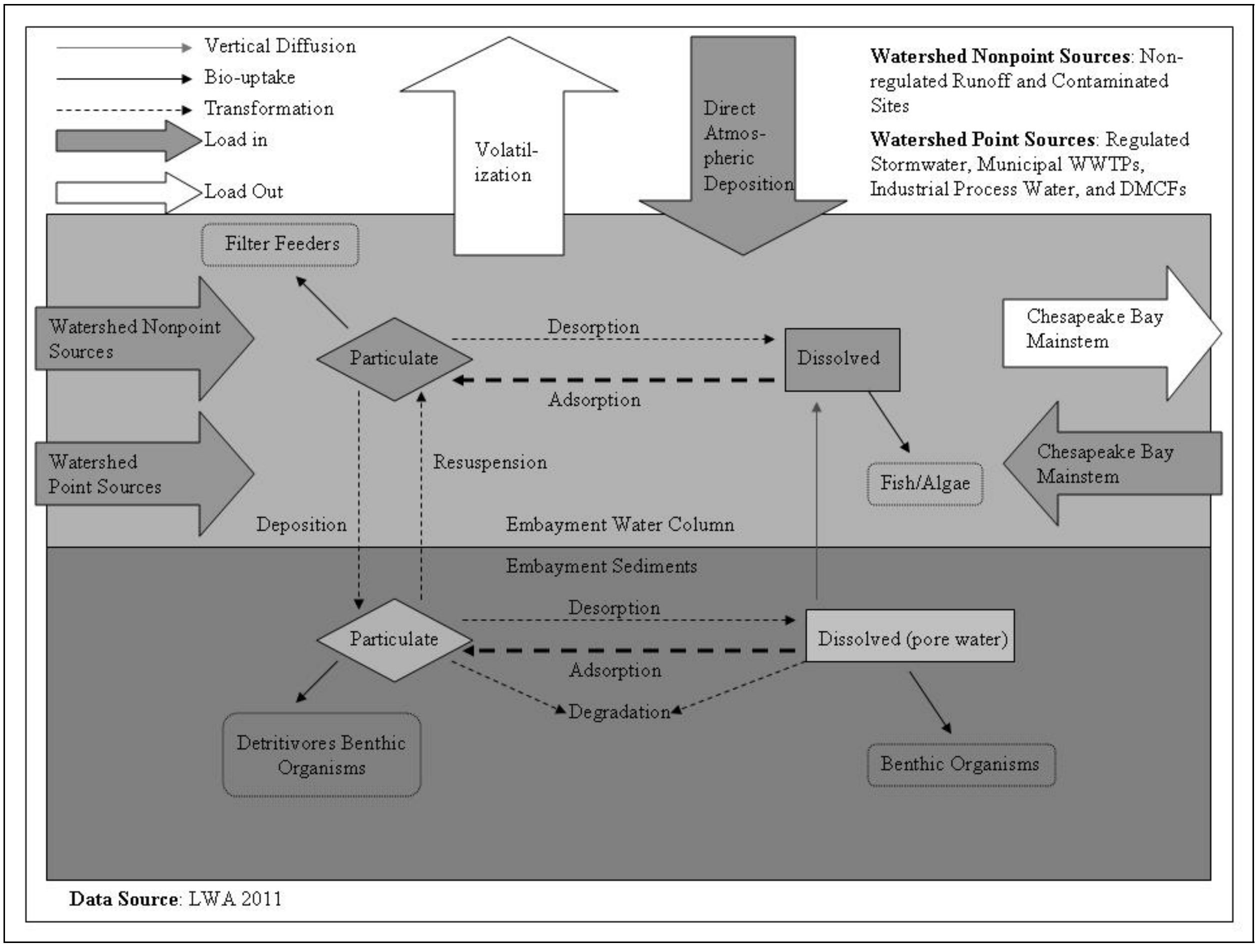


Figure 4: Conceptual Model of the Key Transport and Transformation Processes of PCBs in Surface Water and Bottom Sediments of the Baltimore Harbor Embayment and Entry Points to the Food Chain

4.1 Nonpoint Sources

For the purposes of this TMDL, under current conditions, the following nonpoint sources have been identified: resuspension and diffusion from bottom sediments, direct atmospheric deposition to the embayment, contaminated sites, tidal influence from the Chesapeake Bay mainstem, tributaries outside of the embayment's direct drainage, and runoff from non-regulated watershed areas within the embayment's direct drainage.

<u>Resuspension and Diffusion from Bottom Sediments</u>

Because PCBs tend to bind to the organic carbon fraction of suspended sediment in the water column, which settles to the embayment floor, a large portion of the tPCB loads delivered from various point and nonpoint sources to the embayment will end up in the bottom sediments. This accumulation of PCBs can subsequently become a significant source of PCBs to the water column in the embayment via the disturbance and resuspension of sediments. Dissolved tPCB concentrations in sediment pore water will also diffuse to the water column. The water quality model, using observed tPCB concentrations in the water column and sediment, predicts a net tPCB transport of 9,107.3 g/year entering the Baltimore Harbor embayment from the bottom sediments, which constitutes a significant source of PCBs to the embayment; however, this load contribution is resultant from other point and nonpoint source inputs (both historic and current) within the embayment's watershed. Thus, this source is not considered to be directly controllable (reducible).

Chesapeake Bay Mainstem Tidal Influence

The Baltimore Harbor embayment is highly influenced by tidal exchange of PCBs from the Chesapeake Bay mainstem. A three-layer circulation is well developed in the embayment. Both the upper and lower layers of the embayment are the dominant pathways of transporting pollutants from the Susquehanna River and upper Bay to the embayment. Such transport is intensified during high-discharge periods. The upper layer inflow transports water mass with high concentrations of substances associated with diluted freshwater from the Susquehanna River while the inflow from the lower layer transports water mass and substances from the deep channel of the upper Chesapeake Bay (Hong et al. 2010). The model sensitivity test shows that water column tPCB concentrations in the embayment are highly controlled by the tPCB concentrations in the Upper Bay (see Appendix G). The water quality model, using observed tPCB concentrations measured at the mouth of Baltimore Harbor embayment, predicts an estimated tPCB input and output associated with the flood and ebb tides of 183,548.0 and 184,660.9 g/year, respectively. These loads result in a net tPCB transport of 1,112.9 g/year from the Baltimore Harbor embayment to the Chesapeake Bay mainstem, due to the higher water column concentrations inside the embayment. However, upon reductions to watershed loads and loads from the resuspension and diffusion from bottom sediments, this net transport of PCBs out of the embayment and into the Bay mainstem could shift in the future. Even if this shift occurred though, the load contribution is resultant from historic and present point and nonpoint source inputs throughout the Upper Chesapeake Bay watershed, and it is therefore still not considered to be a directly controllable source (reducible).

Atmosphere Deposition

PCBs enter the atmosphere through volatilization. There is no recent study of the atmospheric deposition of PCBs to the surface of the Baltimore Harbor embayment. CBP's Atmospheric Deposition Study (US EPA 1999) 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. In the Delaware River estuary, an extensive atmospheric deposition monitoring program found PCB deposition rates ranging from 1.3 (non urban) to 17.5 (urban) µg/m^2/year of tPCBs (DRBC 2003). A study in the Baltimore Harbor conducted by Bamford et al. (2002a) estimated deposition ranges from 6 -180 ng/m^2/day, or 2.2 - 65.7 µg/m^2 /year. The District of Columbia's Anacostia PCB TMDL (DC DOH 2003) applied CBP's net atmospheric deposition rate of 16.3 µg/m^2/year in that particular urbanized watershed. Since urban land use comprises the majority of the Baltimore Harbor embayment's watershed (45.1%, see Table 2), the 16.3 µg/m^2/year tPCB depositional rate for urban areas resultant from CBP's 1999 study is within the range of measurements from the Bamford study and thus appropriate for the Baltimore Harbor embayment. Therefore, this value was used in the development of these TMDLs. The direct atmospheric deposition load to the surface of the embayment of 1,360.9

g/year was calculated by multiplying the surface area of the Baltimore Harbor embayment (83.49 km^2) and the deposition rate of 16.3 $\mu g/m^2$/year.

Similarly, the atmospheric deposition load to the embayment's watershed can be calculated by multiplying 16.3 $\mu g/m^2$/year by the embayment's watershed area (total) of 1,491.7 km^2, which results in a load of 24,314 g/year. However, according to Totten et al. (2006), not all of the atmospherically deposited tPCB load to the terrestrial part of the watershed is expected to be delivered to the embayment. Applying the PCB pass-through efficiency estimated by Totten et al. (2006) for the Delaware River watershed of approximately 1%, the atmospheric tPCB load to the Baltimore Harbor embayment from the watershed is approximately 243.1 g/year. This load, however, is inherently modeled as part of the tributary loads or non-regulated watershed runoff/National Pollutant Discharge Elimination System (NPDES) Regulated Stormwater direct drainage loads described below and in Section 4.2.

Watershed Sources

Non-regulated Watershed Runoff

From April 2008 to March 2009, MDE collected monthly water column samples for PCB analysis at four non-tidal monitoring stations in major tributaries draining to the Baltimore Harbor embayment (See Appendix D). Additionally, flow information from the regional USGS gages closest to each non-tidal monitoring station was obtained for each sample date, and the average daily flow was calculated. A tPCB load for each sample was then calculated based on the observed tPCB concentration and average daily flow, and the relationship between loads and flows was developed via regression analysis for each monitoring station. With this relationship, the tPCB load corresponding to any flow can be estimated. Therefore, a load time series was developed using average daily flow information for each station.

The specific non-regulated watershed runoff tPCB load only corresponds to the direct drainage areas of the Baltimore Harbor embayment's watershed. Therefore, the load is based off average daily flow information from USGS gages within these direct drainage areas only. Additionally, the load specifically corresponds to the non-urbanized areas (i.e., primarily forest and agricultural areas) of the embayment's direct drainage. The load associated with the urbanized area of the embayment's direct drainage represents the NPDES Regulated Stormwater tPCB baseline load. The load calculation is described in further detail in Appendix D, and the breakout between the non-regulated watershed runoff tPCB load and the NPDES Regulated Stormwater tPCB baseline load is described in more detail in Section 4.2.

Tributaries

There are three upstream tributaries draining into the Baltimore Harbor embayment (i.e., these freshwater inputs are not considered to be part of the direct drainage to the embayment): the Jones Falls, Gwynns Falls, and Patapsco River Lower North Branch. The baseline tPCB loads from these upstream tributaries are estimated based on the same methodology used to calculate the non-regulated watershed runoff tPCB load. The loads are calculated based on a load time series and average daily flow information from gages within each upstream watershed. These loads are presented as single values, representing the total tPCB load at the outlet of the individual basins. However, they could include both point and nonpoint sources, but for the purposes of this analysis, will be treated as a single nonpoint source load.

Table 4 summarizes the nonpoint source watershed loads to the Baltimore Harbor embayment, Curtis Creek/Bay, and Bear Creek only (i.e., Non-regulated Watershed Runoff and Tributary Sources).

Table 4: Nonpoint Source Watershed tPCB Baseline Loads for the Baltimore Harbor Embayment, Curtis Creek/Bay, and Bear Creek

Impaired Segment	Watershed Source		Baseline Load (g/year)
Baltimore Harbor	Tributaries	Jones Falls[1]	299.34
		Gwynns Falls[1]	541.42
		Patapsco River Lower North Branch[1]	688.85
	Non-regulated Watershed Runoff[2]		362.49
Total			1,892.1
Curtis Creek/Bay	Non-regulated Watershed Runoff[2]		77.19
Bear Creek	Non-regulated Watershed Runoff[2]		26.33

Notes: [1] Although the tributary loads are reported here as a single nonpoint source value, it could include both point and nonpoint source loads.
[2] Load applies to the direct drainage portion of the applicable watershed only.

About 243.1 g/year of the Baltimore Harbor embayment watershed's baseline load is attributed to atmospheric deposition to the land surface of the watershed. The watershed tPCB baseline load calculations for both the direct drainage area and the tributaries accounts for this load from atmospheric deposition, and it is inherently captured within the total watershed baseline load of 1,892.1g/year.

Contaminated Sites

The term 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. A total of four contaminated sites have been identified within the direct drainage area of the Baltimore Harbor embayment's watershed. Table 5 provides information on these sites, and Figure 5 depicts their locations.

The list of sites has been compiled based on information gathered from the EPA's Superfund database and MDE's Land Restoration Program Geospatial Database (LRP-MAP) (US EPA 2011a; MDE 2011c). Five sites have been identified with PCB soil concentrations at or above method detection levels, as determined via soil sample results contained within MDE Land Management Administration's (LMA) contaminated site survey and investigation records. The median tPCB concentration of the site samples was multiplied by the soil loss rate, which is a function of soil type, pervious area, and land cover, to estimate the tPCB edge of field (EOF) load. Since all of the sites were immediately adjacent to the tidal embayment, a sediment delivery ratio of one was applied, and as a result the final edge-of-stream (EOS) load is equivalent to the final EOF load.

The contaminated site tPCB baseline load to the Baltimore Harbor embayment is estimated to be 14.5 g/year. This load is the summation of individual PCB loads from the four identified contaminated sites within the direct drainage area of the Baltimore Harbor embayment's watershed. Two of these sites have already undergone some degree of soil remediation, in which case the estimated tPCB load is reflective of post remediation PCB soil levels. A more detailed description of the methodology used to estimate the contaminated site tPCB baseline load is presented in Appendix J.

Table 5: Summary of Contaminated Site tPCB Baseline Loads

Site Name	Jurisdiction	Site Description	Area (acres)	EOS Load (g/year)
B&O Railroad Landfill	Anne Arundel	No Soil Remediation	305.2	6.16
Crown Central Petroleum	Baltimore City	Minimal Soil Remediation	12.3	0.51
Old Fairfield[1]	Baltimore City	No Soil Remediation	35.1	7.56
Olin Corporation[1]	Baltimore City	Post Soil Remediation	41.0	0.28
Total			**393.6**	**14.5**

Note: [1] Old Fairfield and Olin Corporation are specifically located within the watershed draining to the Curtis Creek/Bay. Thus, the total contaminated site loading to Curtis Creek/Bay is 7.8 g/year.

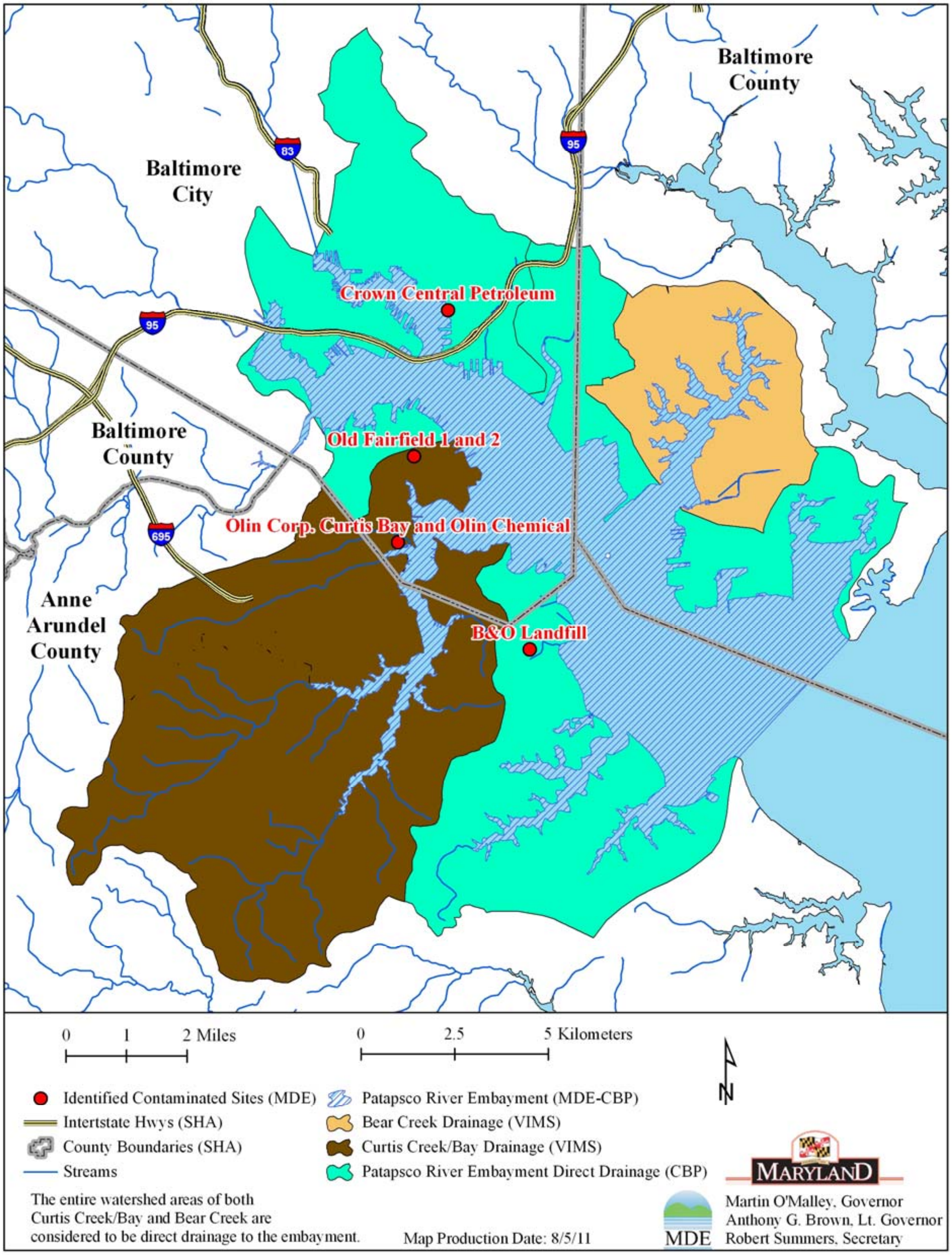


Figure 5: Location of Contaminated Sites in the Direct Drainage Area of the Baltimore Harbor Embayment's Watershed

4.2 Point Sources

Point sources in the direct drainage area to the Baltimore Harbor embayment's watershed include two municipal waste water treatment plants (WWTPs), two dredged material containment facilities (DMCFs), five industrial process water discharges, and stormwater discharges that are regulated under Phase I and Phase II of the NPDES storm water program.

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 NPDES stormwater permits can include the following types of discharges:

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

A list of all the NPDES regulated stormwater permits within the direct drainage area of the Baltimore Harbor embayment's watershed that could potentially convey PCB loads to the embayment has been presented in Appendix H. This section provides detailed explanations regarding the calculation of the point source tPCB baseline loads.

Industrial Process Water Facilities

Five industrial process water facilities have been identified as 1) being located within the direct drainage area of the Baltimore Harbor embayment's watershed, and 2) having the potential to discharge PCBs to the embayment. The industrial process water facilities were identified using guidance developed by Virginia (VA) for monitoring point sources in support of TMDL development. As per VA's guidance, specific types of industrial and commercial operations are more likely than others to discharge PCBs based on historic or current activities. The State 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 within several of VA's PCB TMDLs, which have been approved by the EPA, such as the Roanoke (Staunton) River watershed PCB TMDL (VADEQ 2010). Five industrial process water facilities with an SIC code defined in the VA guidance as having the potential to discharge PCBs were identified within the direct drainage area of the Baltimore Harbor embayments's watershed. Table 6 provides a list of these facilities with their corresponding SIC code information, and Figure 6 depicts the facility locations. Additional facilities were also identified with the potential to discharge PCBs; however, they were considered *de minimis*, as the total average flow for the facilities was below 1.0 Million Gallons per day (MGD).

Table 6: Summary of Industrial Process Water Facilities in the Direct Drainage Area of the Baltimore Harbor Embayment's Watershed

NPDES #	Facility Name	SIC Code	SIC Code Type
MD0001201	RG Steel	3312	Primary Metal Industries
MD0001503	Constellation Power - Fort Smallwood Complex	4931	Electrical Services
MD0001481	Constellation - Riverside Generating Plant	4931	Electrical Services
MD0060640	Wheelabrator Baltimore, LP	4953	Sanitary Services
MD0070041	Constellation Energy Group - Gould Street Generating Plant	4911	Electrical Services

PCB monitoring data is available for two of the five industrial process water facilities, Constellation Power - Fort Smallwood Complex (NPDES: MD0001503) and RG Steel Sparrows Point LLC (NPDES: MD0001201). MDE collected multiple effluent samples for PCB analysis at outfalls 001A of the Constellation facility and outfall 014A for the RG Steel facility in April and May of 2006. The baseline tPCB loads for these facilities were estimated by multiplying the average flows by the average observed tPCB concentrations per facility. To calculate the tPCB baseline loads for facilities without tPCB monitoring data, the individual facilities' average flows were used in conjunction with an average of the observed concentrations at the two monitored facilities.

The aggregate tPCB baseline load for all industrial process water facilities is 859.4 g/year. The average flows and average tPCB concentrations for each individual facility are presented in Appendix L.

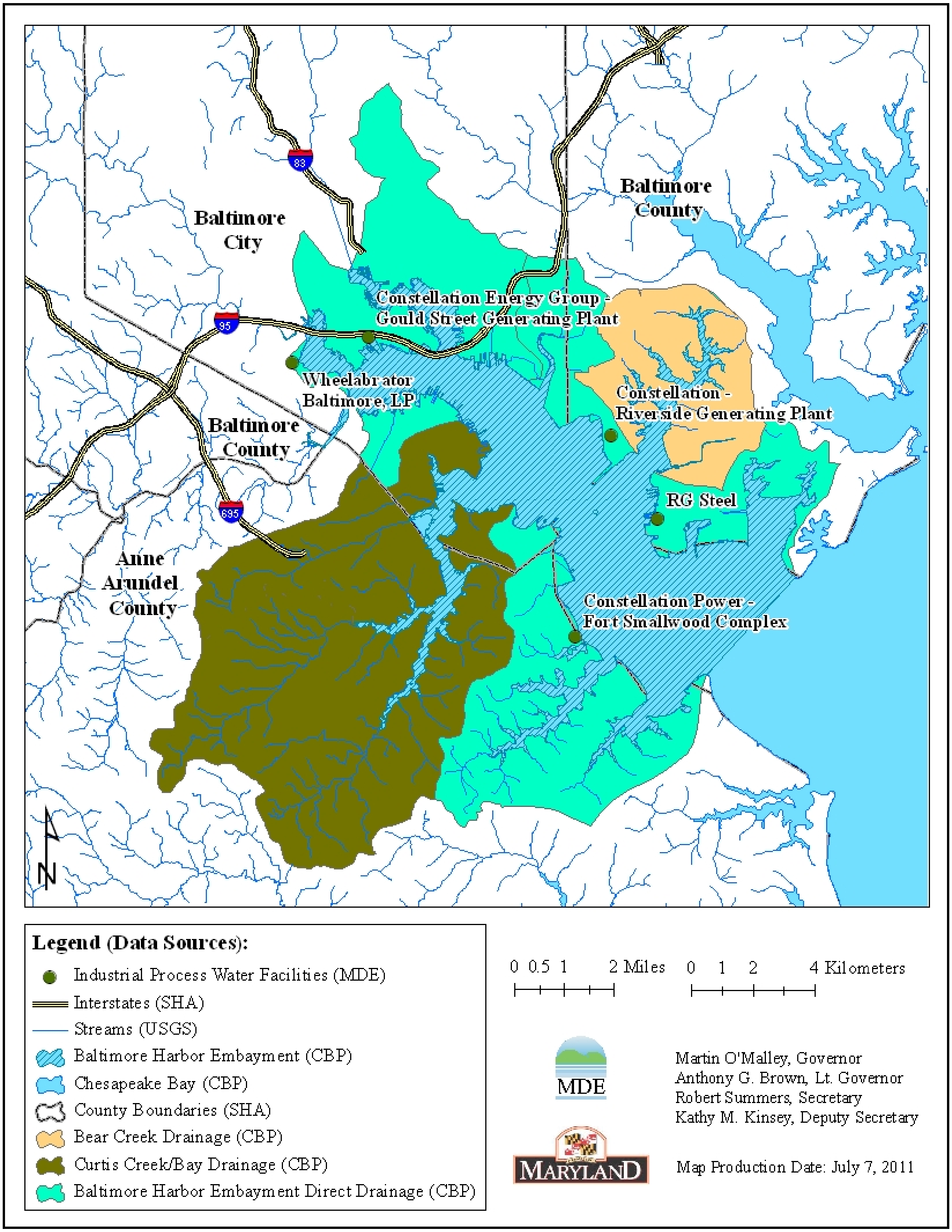


Figure 6: Location of Industrial Process Water Facilities in the Direct Drainage Area of the Baltimore Harbor Embayment's Watershed

Municipal WWTPs

Two municipal WWTPs, Patapsco WWTP (NPDES: MD0021601) and Cox Creek WWTP (NPDES: MD0021661), have been identified within the direct drainage of the Baltimore Harbor embayment's watershed. These WWTPs discharge directly to the embayment (see Figure 7). MDE collected multiple effluent samples for each facility in March and May of 2006 for PCB analysis. The baseline tPCB loading was calculated based on the average discharge flow for the period of March 2010 thru February 2011 and the average observed tPCB concentration. The estimated baseline loads are 32.1 g/year and 334.7 g/year, for the Cox Creek and Patapsco municipal WWTPs, respectively. The average concentration, average flow, and tPCB baseline loading for each facility is presented in Table 7.

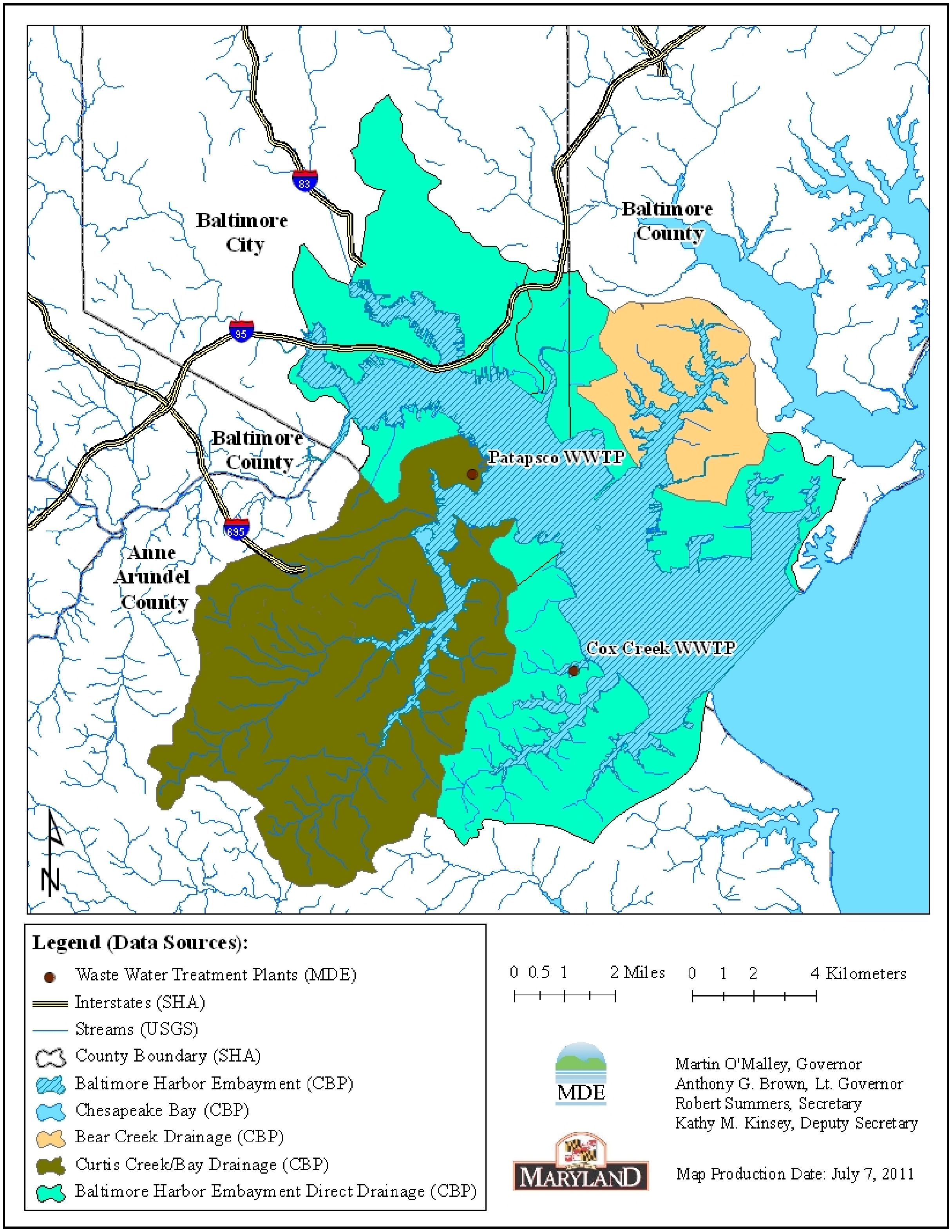


Figure 7: Location of Municipal WWTPs in the Direct Drainage Area of the Baltimore Harbor Embayment's Watershed

Table 7: Summary of Municipal WWTP tPCB Baseline Loads

Facility Name	NPDES #	Jurisdiction	Average Concentration (ng/L)	Average Flow (MGD)	tPCB Baseline Load (g/day)	tPCB Baseline Load (g/year)
Cox Creek WWTP	MD0021661	Anne Arundel County	2.152	10.81	0.09	32.1
Patapsco WWTP	MD0021601	Baltimore City	4.182	57.92	0.92	334.7

DMCFs

Two DMCFs, Masonville (NPDES: MDDRG3650) and Cox Creek (NPDES: MDDRG3424), have been identified within the direct drainage area of the Baltimore Harbor embayment's watershed. These facilities discharge directly to the embayment (see Figure 8). Table 8 lists these facilities with their general identification information. The Masonville DMCF is not yet operational, and tPCB elutriate concentrations reported from Cox Creek DMCF monitoring data are below detection levels. The applied analytical method provides a detection limit that is insufficient for measuring PCBs at levels below the water column TMDL endpoint tPCB concentration. Thus, no measurable tPCB concentration data is available for either of the DMCFs. With no tPCB data available from these facilities, the average value of bottom water column tPCB concentrations from monitoring stations adjacent to the navigational channels in the embayment is applied as a surrogate for elutriate concentrations from these facilities. Bottom water column tPCB concentrations are the best available representation of conditions at the sediment-water interface, which is comparable to elutriate tPCB concentrations produced from the dewatering of dredged material (from the navigational channels) at these containment facilities. A table of bottom water column tPCB concentration data and a figure of sampling locations are presented in Appendix K. The baseline tPCB loads for these facilities were estimated by multiplying the average observed flows (the Cox Creek average flow is also used for the Masonville DMCF, since the facility is not yet operational) by the average value of observed bottom water column tPCB concentrations at monitoring stations adjacent to the navigational channels within the embayment. The aggregate tPCB baseline load for DMCFs is 77.6 g/year. The average flows and average tPCB concentration applied for the facilities are presented in Appendix L. The location of the monitoring stations adjacent to the navigational channels and their associated bottom water column tPCB concentration data are presented in Appendix K.

Table 8: Summary of DMCFs in the Direct Drainage Area of the Baltimore Harbor Embayment's Watershed

Facility Name	NPDES #	Jurisdiction
Masonville DMCF	MDDRG3650	Baltimore City
Cox Creek DMCF	MDDRG3650	Baltimore City

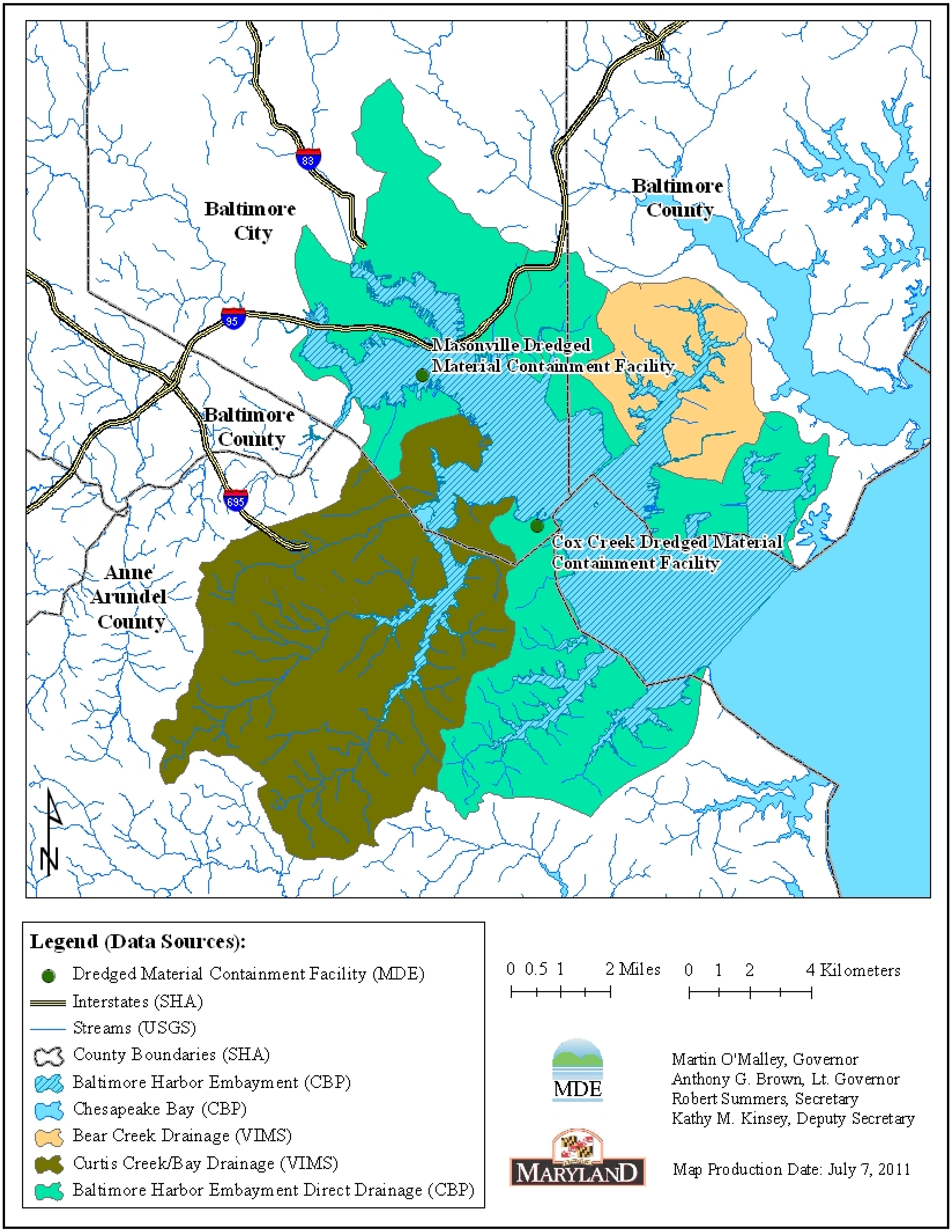


Figure 8: Location of DMCFs in the Direct Drainage Area of the Baltimore Harbor Embayment's Watershed

NPDES Regulated Stormwater

MDE estimates pollutant loads from NPDES regulated stormwater areas based on urban land use 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 direct drainage area of the Baltimore Harbor embayment's watershed spans Anne Arundel County, Baltimore County, and Baltimore City. The NPDES stormwater permits within the direct drainage area of the watershed include: (i) the area covered under the Anne Arundel County, Baltimore County, and Baltimore City Phase I jurisdictional MS4 permits, (ii) the State Highway Administration's (SHA) Phase I MS4 permit, (iii) any state and federal general Phase II MS4s, (iv) industrial facilities permitted for stormwater discharges, and (v) construction sites (see Appendix H for a complete list of NPDES Regulated stormwater permits within the embayment's direct drainage).

The NPDES Regulated Stormwater tPCB Baseline Load was estimated by multiplying the percentage of urban land use within the direct drainage area to each impaired segment by the total watershed baseline load for these direct drainage areas. The remainder of the direct drainage area watershed baseline load per segment is associated with the non-regulated watershed runoff tPCB baseline load (nonpoint source load described in Section 4.1). Since the identified contaminated sites are located within the urban land use area, their total loading (14.5 g/year) is subtracted from the NPDES Regulated Stormwater tPCB baseline loads, resulting in final NPDES Regulated Stormwater tPCB Baseline Loads of 1,624.5, 383.9, and 322.9 g/year, for the Baltimore Harbor embayment, Curtis Creek/Bay, and Bear Creek, respectively. Table 9 lists the aggregate NPDES Regulated Stormwater tPCB Baseline Loads for each impaired segment, subdivided by jurisdiction (Baltimore County, Anne Arundel County, and Baltimore City).

Table 9: Summary of NPDES Regulated Stormwater tPCB Baseline Loads

Impaired Segment	Jurisdiction	tPCB Baseline Load (g/year)[1]
Bear Creek	Baltimore County	322.85
Curtis Creek/Bay	Anne Arundel County	357.68
	Baltimore City	26.22
	Total	**383.89**
Baltimore Harbor	Anne Arundel	850.74
	Baltimore County	338.50
	Baltimore City	435.27
	Total	**1,624.58**

Notes: [1] The load per jurisdiction represents an aggregation of loads from all of the permitted stormwater entities within the jurisdiction.

4.3 Source Assessment Summary

Point and nonpoint sources of PCBs have been identified and estimated throughout the Baltimore Harbor embayment's watershed. Point sources include NPDES Regulated Stormwater, two municipal WWTPs, two DMCFs, and five industrial process water facilities. Additional industrial facilities with the potential to discharge PCBs to the embayment were also identified; however, they were considered de minimis, since their total average flow was less than 1.0 MGD. Nonpoint sources include resuspension and diffusion from bottom sediments, direct atmospheric deposition to the embayment, non-regulated watershed runoff, identified contaminated sites, and the tidal influence from the Chesapeake Bay mainstem. Estimated tPCB loads from these point and nonpoint sources represent the baseline conditions for the impaired segments of the embayment.

Tables 10, 11, and 12 summarize the total baseline tPCB loads to the Baltimore Harbor embayment, Curtis Creek/Bay, and Bear Creek. As explained in Section 4.1, since the loads from resuspension and diffusion from bottom sediments are not considered to be directly controllable (reducible) within the framework of the TMDL, they are not included in the tPCB baseline load summaries. Additionally, since 1) the tidal influence from the Chesapeake Bay mainstem does not contribute tPCB loads to the embayment under current conditions, and 2) the source is not considered to be directly controllable (reducible) within the framework of this TMDL, it is not included in the tPCB baseline load summary.

Table 10: Summary of tPCB Baseline Loads in the Baltimore Harbor Embayment

PCB Source	Baseline Load (g/year)	Percent of Total Baseline Load (%)
Direct Atmospheric Deposition (to the Surface of the Embayment)	1,360.88	22.0
Tributaries[1]		
Jones Fall	299.34	4.8
Gwynns Fall	541.42	8.7
Patapsco River Lower North Branch	688.85	11.1
Non-regulated Watershed Runoff[2]	362.49	5.9
Contaminated Sites	14.51	0.2
Nonpoint Sources	***3,267.49***	***52.7***
Industrial Process Water	859.38	13.9
WWTPs	366.81	5.9
DMCFs	77.60	1.3
NPDES Regulated Stormwater[2,3]		
Anne Arundel County	850.74	13.7
Baltimore County	338.50	5.5
Baltimore City	435.27	7.0
Point Sources	***2,928.31***	***47.3***
Total	**6,195.79**	**100.0**

Notes: [1] Although the tributary loads are reported here as a single nonpoint source value, they could include both point and nonpoint source loads.
[2] Load applies to the direct drainage portion of the applicable watershed only.
[3] Load per jurisdiction applies to all NPDES stormwater dischargers within the direct drainage area of the jurisdiction to the Baltimore Harbor embayment. These dischargers are identified in Appendix H.

Table 11: Summary of tPCB Baseline Loads in the Curtis Creek/Bay

PCB Source[1]	**Baseline Load (g/year)**	**Percent of Total Baseline Load (%)**
Direct Atmospheric Deposition (to the Surface of the Embayment)	121.26	20.5
Non-regulated Watershed Runoff[2]	77.19	13.1
Contaminated Sites	7.84	1.3
Nonpoint Sources	***206.29***	***35.0***
Industrial Process Water[3]	-	-
WWTPs[3]	-	-
DMCFs[3]	-	-
NPDES Regulated Stormwater[2,4]		
Anne Arundel County	357.68	60.6
Baltimore City	26.22	4.4
Point Sources	***383.89***	***65.0***
Total	**590.18**	**100.0**

Notes: [1] None of the upstream tributaries (i.e., Jones Falls, Gwynns Falls, and the Patapsco River Lower North Branch) drain directly into Curtis Creek/Bay.
[2] Load applies to the direct drainage portion of the applicable watershed only.
[3] No industrial process water facilities, WWTPs, or DMCFs have been identified in the applicable watershed.
[4] Load per jurisdiction applies to all NPDES stormwater dischargers within the direct drainage area of the jurisdiction to Curtis Creek/Bay. These dischargers are identified in Appendix H.

Table 12: Summary of tPCB Baseline Loads in the Bear Creek

PCB Source[1]	Baseline Load (g/year)	Percent of Total Baseline Load (%)
Direct Atmospheric Deposition (to the Surface of the Embayment)	79.32	18.5
Non-regulated Watershed Runoff[2]	26.33	6.1
Contaminated Sites[4]	-	-
Nonpoint Sources	***105.65***	***24.7***
Industrial Process Water[3]	-	-
WWTPs[4]	-	-
DMCFs[4]	-	-
NPDES Regulated Stormwater[2]		
Baltimore County[5]	322.85	75.3
Point Sources	***322.85***	***75.3***
Total	**428.50**	**100.0**

Notes: [1] None of the upstream tributaries (i.e., Jones Falls, Gwynns Falls, and the Patapsco River Lower North Branch) drain directly into Bear Creek.
[2] Load applies to the direct drainage portion of the applicable watershed only.
[3] One outfall from the RG Steel facility discharges to Bear Creek. However, this facility falls under an aggregate baseline load for all industrial process water discharges, which is accounted for in the TMDL for the Baltimore Harbor embayment. An individual baseline load for this outfall will therefore not be presented in this table.
[4] No industrial process water facilities, WWTPs, DMCFs, or contaminated sites have been identified in the applicable watershed.
[5] Load applies to all NPDES stormwater dischargers within the direct drainage area of the jurisdiction to Bear Creek. These dischargers are identified in Appendix H.

5. TOTAL MAXIMUM DAILY LOADS AND LOAD ALLOCATION

5.1 Overview

A TMDL is the total amount of an impairing substance that a waterbody can receive and still meet WQSs. The TMDL may be expressed as a mass per unit time, toxicity, or other appropriate measure and should be presented in terms of WLAs, load allocations (LAs), and either an implicit or explicit margin of safety (MOS) (CFR 2011a):

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

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

5.2 Analysis Framework

An integrated modeling approach was used for this TMDL study. The model framework includes hydrodynamics, eutrophication, sorbent dynamics between PCBs and organic carbon (OC), and PCB transport and fate. The conceptual basis of the model is that the transport and fate of PCBs is strongly influenced by adsorption to OCs and exchanges between the water column and bottom sediments (Zhang et al. 2008, 2009). The EFDC (Environmental Fluid Dynamic Computer Code) (Hamrick 1992; Park et al. 1995) was used for the model framework and for model simulations. The EFDC is a general purpose modeling tool for simulating 1, 2, and 3 dimensional flow and transport in surface water systems, including rivers, lakes, estuaries, reservoirs, wetlands, and oceanic coastal regions. The EFDC model has been integrated into the EPA's TMDL Modeling Toolbox for the support of TMDL development (US EPA 2011b). The model simulates surface water elevation, currents, salinity, and suspended sediment. The eutrophication submodel is identical to the Chesapeake Bay eutrophication model, which is capable of simulating OCs (particulate and dissolved) and phytoplankton. The EFDC toxic submodel is based on the adsorption-desorption processes of suspended sediment. This submodel was revised to use OCs as sorbents based on the model developed for Lake Michigan by Zhang et al. (2008, 2009), which was recently applied in the Potomac River PCB TMDL study (Haywood and Buchanan 2007). The hydrodynamic model provides a dynamic transport field for the eutrophication submodel and PCB submodel, while OC species simulated by the eutrophication model are linked to the PCB model. The PCB submodel simulates processes of adsorption/desorption, volatilization, suspension/diffusion, settling between water-sediment interfaces, atmospheric deposition, transport of point and nonpoint sources, and transport between the Baltimore Harbor embayment and the upper Chesapeake Bay/Chesapeake Bay mainstem. Figure 9 depicts the model framework. More detailed model descriptions are presented in Appendices F and G.

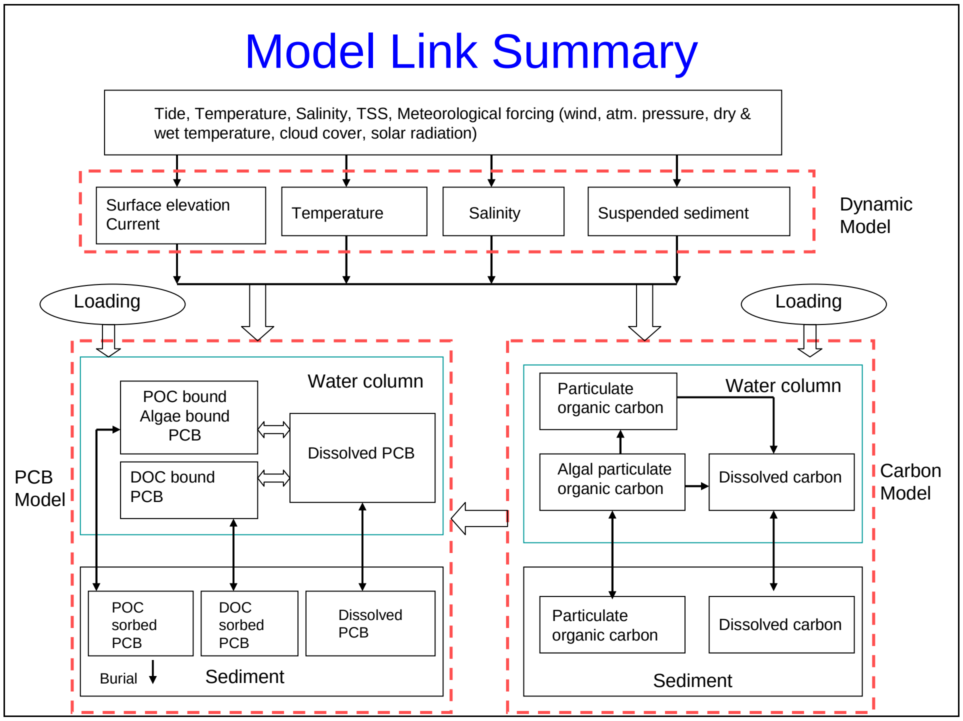


Figure 9: PCB Model Framework Diagram

In order to accurately simulate the hydrodynamics of the Baltimore Harbor embayment and OC species, while overcoming the influence of the boundary condition between the embayment and the Chesapeake Bay mainstem, the model domain encompasses the upper Chesapeake Bay. Furthermore, the model's open boundary is located at the mainstem of the Bay near the mouth of the Patuxent River, where observations of tide, salinity, temperature, and water quality variables are available for the model boundary conditions. The carbon model was calibrated for a three-year period from 1996-1998, which are wet, dry, and mean water years. The Chesapeake Bay watershed model outputs were used to specify flows and nutrient and carbon loads from the embayment's watershed. A small domain model, which only encompasses the Baltimore Harbor embayment, was used to simulate PCBs, so that PCB concentrations at the open boundary condition can be appropriately modeled using observed data. Based on data analysis, a strong correlation exists between tPCBs and the summation of the tetra-, penta-, and hexa-PCBs, since these three homologs are dominant in water column, sediment, and fish tissue PCB concentrations. Therefore, model simulations of tetra-, penta-, and hexa-PCBs were conducted, and the sum of the three were converted to tPCB using the relationship established using the observed data in the embayment. This approach enabled the model's kinetic parameters to be specified appropriately. A large amount of data collected between 1996-2008 were used for the model set up, and the model was calibrated for tetra-, penta-, and hexa-PCBs based on the intensive field survey in 1997. The model calibration demonstrates that it is capable of effectively simulating PCBs, and is therefore supportive of TMDL development in the Baltimore Harbor embayment.

In order to assess the attainment of the TMDL endpoints for tPCBs in both the water column and sediment, the Baltimore Harbor embayment was divided into 11 segments (see Figure 10). The average annual tPCB concentrations in both the water column and bottom sediments within each segment were required to meet the endpoints established in this TMDL (see Section 3). The hydrological sequence used the mean flow year of 1998 to run the model repeatedly for 60-80 years. Different scenarios were conducted. Loads from point and nonpoint sources were reduced until the endpoints were met in each segment. The results indicated that when the water column TMDL endpoint tPCB concentration (0.27 ng/L) was met, the sediment tPCB concentration was still higher than the site-specific sediment TMDL endpoint tPCB concentration (3.1 ng/g). Approximately 60 years were required for the bottom sediment to meet the endpoint, given the mean hydrological condition. A load reduction of 91.5% from watershed point and nonpoint sources, with slight variations in the regulated stormwater sector due to the locations of the contaminated sites, and 57.6% from atmospheric deposition are required to meet both the water column and sediment TMDL endpoints.

Relative to the tidal influence from the Chesapeake Bay mainstem and Upper Chesapeake Bay, the Susquehanna River is the major freshwater input, and as a result the major source of PCBs, to the upper Bay (Ko and Baker 2004). It takes less than 30 days for water and dissolved substances from the Susquehanna River travel to the mouth of the Baltimore Harbor embayment during a high flow period (Hong et al. 2010). In order to determine the temporal changes in tPCB loads from the Susquehanna River to the Upper Chesapeake Bay, Ko and Baker (2004) measured tPCB concentrations downstream of the Susquehanna River and compared their results with those reported by Foster et al. (2000) and Godfrey et al. (1995). According to this analysis, flow normalized tPCB loads decreased from 37 kg/m^3/year in 1992 to 24 kg/m^3/year in 1998. Based on these results, it is estimated that on average the tPCB concentrations in the Upper Chesapeake Bay are decreasing at a rate of 6.5% per year. Due to the interactions between the water column and bottom sediments and additional sources from lateral adjacent watersheds, the PCB attenuation rate near the mouth of the Baltimore Harbor embayment may deviate from this value. Freshwater flow from the Susquehanna River will only account for a portion of the water that transports across the boundary of the Baltimore Harbor embayment under tidal influence. No historical data is currently available at the boundary to estimate the rate of decline, though water quality data for sediments and water column in the embaymnent from 2000 and 2008 demonstrate that PCB concentrations are declining over time. Figures depicting this information are presented in Appendix K. Thus, it was assumed within the model that boundary condition tPCB concentrations between the embayment and the Chesapeake Bay mainstem will, as a conservative estimate, decrease at a rate of 5%, following the current trend but taking into consideration specific conditions within the embayment. This annual 5% decline in concentrations per year equates to a 90% reduction within 35-45 years. A time series of average annual tPCB concentrations in the water column and sediment for the Baltimore Harbor embayment, based on a model run applying the natural rate of decline as well as the point and nonpoint source load reductions necessary to achieve the TMDL, is presented in Figure 11.

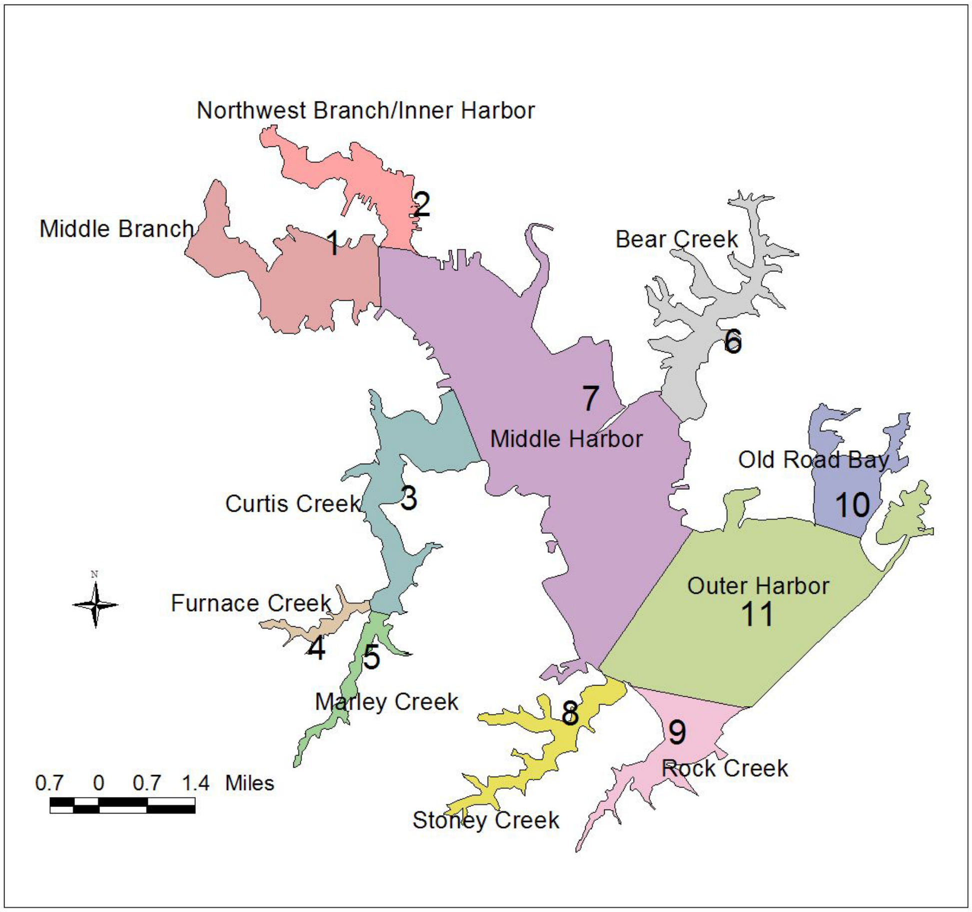
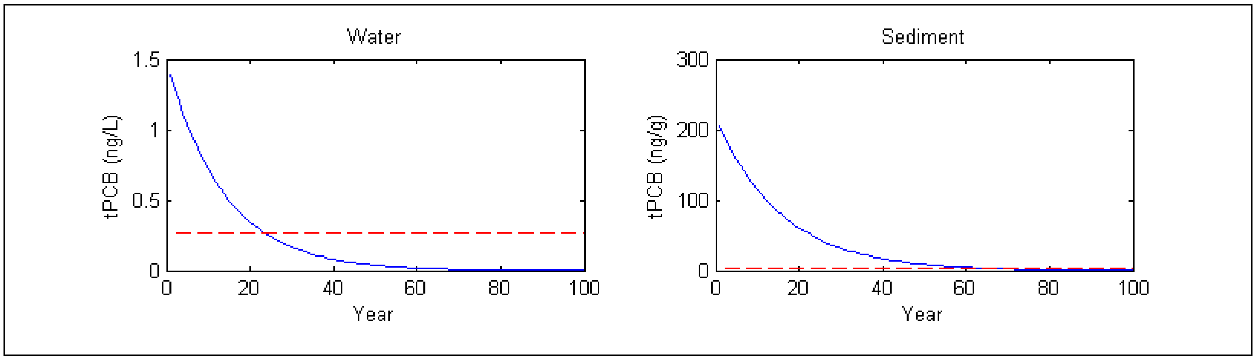


Figure 10: Segmentation Used to Assess the Attainment of TMDL endpoints in the Baltimore Harbor Embayment



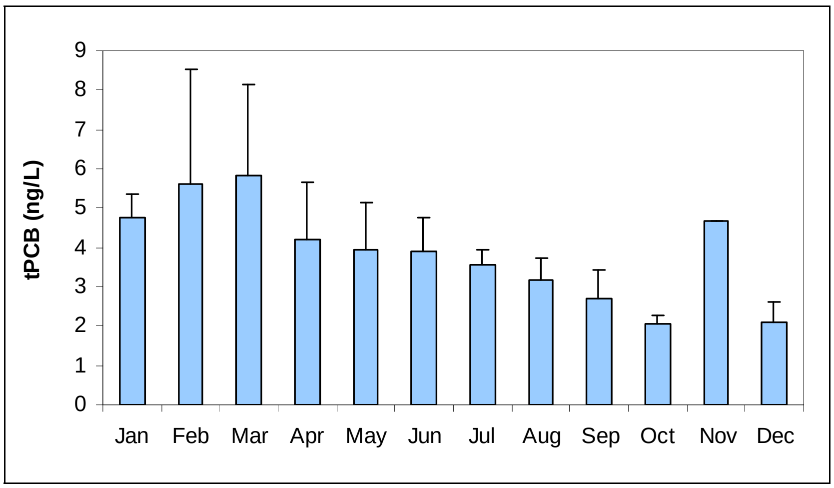
Note: Dashed line indicates water column and sediment targets. Model run incorporates 5% natural rate of decline as well as the point and nonpoint source load reductions necessary to achieve the TMDL endpoints

Figure 11: TMDL Time-Series for Average Water Column and Bottom Sediment tPCB Concentrations Within the Baltimore Harbor Embayment

5.3 Critical Condition and Seasonality

Federal regulations require that TMDL analysis take into account the impact of critical conditions and seasonality on water quality (CFR 2011b). The intent of this requirement is to ensure that the water quality is protected during the most vulnerable times.

Water column tPCB concentration data is available at over 30 stations throughout the Baltimore Harbor embayment. The month and year in which the data was collected for these stations varies dramatically. Therefore, it would not be reasonable to assess seasonality based on monthly averages of tPCB concentrations for all stations. A seasonality analysis was conducted, however, for the Key Bridge monitoring station, located in the Middle Branch of the Baltimore Harbor, which contains PCB water column data for every month of the year. The average monthly concentrations for this station are displayed in Figure 12, which indicates that the tPCB concentrations spike during the winter and spring months. The increase in concentration for November is likely the result of limited sample size, as only a single concentration was measured.



Note: Error bar denotes the standard deviation.

Figure 12: Seasonality Analysis of tPCB Concentrations at the Key Bridge Monitoring Stations in the Middle Branch of the Baltimore Harbor.

The TMDLs are protective of human health at all times; thus, they implicitly account for seasonal variations as well as critical conditions. Seasonality is accounted for within the model simulation, since it is run for one full year, representative of average annual flow, with multiple iterations, which account for seasonal changes in the hydrologic and hydrodynamic conditions. Also, since PCB levels in fish tissue become elevated due to long-term exposure it has been determined that the selection of the average annual tPCB water column and sediment concentrations within each impaired segment for comparison to the endpoints applied within the TMDLs adequately considers the impact of seasonal variations and critical conditions on the "fishing" designated use in the Baltimore Harbor embayment, Curtis Creek/Bay, and Bear Creek. Furthermore, the water column TMDL endpoint tPCB concentration is lower than the current human health criterion for fish consumption. The water column TMDL endpoint tPCB concentration is also more protective of water quality than the freshwater and saltwater chronic criteria tPCB concentrations, which are necessary to protect aquatic life. In addition, the sediment TMDL endpoint tPCB concentration is also lower, and thus more conservative, than the TEL, which is protective of benthic aquatic life.

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 2011b). 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 TMDLs established to meet the "fishing" designated use in the Baltimore Harbor embayment.

5.4.1 Wasteload Allocations

Industrial Process Water Facilities

Five industrial process water facilities have been identified as 1) being located within the direct drainage area of the Baltimore Harbor embayment's watershed, and 2) having the potential to discharge PCBs to the embayment. A list of these facilities was presented in Table 6 of Section 4.2. The aggregate tPCB baseline load for industrial process water facilities is 859.4 g/year, which is calculated by multiplying the average observed flows by the average observed tPCB concentrations per facility. The average flows and average tPCB concentrations for each individual facility are presented in Appendix L.

The WLAs for the industrial process water facilities are calculated by multiplying the water column TMDL endpoint tPCB concentration of 0.27 ng/L by the average observed flows for the facilities. For the RG Steel facility, a portion of the intake water used in facility operations is routed from the Back River WWTP. The Back River WWTP is located in the watershed draining to Back River Oligohaline Tidal Chesapeake Bay Segment (also referred to as an embayment). The WWTP has two outfalls, 001 and 002. Outfall 001 discharges to the Back River embayment, and an allocation has been assigned to the outfall within the Back River embayment PCB TMDL (MDE 2011d). However, the entirety of the effluent from Outfall 002 is routed to RG Steel, for use in its industrial processes. Therefore, a portion of the WLA for RG Steel is accounted for by the Back River WWTP Outfall 002 effluent. The specific portion of the RG Steel WLA accounted for by the effluent from the Back River WWTP Outfall 002 is based on the water column TMDL endpoint tPCB concentration of 0.27 ng/L and the design flow of the WWTP allocated to the outfall of 50 MGD. The aggregate tPCB WLA for all industrial process water facilities is 498.6 g/year, which constitutes a 42.0% reduction from baseline conditions. Once again, the average flows for each industrial process water facility are presented in Appendix L. There are currently no effluent PCB limits established in discharge permits for industrial process water facilities. The inclusion of a WLA in this document does not reflect any determination to impose an effluent limit in future permits.

Industrial facilities in the Baltimore Harbor embayment's watershed typically withdraw water from the embayment itself or nearby WWTPs for use in their cooling water operations and plant processes. As documented in this TMDL, WWTP effluent and the water column of the Baltimore

Harbor embayment contain elevated levels of PCBs. Further characterization of industrial process water facility tPCB baseline loads will need to be conducted within the initial stages of the implementation process, since the current load estimation is based on limited tPCB monitoring data from only two facilities [RG Steel (NPDES: MD0001201) and Constellation Power – Fort Small Wood Complex (NPDES: MD0001503)]. The baseline loads for the additional three industrial process water facilities are estimated by applying the average tPCB concentration from the two monitored facilities. Additionally, measurement of influent concentrations will allow for an estimation of the direct PCB contribution from the facility and a subsequent correction of the tPCB baseline load calculations. Facilities that withdraw water from the Baltimore Harbor embayment and do not contribute additional PCBs to the system would not be in violation of the WLA, since the source of PCBs in their effluent would be due to pass-through conditions. Facilities that withdraw water directly from WWTP effluent will be accounted for under the WLA assigned to the WWTP (either partially or fully, dependant on if their intake water is partially of fully withdrawn from the WWTP), and if they do not contribute additional PCBs to the system, they would not be in violation of the WLA, since the PCB levels in their discharge should be equivalent to levels in their intake water from the WWTP. MDE is currently collecting samples from four of the industrial process water facilities with the largest average flows (i.e., > 50 MGD). Both influent and effluent concentrations will be measured as a part of this study.

Municipal WWTPs

Two municipal WWTPs, Cox Creek WWTP (NPDES: MD0021661) and Patapsco WWTP (NPDES: MD0021601), have been identified within the direct drainage of the Baltimore Harbor embayment's watershed. The estimated tPCB baseline loads are 32.1 g/year and 334.7 g/year for the Cox Creek and Patapsco municipal WWTPs, respectively, which were calculated based on the average discharge flows for the period of March 2010 thru February 2011 and the average observed tPCB concentrations per facility. The WLAs are calculated based on the water column TMDL endpoint tPCB concentration of 0.27 ng/L and the current design flows for the facilities. The WLAs are presented in Table 13. The elevated tPCB concentrations in municipal wastewater are believed to be primarily due to external sources (e.g., source water, atmospheric deposition, and stormwater runoff) infiltrating the wastewater collection system through broken sewer lines and connections. Additionally, these facilities are currently installing advanced treatment technologies, which will improve the removal efficiency of organic compounds, including PCBs, in their treatment process. These improvements will further reduce the existing tPCB baseline loads, thus making progress towards meeting the load reduction required to achieve the WLA. There are currently no effluent PCB limits established in the discharge permits for municipal WWTPs. Inclusion of a WLA in this document does not reflect any determination to impose an effluent limit in future permits.

Table 13: Summary of Municipal WWTP tPCB WLAs, Baseline Loads, and Load Reductions

Facility Name	NPDES #	tPCB Water Column TMDL Endpoint (ng/L)	Design Flow (MGD)	tPCB WLA (g/year)	tPCB Baseline Load (g/year)	tPCB Reduction (%)
Cox Creek WWTP	MD0021661	0.27	15.0	5.6	32.1	82.6
Patapsco WWTP	MD0021601	0.27	73.0	27.2	334.7	91.9

Further characterization of the municipal WWTP baseline loads will need to be conducted through the NPDES permitting implementation process, since the current load estimation is based on limited tPCB data from the plants' effluent. With additional information, along with current WWTP Enhanced Nutrient Removal (ENR) upgrades, more accurate tPCB loads from these facilities can be estimated, which may result in a change to the overall reduction.

DMCFs

Two DMCFs, Masonville (NPDES: MDDRG3650) and Cox Creek (NPDES: MDDRG3424), have been identified within the direct drainage area of the Baltimore Harbor embayment's watershed. The aggregate tPCB baseline load for the DMCFs is 77.6 g/year. The baseline tPCB loads for these facilities were estimated by multiplying the average observed flows (the Cox Creek average flow is also used for the Masonville DMCF, since the facility is not yet operational) by the average observed value of the bottom water column tPCB concentrations at monitoring stations adjacent to the navigational channels within the embayment. The average flows and average tPCB concentration applied for the facilities are presented in Appendix L. The location of the monitoring stations adjacent to the navigational channels and their associated bottom water column concentration data are presented in Appendix K (see also Section 4.2 for further details).

These facilities are responsible for the disposal and containment of contaminated sediments dredged from navigation channels within the Baltimore Harbor embayment. The navigation channels will fill in with sediment over time, thus requiring dredging to maintain acceptable depths for shipping traffic to the Port of Baltimore. Even though PCBs preferentially bind to sediment, discharges from these facilities are expected to contain PCBs due to the diffusion and desorption of PCBs from these sediments. These facilities do not have the capability to treat their discharges for PCBs, but any PCBs in their discharges are due to PCBs in the bottom sediments that were dredged, indicating a pass through condition (i.e., no additional PCBs are generated during the containment process, similar to the industrial process water facilities). In addition, these two facilities will receive 1.0 million cubic yards of maintenance dredged material on an annual basis, which will sequester a significant mass of PCBs bound to the contaminated sediment. Therefore, the WLA for these DMCFs will be set equivalent to their estimated tPCB baseline load. At this time, there are no alternative options for disposal of dredged material from this embayment. The aggregate allocation assigned to DMCFs accounts for PCBs released during regular operations from all current and future containment facilities within the Baltimore Harbor embayment. As current facilities reach full containment capacity, these facilities need to be closed, and new facilities opened. The aggregate allocation accounts for this change-over in containment facilities within the embayment.

Further characterization of the DMCF baseline loads will need to be conducted within the initial stages of the implementation process via methods that have appropriate detection levels (described below), since the current load estimation is based on surrogate tPCB data representative of elutriate concentrations. With additional information, more accurate tPCB loads from these facilities can be estimated.

For municipal WWTPs, industrial process water facilities, and DMCFs, congener specific analytical methods should be used when collecting future samples from these facilities. 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. Other methods deemed appropriate, and approved in advance by the permitting authority, could also be used. In establishing the necessity and extent of data collection, MDE will take into account data that is already available, as well as the proper characterization of intake (or pass through) conditions, consistent with NPDES program "reasonable potential" determinations and the applicable provisions of the Environment Article and the Code of Maryland Regulations (COMAR) for permitted facilities, including regulated stormwater.

NPDES Regulated Storm Water

Per EPA Requirements, "storm water discharges that are regulated under Phase I or Phase II of the NPDES stormwater program are point sources that must be included in the WLA portion of a TMDL". EPA recognizes that available data and information are usually not detailed enough to determine WLAs for NPDES regulated stormwater discharges on an outfall-specific basis (US EPA 2002). Therefore, NPDES regulated stormwater allocations to the direct drainage of the Baltimore Harbor embayment's watershed will be expressed as a single, aggregate WLA for each county (or local political jurisdiction, i.e., Baltimore City). Upon approval of the TMDLs, "NPDES-regulated municipal stormwater and small construction storm water discharges effluent limits should be expressed as Best Management Practices (BMPs) or other similar requirements, rather than as numeric effluent limits" (US EPA 2002).

The NPDES Regulated Stormwater WLAs were established by reducing the NPDES Regulated Stormwater Baseline Loads proportionally to the Non-regulated Watershed Runoff Baseline Loads, after the WLAs for the remaining source sectors were set, until the TMDL was achieved. For more information on methods used to calculate the NPDES Regulated Stormwater PCB Baseline Loads, please see Section 4.2. The NPDES Regulated Stormwater WLAs may include any or all of the NPDES stormwater discharges listed in Section 4.2 (see Appendix H for a complete list of stormwater permits within the embayment's direct drainage). As stormwater assessment and/or other program monitoring efforts result in a more refined source assessment, MDE reserves the right to revise the current NPDES Regulated Stormwater WLA provided the revisions are protective of the "fishing" designated use in the Baltimore Harbor embayment.

The NPDES Regulated Stormwater Baseline Loads to the Baltimore Harbor embayment, Curtis Creek/Bay, and Bear Creek constitute a large portion of the total baseline load to the embayment, and they therefore require a 91.5% reduction, with slight variations due to the locations of the contaminated sites. The NPDES Regulated Stormwater WLAs are 126.4, 26.1, and 27.6 g/year, respectively, for the Baltimore Harbor embayment, Curtis Creek/Bay, and Bear Creek. Table 14 lists the aggregate NPDES Regulated Stormwater WLAs for each impaired segment subdivided by jurisdiction (Baltimore County, Anne Arundel County, and Baltimore City).

Table 14: Summary of NPDES Regulated Stormwater tPCB Baseline Loads, WLAs, and Load Reductions

Impaired Segment	Jurisdiction	tPCB Baseline Load (g/year)	tPCB WLA (g/year)	tPCB Reduction (%)[1]
Bear Creek	Baltimore County	322.85	27.60	91.5
Curtis Creek/Bay	Anne Arundel	357.68	23.13	93.5
	Baltimore City	26.22	2.91	88.9
	Total	**383.89**	**26.05**	93.2
Baltimore Harbor	Anne Arundel	850.74	66.97	92.1
	Baltimore County	338.50	28.94	91.5
	Baltimore City	435.27	30.44	93.0
	Total	**1,624.51**	**126.35**	92.2

Note: [1] The load per jurisdiction represents an aggregation of loads from all of the permitted stormwater entities within the jurisdiction.

5.4.2 Load Allocations

LAs have been assigned to the following nonpoint sources in order to meet the "fishing" designated use in the Baltimore Harbor embayment: direct atmospheric deposition to the surface of the embayment, upstream tributaries, and non-regulated watershed runoff (direct drainage area only). The model results show that in order to meet the "fishing" designated use in the embayment, load reductions of 57.6% from atmospheric deposition as well as 91.5% from direct drainage non-regulated watershed runoff and upstream tributaries are required. A smaller reduction for atmospheric deposition is required since it has a much smaller impact on water quality than the watershed land sources. The atmospherically deposited load is evenly distributed over the surface water of the entire embayment. However, watershed sources will vary, relative to their impact on water quality, throughout the embayment, thus resulting in higher tPCB concentrations in specific portions of the embayment, thereby requiring a greater reduction to achieve the TMDL condition. Given that a number of contaminated sites have already undergone some degree of remediation and their baseline loads constitute a relatively small percentage of the Total Baseline Load (0.2% - Baltimore Harbor Embayment; 1.3% - Curtis Creek/Bay), these sites were currently not subjected to any reductions. Loads from resuspension and diffusion from bottom sediments and the tidal influence from the Chesapeake Bay mainstem needed to be included within the model to predict tPCB concentrations within the embayment; however, the load from resuspension and diffusion from the bottom sediments is not deemed to be directly controllable within the framework of the TMDL. Therefore, this source will not be assigned an allocation or a required reduction. Also, the tidal influence from the Chesapeake Bay mainstem is neither a current source of PCBs to the embayment under current conditions, nor is it deemed to be directly controllable within the framework of the TMDL. Therefore, this source will also not be assigned an allocation or a required reduction. These loads are expected to reduce over time via natural attenuation, as evidenced by the observed decrease in tPCB concentrations in both the Upper Chesapeake Bay and at the tidal boundary between the embayment and the Bay mainstem.

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.

A large uncertainty in model predictions can be expected due to the uncertainties inherited in model parameters, forcing conditions in the model, and the limited data set applied within the model. To assess model uncertainty, a sensitivity analysis was conducted to evaluate the effects of changes in model forcing, model parameters, and external loads on the model results. The sensitivity analysis can provide information on whether or not model predictions are reliable given the uncertainties in the model parameters, model forcing conditions, and loads. A total of five sensitivity analysis simulations were conducted to identify individual model forcing conditions and model parameters on model predictions. The sensitivity analysis simulation details and results are presented in Appendix G. Based on this model sensitivity test, MDE applied an explicit 5% MOS to account for uncertainty, in order to provide adequate and environmentally protective TMDLs.

5.6 TMDL Summary

Tables 15, 16, and 17 summarize the tPCB baseline loads, TMDL allocations, load reductions, and maximum daily loads (MDLs) (see Appendix I for further details regarding MDL calculations) for the Baltimore Harbor embayment, Curtis Creek/Bay, and Bear Creek.

Table 15: Summary of tPCB Baseline Loads, TMDL Allocations, Load Reductions, and MDLs in the Baltimore Harbor Embayment

PCB Source	Baseline Load (g/year)	Percent of Total Baseline Load (%)	TMDL (g/year)	Load Reduction (%)	MDL (g/day)
Direct Atmospheric Deposition (to the Surface of the Embayment)	1,360.88	22.0	576.47	57.6	5.30
Tributaries[1]					
Jones Fall	299.34	4.8	25.59	91.5	0.24
Gwynns Fall	541.42	8.7	46.29	91.5	0.43
Patapsco River Lower North Branch	688.85	11.1	58.90	91.5	0.54
Non-regulated Watershed Runoff[2]	362.49	5.9	30.99	91.5	0.29
Contaminated Sites	14.51	0.2	14.51	0.0	0.13
Nonpoint Sources/LAs	***3,267.49***	***52.7***	***752.75***	***77.0***	***6.93***
Industrial Process Water[4]	859.38	13.9	498.60	42.0	4.24
WWTPs	366.81	5.9	32.83	91.1	0.28
DMCFs	77.60	1.3	77.60	0.0	0.66
NPDES Regulated Stormwater[2,3]					
Anne Arundel County	850.74	13.7	66.97	92.1	0.62
Baltimore County	338.50	5.5	28.94	91.5	0.27
Baltimore City	435.27	7.0	30.44	93.0	0.28
Point Sources/WLAs	***2,928.31***	***47.3***	***735.22***	***74.9***	***6.34***
MOS (5%)	**-**	**-**	**78.31**	**-**	**0.70**
Total	**6,195.79**	**100.0**	**1,566.29**	**74.7**	**13.96**

Notes: [1] Although the tributary loads are reported here as a single nonpoint source value, they could include both point and nonpoint source loads.
[2] Load applies to the direct drainage portion of the applicable watershed only.
[3] Load per jurisdiction applies to all NPDES stormwater dischargers within the direct drainage area of the jurisdiction to the Baltimore Harbor embayment. These dischargers are identified in Appendix H.
[4] 18.66 g/year of the 498.6 g/year allocated to industrial process water point sources is assigned to the Back River WWTP Outfall 002, since the effluent from the outfall is routed to RG Steel for use in their industrial processes. The allocation to the Back River WWTP Outfall 002 is calculated as the part of the WWTP design flow allocated to the outfall, which is 50 Million Gallons per Day (MGD), multiplied by the water column TMDL endpoint, which is 0.27 ng/L.

Table 16: Summary of tPCB Baseline Loads, TMDL Allocations, Load Reductions, and MDLs in Curtis Creek/Bay

PCB Source[1]	Baseline Load (g/year)	Percent of Total Baseline Load (%)	TMDL (g/year)	Load Reduction (%)	MDL (g/day)
Direct Atmospheric Deposition (to the Surface of the Embayment)	121.26	20.5	51.37	57.6	0.47
Non-regulated Watershed Runoff[2]	77.19	13.1	6.60	91.5	0.06
Contaminated Sites	7.84	1.3	7.84	0.0	0.07
Nonpoint Sources/LAs	***206.29***	***35.0***	***65.81***	***68.1***	***0.61***
Industrial Process Water[3]	-	-	-	-	-
WWTPs[3]	-	-	-	-	-
DMCFs[3]	-	-	-	-	-
NPDES Regulated Stormwater[2,4]					
Anne Arundel County	357.68	60.6	23.13	93.5	0.21
Baltimore City	26.22	4.4	2.91	88.9	0.03
Point Sources/WLAs	***383.89***	***65.0***	***26.05***	***93.2***	***0.24***
MOS (5%)	**-**	**-**	**4.83**	**-**	**0.04**
Total	**590.18**	**100.0**	**96.68**	**83.6**	**0.89**

Notes: [1] None of the upstream tributaries (i.e., Jones Falls, Gwynns Falls, and the Patapsco River Lower North Branch) drain directly into Curtis Creek/Bay.
[2] Load applies to the direct drainage portion of the applicable watershed only.
[3] No industrial process water facilities, WWTPs, or DMCFs have been identified in the applicable watershed.
[4] Load per jurisdiction applies to all NPDES stormwater dischargers within the direct drainage area of the jurisdiction to Curtis Creek/Bay. These dischargers are identified in Appendix H.

Table 17: Summary of tPCB Baseline Loads, TMDL Allocations, Load Reductions, and MDLs in Bear Creek

PCB Source[1]	Baseline Load (g/year)	Percent of Total Baseline Load (%)	TMDL (g/year)	Load Reduction (%)	MDL (g/day)
Direct Atmospheric Deposition (to the Surface of the Embayment)	79.32	18.5	33.60	57.6	0.31
Non-regulated Watershed Runoff[2]	26.33	6.1	2.25	91.5	0.02
Contaminated Sites[4]	-	-	-	-	-
Nonpoint Sources/LAs	***105.65***	***24.7***	***35.85***	***66.1***	***0.33***
Industrial Process Water[3]	-	-	-	-	-
WWTPs[4]	-	-	-	-	-
DMCFs[4]	-	-	-	-	-
NPDES Regulated Stormwater[2,5]					
Baltimore County	322.85	75.3	27.60	91.5	0.25
Point Sources/WLAs	***322.85***	***75.3***	***27.60***	***91.5***	***0.25***
MOS (5%)	**-**	**-**	***3.34***	**-**	**0.03**
Total	**428.50**	**100.0**	***66.80***	***84.4***	**0.61**

Notes: [1] None of the upstream tributaries (i.e., Jones Falls, Gwynns Falls, and the Patapsco River Lower North Branch) drain directly into Bear Creek.
[2] Load applies to the direct drainage portion of the applicable watershed only.
[3] One outfall from the RG Steel facility discharges to Bear Creek. However, this facility falls under an aggregate WLA for all industrial process water discharges, which is accounted for in the TMDL for the Baltimore Harbor embayment. An individual baseline load and WLA for this outfall will therefore not be presented in this table.
[4] No WWTPs, DMCFs, or contaminated sites have been identified in the applicable watershed.
[5] Load applies to all NPDES stormwater dischargers within the direct drainage area of the jurisdiction to Bear Creek. These dischargers are identified in Appendix H.

6. ASSURANCE OF IMPLEMENTATION

This section provides the basis for reasonable assurance that the tPCB TMDLs for the Baltimore Harbor embayment will be achieved and maintained. As discussed in the previous sections, resuspension and diffusion from bottom sediments currently constitutes a major source of tPCBs to the Baltimore Harbor embayment; however, within the TMDL framework, this source is not deemed to be directly controllable. Also, assuming a future decrease in watershed loads and loads from the resuspension and diffusion from bottom sediments, tidal influences from the Chesapeake Bay mainstem could be a significant source of PCBs to the embayment in the future. However, due to the high water column tPCB concentrations in the embayment, when compared to the Bay mainstem, currently, ebb tides result in a net transport of PCBs out of the embayment.

The TMDLs presented in this report call for substantial reductions in PCB loads from diffuse sources present throughout the Baltimore Harbor embayment's watershed. Given that PCBs are no longer manufactured, and their use has been substantially restricted, it is reasonable to expect that with time PCB concentrations in the aquatic environment will decline. Observations show that the average tPCB concentration in the Upper Chesapeake Bay is decreasing at a rate of 6.5% per year (MDE 2009). No historical data is currently available to estimate the specific rate of decline at the boundary between the embayment and the bay mainstem; however, water quality data for sediments and the water column in the embaymnent from 2000 and 2008 demonstrate that PCB concentrations are declining over time (see Appendix K). Thus, within this analysis, as a conservative estimate, a 5% rate of decline in tPCB concentrations at the boundary between the embayment and the Bay mainstem has been assumed, following the current trend in the Upper Bay but at the same time taking into consideration specific conditions within the embayment. Given this rate of decline, the tPCB levels in the Baltimore Harbor embayment are expected to decline over time due to natural attenuation, such as the burial of contaminated sediments with newer, less contaminated materials, flushing of sediments during periods of high stream flow, and biodegradation.

Aside from the processes of natural attenuation, there are two alternatives that can assist in reducing the tPCB concentrations in the water column so as to meet WQSs. First, the physical removal of the PCB-contaminated sediments (i.e., dredging – specifically, additional dredging outside of that which is already currently conducted for the navigational channels) would minimize one of the primary sources of tPCBs to the water column. In this particular situation, dredging is the least desirable alternative because of its potential biological destruction. It damages the habitat of benthic macroinvertebrates and may directly kill some organisms. The process of stirring up suspended sediments during dredging may damage the gills and/or sensory organs of benthic macroinvertebrates and fish. Suspended sediments can also affect the prey gathering ability of sight-feeding fish. In addition, the resuspension of contaminated sediments provides organisms with additional exposure to PCBs. In the case of the Baltimore Harbor embayment, natural attenuation is a better implementation method because it involves less habitat disturbance/destruction and is less costly. Second, should the net transport of tPCB loads at the boundary between the Baltimore Harbor embayment and the Chesapeake Bay mainstem shift, a reduction in the Bay mainstem tPCB loads, which is expected due to the 6.5% yearly observed decline in the Upper Chesapeake Bay, would greatly accelerate the process of natural attenuation within the embayment. Thus, discovering and remediating any existing PCB land sources throughout the Upper Chesapeake Bay watershed via future TMDL development and implementation efforts will further help to meet water quality goals in the Baltimore Harbor embayment.

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. Therefore, natural attenuation and a reduction in loads from the Chesapeake Bay mainstem alone are not expected to completely eliminate the PCB impairment in the Baltimore Harbor embayment.

Due to the potential existence of unidentified sources of PCB contamination through the watershed and the significant load reductions required to meet the TMDL endpoints, achievement of these TMDLs may not be feasible by solely enforcing effluent limitations on known point sources and implementing BMPs on nonpoint sources. Therefore, an adaptive approach of implementation is anticipated, with subsequent monitoring to assess the effectiveness of the ongoing implementation efforts to manage potential risks to both recreational and subsistence fish consumers.

The success of the implementation process will 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. A collaborative approach involving MDE and the identified NPDES permit holders as well as those responsible for nonpoint PCB runoff throughout the watersheds will be used to work toward attaining the WLAs and LAs presented in this report. The reductions will be implemented in an adaptive and iterative process that will 1) identify specific sources, or areas of PCB contamination, within the embayment's watershed and 2) target remedial action to those sources with the largest impact on water quality, while giving consideration to the relative cost and ease of implementation. The implementation efforts will be periodically evaluated, and if necessary, improved, in order to further progress toward achieving the water quality goals.

Any future monitoring should include congener specific analytical methods. Ideally, the most current version of EPA Method 1668 should be used, or other equivalent methods capable of providing low-detection level, congener specific results. In establishing the necessity and extent of data collection, MDE will collaborate with the affected stakeholders, and take into account data that is already available as well as the proper characterization of intake (or pass through) conditions, consistent with NPDES program "reasonable potential" determinations and the applicable provisions of the Environment Article and COMAR for permitted facilities.

Under certain conditions, EPA's NPDES regulations allow the use of non-numeric, BMP water quality based effluent limits (WQBELs). BMP WQBELs can be used where "numeric effluent limitations are infeasible; or the practices are reasonably necessary to achieve effluent limitations and standards or to carry out the purposes and intent of the CWA" (CFR 2011c). For example, MDE's Phase I MS4 permits require restoration targets for impervious surfaces (i.e., restore 10%

or 20% of a jurisdiction's total impervious cover with no stormwater management/BMPs), and these restoration efforts have known total suspended solids (TSS) reduction efficiencies. Since PCBs are known to adsorb to sediments and their concentrations correlate with TSS concentrations, the significant restoration requirements in the MS4 permits, which will lead to a reduction in sediment loads entering the Baltimore Harbor embayment, will also contribute toward PCB load reductions and meeting PCB water quality goals. Other BMPs that focus on PCB source tracking and elimination at the source rather than end-of-pipe controls are also warranted. Due to this known relationship between TSS and PCB concentrations, implementation of the existing TMDLs for sediments and nutrients in the Patapsco River Mesohaline Tidal Chesapeake Bay Segment's watershed (i.e., loads specified as part of the Chesapeake Bay Nutrient and Sediment TMDLs) will further progress towards achieving the NPDES Regulated Stormwater WLAs, and additionally the nonpoint source LAs.

Where necessary, the source characterization efforts will be followed with pollution minimization and reduction measures that will include BMPs for reducing runoff from urban areas, identification and termination of ongoing sources (e.g., industrial uses of equipment that contain PCBs), etc. The identified NPDES regulated WWTP and stormwater control agency permits will be expected to be consistent with the WLAs presented in this report. Numerous stormwater dischargers are located in the Baltimore Harbor embayment's watershed including three Municipal Phase I MS4s (Anne Arundel County, Baltimore County, and Baltimore City), the SHA Phase I MS4, industrial facilities, State and Federal Phase II MS4s, and any construction activities on areas greater than 1 acre (see Appendix H of this document to view the current list of known NPDES stormwater dischargers). The current Montgomery County Phase I MS4 permit already requires that the jurisdiction develops an implementation plan to meet its assigned NPDES Regulated Stormwater WLAs. Thus, similar requirements are expected to be put in place in the future Anne Arundel County, Baltimore County, Baltimore City, and Maryland SHA Phase I MS4 permits.

Subtitle 14 of the Environment Article within COMAR establishes the administrative procedures and standards for identifying, investigating, and remediating sites that have a release of, or imminent threat to release, hazardous substances to the environment. Specifically, Section 14.02.04 of the Article requires MDE to establish criteria for ranking these sites relative to their need for investigation and remediation (COMAR 2011e). MDE incorporates factors into the criteria that relate to the degree to which each site poses a risk to public health or the environment. Newly identified sites are placed on a list for tracking purposes.

Consistent with these requirements, MDE has developed a Hazard Ranking Model. The purpose of this model is to calculate a numerical hazard score based on information supplied from the following sources: 1) laboratory derived analytical data of environmental media samples taken at the site, 2) a comparison of the data to EPA based concentrations, and 3) information on natural resources located at the site or in close proximity to the site. Newly identified sites are investigated using EPA's Site Assessment Grant. This investigation determines whether the site qualifies for inclusion on the Federal Superfund list (US EPA 2011a), or instead, if it will be handled under State oversight. Sites that have no responsible party are investigated using State Capital Funds. Additionally, sites may also be investigated and subsequently remediated under the Voluntary Cleanup Program (VCP).

Given that a number of contaminated sites have already undergone some degree of remediation and their baseline loads constitute a relatively small percentage of the Total Baseline Load (i.e., 0.2% - Baltimore Harbor embayment; 1.3% - Curtis Creek/Bay), these sites are not intended to be targeted during the initial stages of implementation and thus at this point were not subjected to any reductions. However, if in the future it becomes clear that the TMDL goals cannot be achieved without load reductions from these sites, additional reduction measures might need to be considered.

Given the persistent nature of PCBs, the difficulty in removing them from the environment, and the significant reductions necessary in order to achieve water quality goals in the Baltimore Harbor embayment, effectiveness of the implementation effort will need to be reevaluated throughout the process to ensure progress is being made towards reaching the TMDLs. As part of Maryland's Watershed Cycling Strategy, follow-up monitoring and assessment will be routinely conducted to evaluate the implementation status. 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.

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Appendix A: List of Analyzed PCB Congeners

PCB analytical services were provided by UMCES. Specific PCB congeners were identified and quantified by high resolution gas chromatography with electron capture detection. 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). Based on this method, 86 chromatographic peaks can be quantified (see Table A-1). Some of the peaks contain one PCB congener, while many are comprised of two or more co-eluting congeners. 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 PCB TMDL (Haywood and Buchanan 2007).

I. Data Description

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

Table B-1: Species Trophic Levels and Home Ranges

Common Name	Scientific Name	Trophic Level	Home Range (miles)
Brown Bullhead Catfish	*Ameiurus nebulosus*	Benthivore-generalist	5.0
Channel Catfish	*Ictalurus punctatus*	Benthivore-generalist	5.0
White Catfish	*Ameiurus catus*	Benthivore-generalist	5.0
White Perch	*Morone americana*	Predator	10.0
White Sucker	*Catostomus commersoni*	Benthivore-generalist	2.0

II. Total BAFs

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

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

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

III. Baseline BAFs

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

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

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

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

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

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

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

Table B-2: Kow 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 tPCB concentrations:

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

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

IV. Adjusted Total BAFs

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

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

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. The lowest tPCB water column concentration of all the fish species will be selected as the TMDL endpoint in order to be supportive of the "fishing" designated use (see Table B-3). In the Baltimore Harbor embayment, the lowest concentrations (0.09 ng/L and 0.16 ng/L) are associated with channel catfish and white catfish. However, the channel catfish and white catfish samples sizes are too small to represent their respective species. Also, since channel catfish are benthivores and primarily feed in the sediment, it would be inappropriate to use this species value to establish the water column TMDL endpoint. Therefore, the next lowest value (white perch, 0.27 ng/L) was selected.

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

Species Name	Number of Fish	tBAF (L/kg)	Baseline BAF (L/kg)	Adj-tBAF (L/kg)	Median Fd (%)[1]	Median Lipid (%)	Water Column tPCB Threshold Concentration (ng/L)
Brown Bullhead Catfish	4	42,649	14,928,689	67,942	25.5	1.8	0.57
Channel Catfish	2	371,982	32,103,761	439,702	25.5	5.4	0.09
White Catfish	1	243,356	23,881,297	243,902	25.5	4.0	0.16
White Sucker	2	17,506	6,784,375	21,169	26.8	1.2	1.84
White Perch	32	141,939	11,255,763	145,344	26.8	4.9	0.27

Note: [1]Median value of the freely-dissolved percentage of the total tPCB concentration for water column samples within each fish's home range.

V. Biota-Sediment Accumulation Factors and Adjusted Sediment BAFs

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

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

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 value 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 and a sediment organic carbon fraction representative of the ecosystem:

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

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. The lowest tPCB sediment concentration of all the fish species will be selected as the TMDL endpoint in order to be supportive of the “fishing” designated use (see Table B-4). In the Baltimore Harbor embayment, the lowest concentration (3.1 ng/g) is associated with channel catfish and will be selected as the sediment TMDL endpoint.

Table B-4: BSAF, Adj-SedBAF, and Sediment tPCB Threshold Concentrations for Each Fish Species

Species Name	BSAF	Adj-SedBAF	Sediment tPCB Threshold Concentration (ng/g)
Brown Bullhead Catfish	4.19	1.96	19.9
Channel Catfish	8.86	12.44	3.1
White Catfish	6.75	7.07	5.5
White Perch	4.21	5.44	7.2
White Sucker	1.74	0.56	70.0

Appendix C: Use of PCB 4, 5, and 6 Homologs in Baltimore Harbor Embayment PCB Modeling and Their Conversion to tPCBs

This appendix provides the rationale and justification for the selection of PCB homologs 4, 5, and 6 as surrogates for tPCBs in modeling the transport and fate of PCBs in the Baltimore Harbor Embayment.

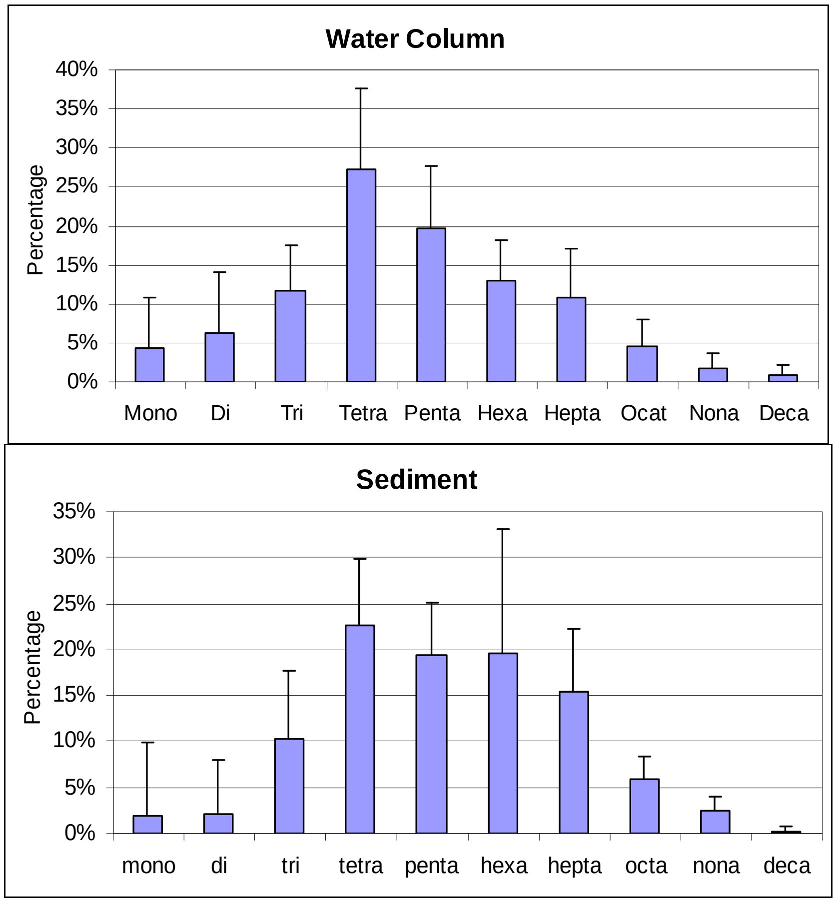
As mentioned in the Introduction, there are 209 PCB congeners and these congeners can be grouped into "homologs" defined by the number of chlorine atoms attached to the carbon rings. The WQSs that form the basis for PCB TMDLs in Maryland's waterbodies are for tPCBs. The WQSs are expressed as tPCB concentrations in the water column, as are the fish tissue screening thresholds. This is consistent with the EPA human health national criteria for PCBs, which are expressed in terms of tPCBs, applied to both water and fish consumption.

From a transport and fate modeling standpoint, it is not practical to model all 209 individual congeners. It would be scientifically unsound to represent tPCBs as a single variable by taking the grand averages of the physical-chemical properties of all 209 congeners and assigning them to a single state variable in the model, as they can vary over many orders of magnitude. One alternate approach is to model each of the 10 homologs and sum the results to form tPCBs. This would substantially decrease the range of uncertainty because the physical-chemical properties of individual homolog groups can be defined much more precisely than those of tPCB. This approach requires 10 separate model simulations and would be extremely intensive in terms of data and computing resources.

An alternative approach is to use a surrogate homolog or group of homologs for tPCBs, if the concentrations of the surrogate were proportional to the tPCB concentrations. For the Delaware estuary PCB TMDL, penta-PCB was used as a surrogate and PCB3+ was used for the Potomac Estuary TMDL. A similar approach was used for the model applied within this TMDL (DRBC 2008; Haywood and Buchanan 2007).

In order to identify the surrogate homolog(s) for tPCBs and build a relationship between them, regression analysis was performed between each homolog and tPCBs for every sediment and water column sample. The results show that for almost all the individual samples, tetra-PCB is the most abundant homolog and its concentration always has the highest correlation with the tPCB concentration among the 10 homologs, followed by penta- and hexa-PCB (see Figure C-1). Furthermore, it was discovered that the sum of tetra-, penta-, and hexa-PCBs has an even higher correlation with tPCB concentrations (see Figures C-2 and C-3). They account for 60.1% and 61.7% of the tPCB concentrations in the water column and bottom sediments (see Table C-1). In addition, an analysis of PCB homolog distributions of stormwater and watershed runoff shows a similar pattern (see Figures C-5 and C-6). For fish tissue, penta- and hexa-PCB have the highest concentrations (see Figure C-4). Therefore, it was decided that the simulation of tetra-, penta-, and hexa-PCB concentrations is the best approach to reflect water column, sediment, and fish tissue PCB distributions, and the sum of the three were used to derive tPCB concentrations. This approach requires three individual model simulations, which is technically sound and feasible, as the physical and chemical properties of each homolog could be reasonably characterized.

To translate homolog concentrations of tetra-, penta-, and hexa-PCBs to tPCBs, the regression method with zero intercept was used to derive the translation relationship (see Table C-2). The values of 1.48 and 1.56 were used to convert the sum of tetra-, penta-, and hexa-PCBs to tPCBs in the water column and sediment, respectively.



Note: The blue bars denote averaged percentages and error bars denote standard deviations.

Figure C-1: Homolog Distribution of Water Column and Sediment Samples

Table C-1: Homolog Distributions of tPCBs in the Water Column and Sediment

Homolog	Mono	Di	Tri	Tetra	Penta	Hexa	Hepta	Octa	Nona	Deca
Water Column	4.2%	6.1%	11.6%	27.3%	19.8%	13.0%	10.8%	4.5%	1.7%	0.8%
Sediment	2.0%	2.1%	10.3%	22.7%	19.4%	19.6%	15.5%	5.8%	2.5%	0.2%

Table C-2: Regression Results Between the Sum of Tetra-, Penta-, and Hexa-PCB Concentrations (x-Variable) and tPCB Concentrations (y-Variable)

	Water Column	Sediment
tPCB	1.3968x + 0.685	1.5167x + 13.544
tPCB (*b*=0)	1.4766x	1.5588x

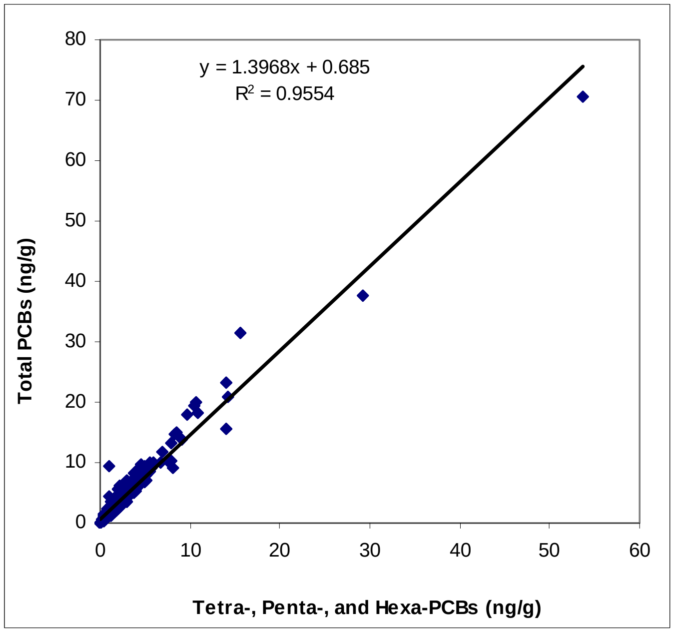


Figure C-2: Regression of tPCB Concentrations Versus the Sum of Tetra-, Penta-, and Hexa-PCB Concentrations in Baltimore Harbor Embayment Water Column

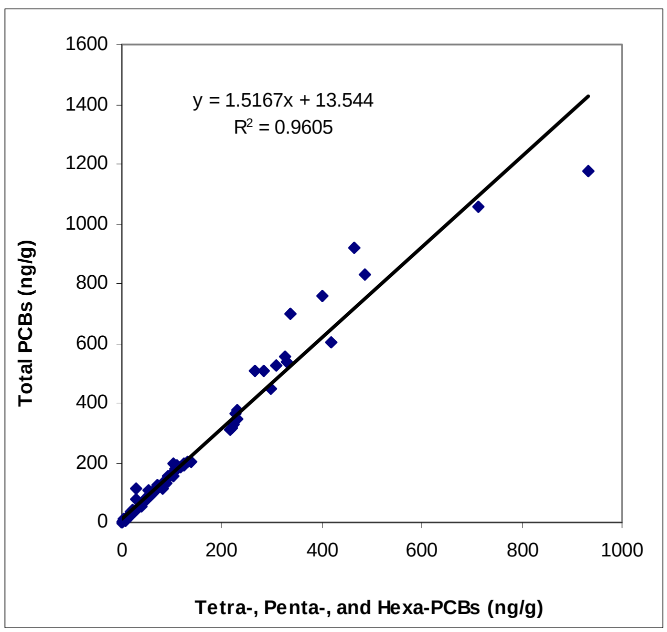


Figure C-3: Regression of tPCB Concentrations Versus the Sum of Tetra-, Penta-, and Hexa-PCB Concentrations in the Baltimore Harbor Embayment Bottom Sediments

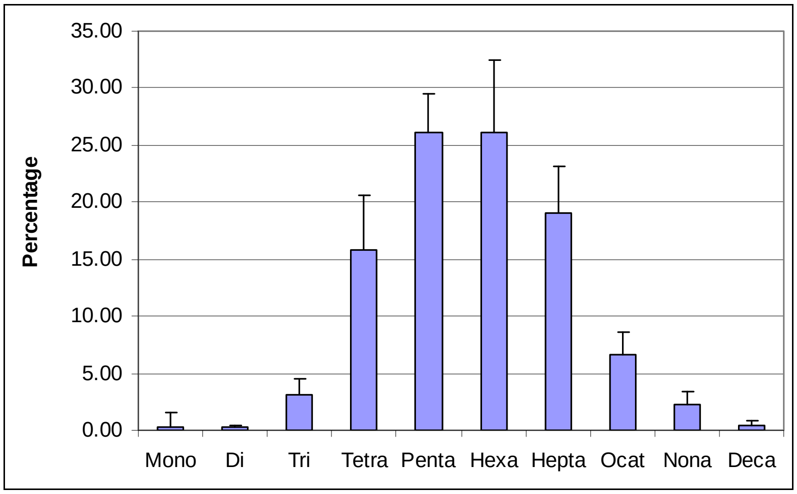


Figure C-4: PCB Homolog Distribution in Fish Tissue Samples

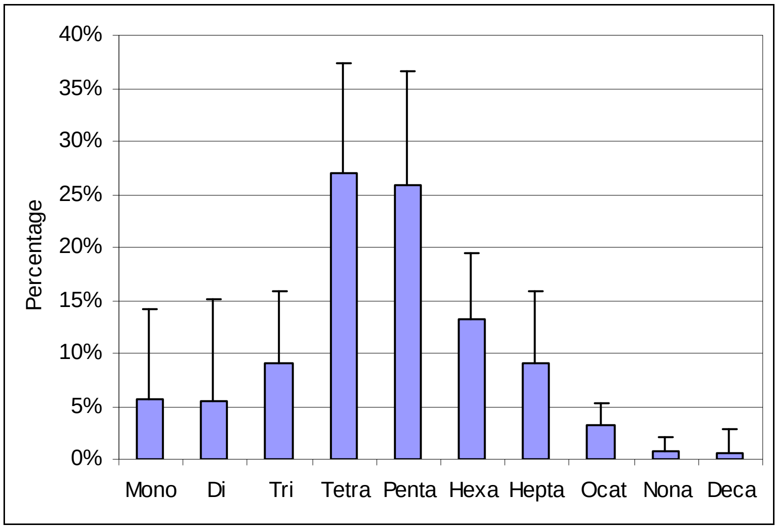


Figure C-5: PCB Homolog Distribution in Watershed Runoff (B-Series) Station Samples

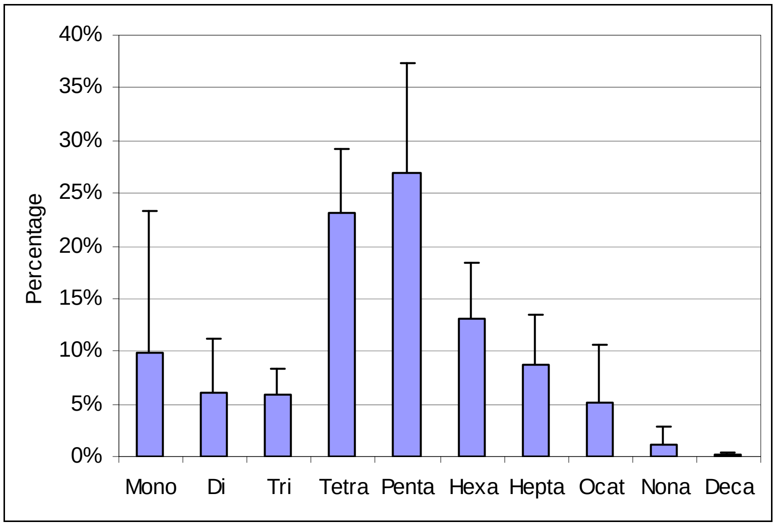


Figure C-6: PCB Homolog Distribution in Stormwater Station Samples

Appendix D: Regression Method to Derive Watershed tPCB Loads

From April 2008 to March 2009, MDE collected monthly water column PCB measurements at the 4 B-series stations in the Baltimore Harbor embayment's watershed (see Table D-1 and Figure D-1). In order to assess whether or not these samples covered all flow ranges so that they could be used to calculate watershed loads, the USGS stations closest to these B-series stations were identified (see Figure D-1), and their daily average flow rates from January 1, 2008 to December 30, 2009 were used to generate the flow duration curves. The flows for the dates on which the B-series station samples were collected were identified on the flow duration curves (see Figure D-2). This comparison indicates that the PCB samples at all of the stations spanned the full range flows. It was therefore justified to apply these samples to calculate the watershed loads.

Table D-1: Water Column tPCB Concentrations at the B-Series Stations

Date	Water Column tPCB Concetration (ng/L)			
	Station B351	Station B421	Station B423	Station B425
4/29/2008	3.18	3.44	2.48	3.72
5/12/2008	0.79	19.44	8.63	2.73
6/24/2008	3.50	1.31	9.39	1.87
7/14/2008	0.45	5.91	5.36	4.87
8/28/2008	3.54	4.53	0.54	1.76
9/26/2008	1.70	1.75	0.68	0.97
10/30/2008	1.51	1.08	0.76	1.28
11/14/2008	0.69	1.99	1.34	1.27
12/10/2008	10.03	7.27	6.11	2.90
1/7/2009	7.11	20.74	8.19	5.88
2/26/2009	1.66	3.04	1.52	0.74
3/26/2009	2.24	0.87	3.58	2.41

Using the average daily flow at these USGS stations and the ratio of the B-series station drainage areas to the USGS station drainage areas, the flows corresponding to each sampling date at the B-Series stations were calculated. The tPCB load was calculated as the flow multiplied by the measured tPCB concentration. Then, the relationship between flow and tPCB loads was generated, as shown in Figure D-3. The logarithmic regression was selected, as the other regressions did not have as high of correlation coefficients (R^2), and problems occurred when using other regressions to project loads at very high flows. Regression results showed that the prediction at station B351 was not satisfactory due to one outlier, which had a very high tPCB load when the flow was low. If the outlier was excluded, the correlation coefficient (R^2) increased from 0.47 to 0.67 (see Figures D-3 and D-4). To account for the variation in flow, the results include all of the data points used to generate the load. Both regressions at Station B421 and Station B423 had negative interceptions and the results were not very satisfactory. Therefore, the regressions of flow against concentrations at these two stations were conducted using both polynomial and logarithmic functions, and the best regressions were chosen to generate the loads (see Figure D-4).

Station B425 is located in a small watershed in an urban region adjacent to the Baltimore Harbor embayment (see Figure D-1). The load obtained from this station is representative of the typical background load of this urban region. The homolog distribution analysis at the storm water stations and B-series stations showed a similar pattern, suggesting that their PCB sources are similar. Since the storm water observation data were not sufficient to estimate tPCB loads directly, the regression at station B425 was used to generate loads for other areas adjacent to the embayment as well.

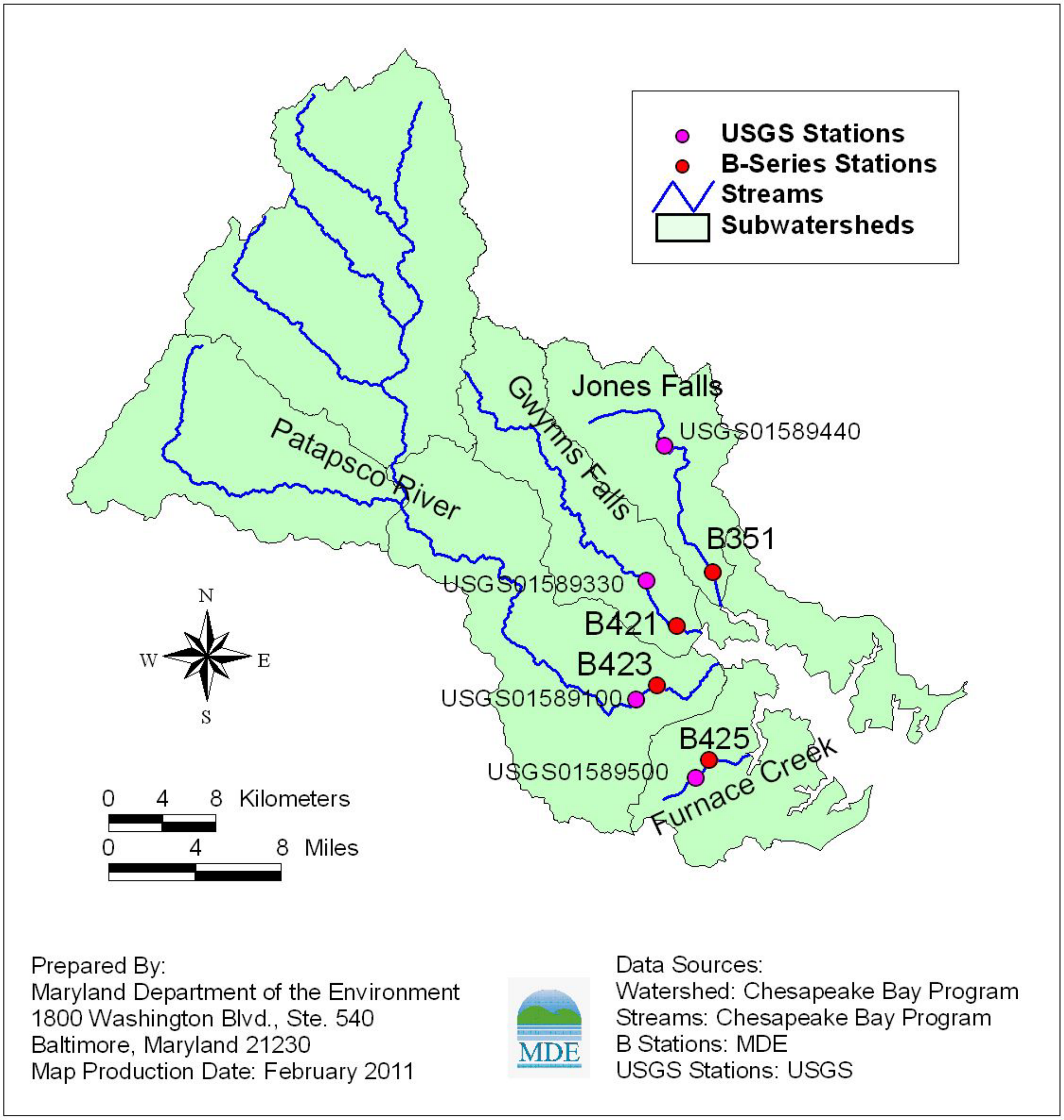
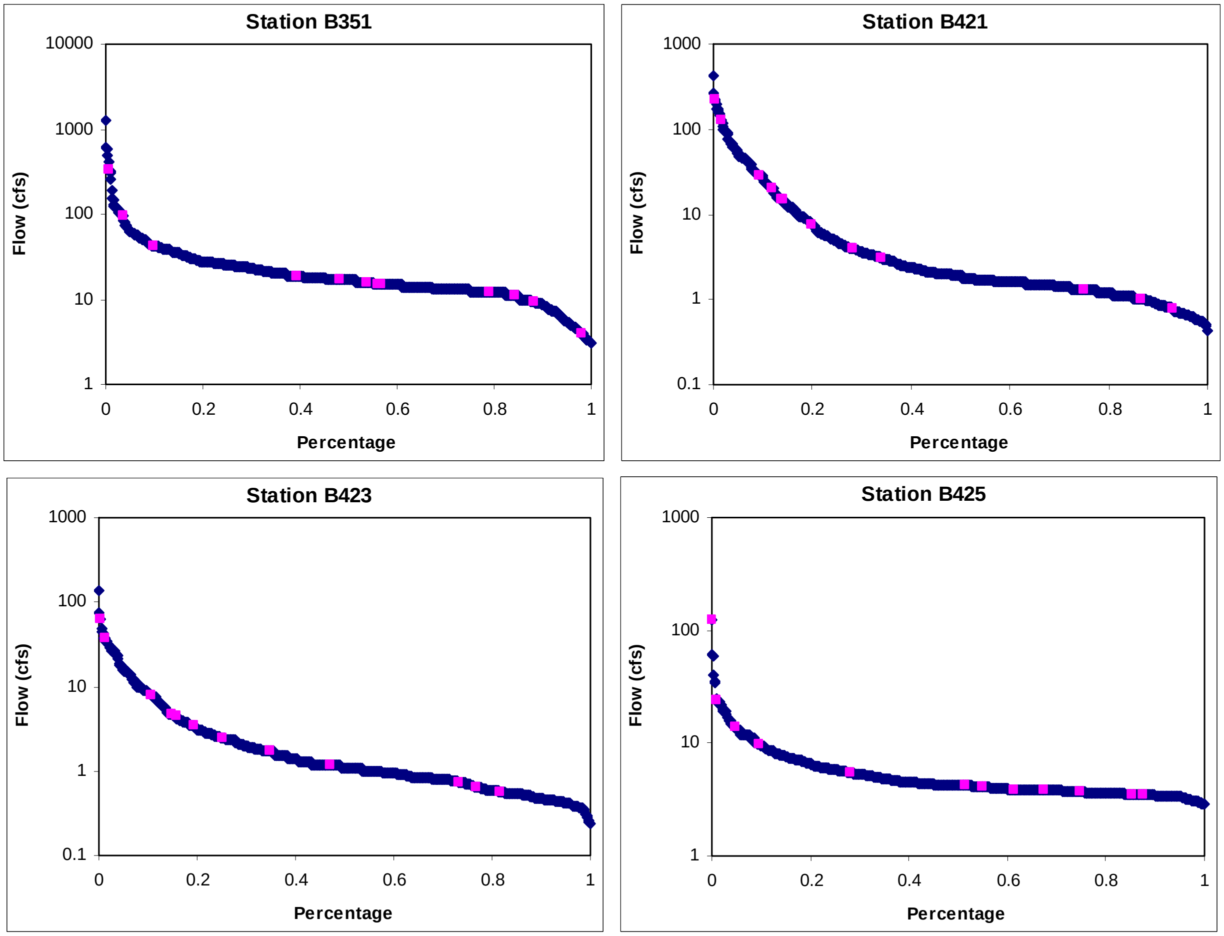


Figure D-1: The Locations of B-Series Sampling Stations and USGS Stations



Note: The magenta points represent the locations of flows of the B-Series station samples

Figure D-2: Relative Locations of Flows of B-Series Station Samples on the Flow Duration Curves

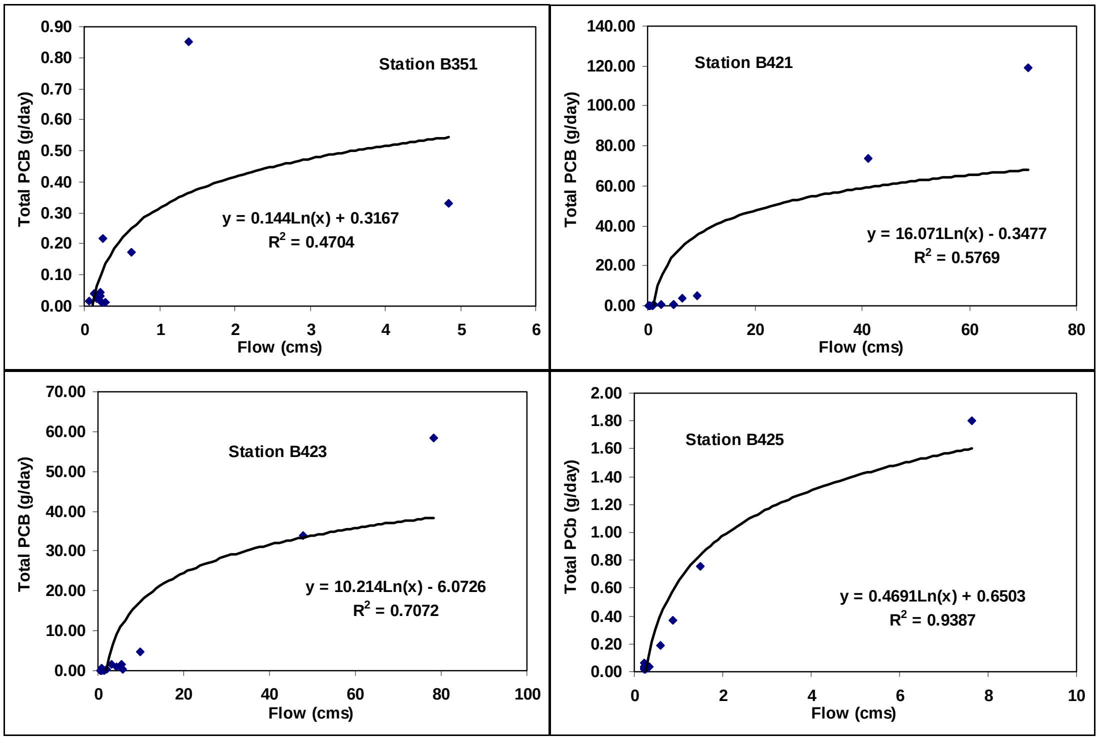


Figure D-3: Relationship between Flow and tPCB Loads at the B-Series Stations

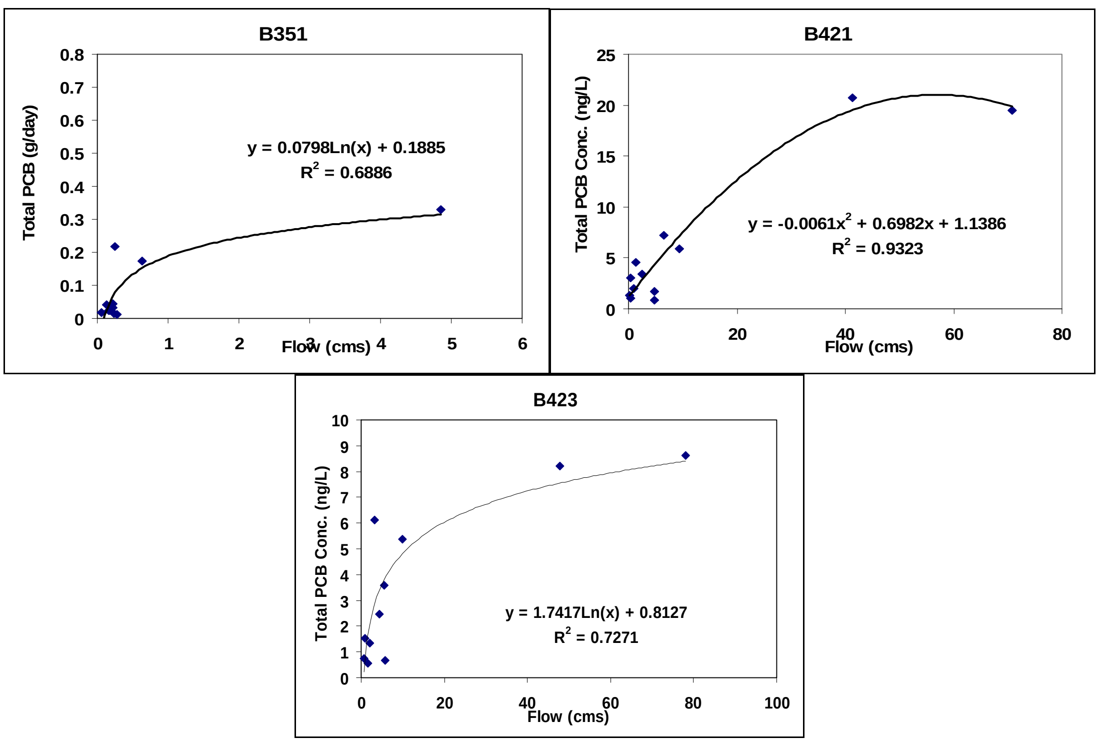


Figure D-4: Corrected Relationship Between Flow and tPCB Loads and Concentrations at Stations B351, B421, and B423

With the equations relating flow and tPCB loads and concentrations, the tPCB loads can be estimated. Using the flows at each subwatershed predicted by the CBP Phase 5 watershed model as the x-variable, the loads were predicted as the y-variable. Figure D-5 shows an example of the predicted tPCB load time series. The estimated loads from major tributaries are listed in Table D-2. After the tPCB loads corresponding to flows were generated, the mean percentage of each homolog was multiplied by the total load to derive the individual homolog load.

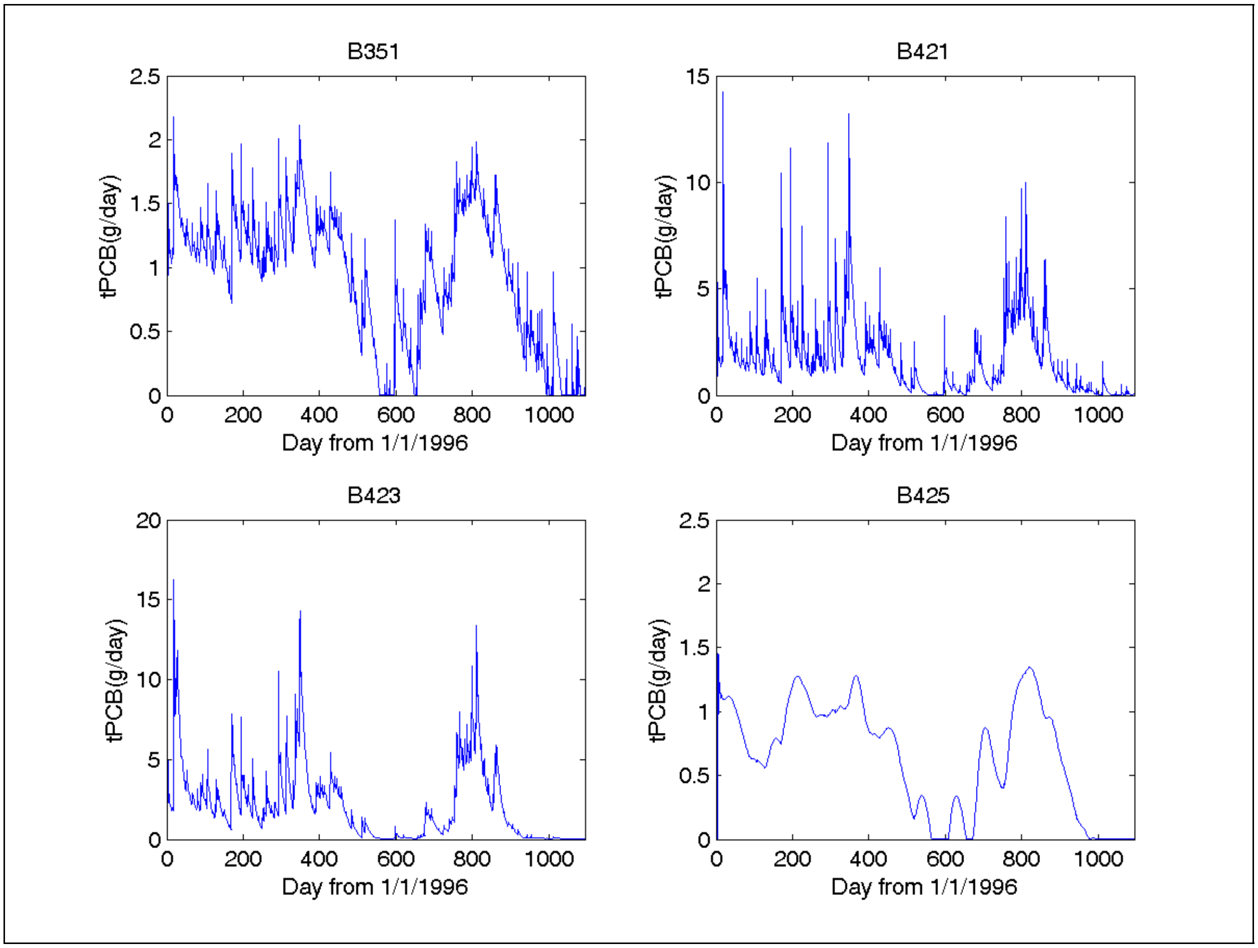


Figure D-5: Time Series of the Predicted tPCB Loads at the B-Series Stations

Table D-2: Estimated Load of tPCBs in Each Subwatershed

tPCB Load (g/year)						
Jones Falls	**Gwynns Falls**	**Patapsco River**	**Curtis Bay**	**Bear Creek**	**Other**	**Total**
299.34	541.42	688.85	468.92	349.18	1183.50	3531.20

Appendix E: Hydrodynamic and Eutrophication Model Calibration and Verification

I. Model Description

The EFDC was applied for these TMDLs. The EFDC model is a general purpose, hydrodynamic model capable of simulating 1-, 2-, and 3-dimensional flow, salinity, temperature, suspended sediment, and eutrophication processes in surface water systems, including rivers, lakes, estuaries, reservoirs, wetlands, and oceanic coastal regions (US EPA 2011b). It is one of the dynamic models used by EPA in support of TMDL development. The EFDC model solves the continuity and momentum equations for surface elevation as well as horizontal and vertical velocities. The model simulates density- and gravitationally-induced circulations, as well as tidal- and wind-driven flows, spatial and temporal distributions of salinity, temperature, suspended sediment concentrations, and conservative tracers. The model has been applied to a wide range of environmental studies in the Chesapeake Bay and other systems (i.e., Hamrick 1992a, 1992b; Shen and Haas 2004; Ji et al. 2007). Water column eutrophication and a sediment diagenesis sub-models have been integrated into EFDC and applied successfully in a number of estuarine environments, including the Elizabeth River (Park et al. 1995; Shen et al. 2009; Sisson et al. 2011).

The EFDC model includes sub-models simulating eutrophication and sediment diagenesis processes (Park et al. 1995). The eutrophication sub-model simulates the spatial and temporal distributions of water quality parameters including dissolved oxygen (DO), algae, and various forms of carbon, nitrogen, phosphorus, and silica. The simulated OC species are used in the PCB sub-model as described in Appendix F. Central to the eutrophication component of the model is the relationship between algal primary production and the concentration of DO. In order to predict primary production and DO, a large suite of state variables representing nutrient dynamics are simulated in the model. The eutrophication model has the following water quality variable groups:

- Algae (green (BG), cyanobacteria (BC), and diatoms (BD))
- Macro-algae (BM)
- OC (labile particulate (LPOC), refractory particulate (RPOC), and dissolved (DOC))
- Organic phosphorus (labile particulate (POC), refractory particulate (RPOC), and dissolved (DOP))
- Phosphate (PO4)
- Organic nitrogen (labile particulate (LPON, refractory particulate (RPON), and dissolved (DON))
- Inorganic nitrogen (ammonium (NH4) and nitrate (NO23))
- Silica (particulate (SU) and bio-available (SA))

The hydrodynamic and eutrophication models are coupled and run at same timestep. A diagram of linkage of the two models is shown in Figure E-1. The biochemical processes simulated by the eutrophication model are shown in Figure E-2.

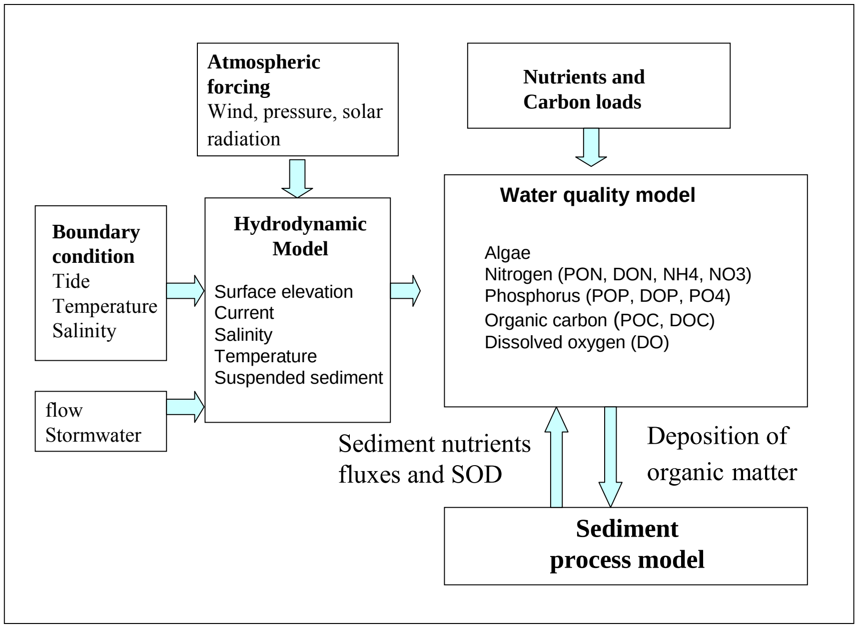


Figure E-1: A Diagram of Model Linkage of Hydrodynamic and Eutrophication Models

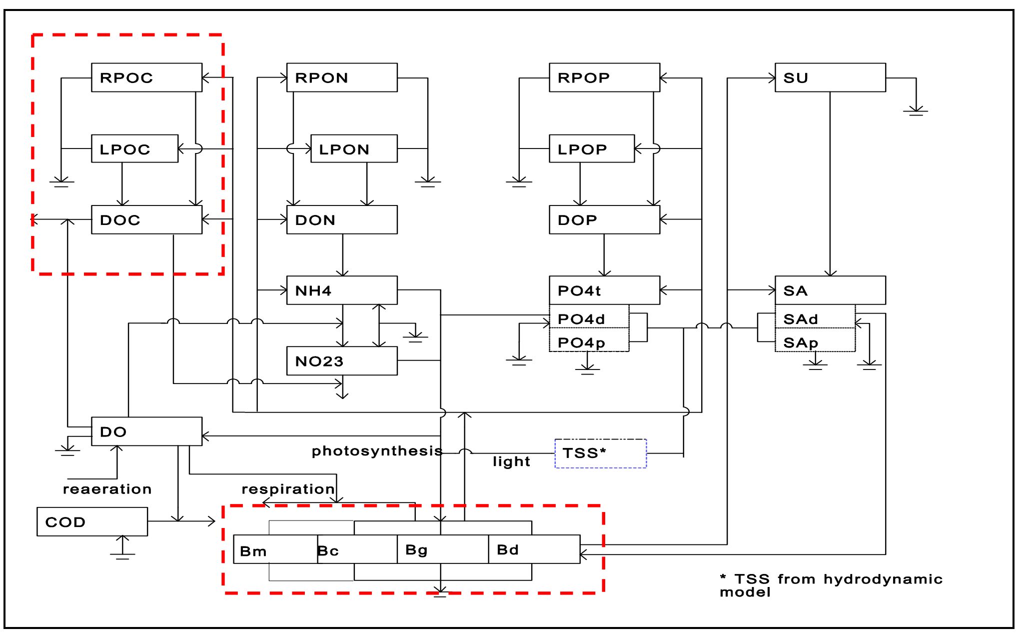


Figure E-2: A Diagram of Eutrophication Processes Simulated by the EFDC Model

II. Model Validation

In order to accurately simulate hydrodynamics and water quality conditions in the Baltimore Harbor embayment and reduce the influence of model boundary conditions, the upper Chesapeake Bay region is selected as the modeling domain of the hydrodynamic model. The model grid is shown in Figure E-3. A total of 3,862 horizontal grid cells with 9 vertical layers were used to represent the upper Bay region. The hydrodynamic model was calibrated against observations of tide, salinity, and temperature.

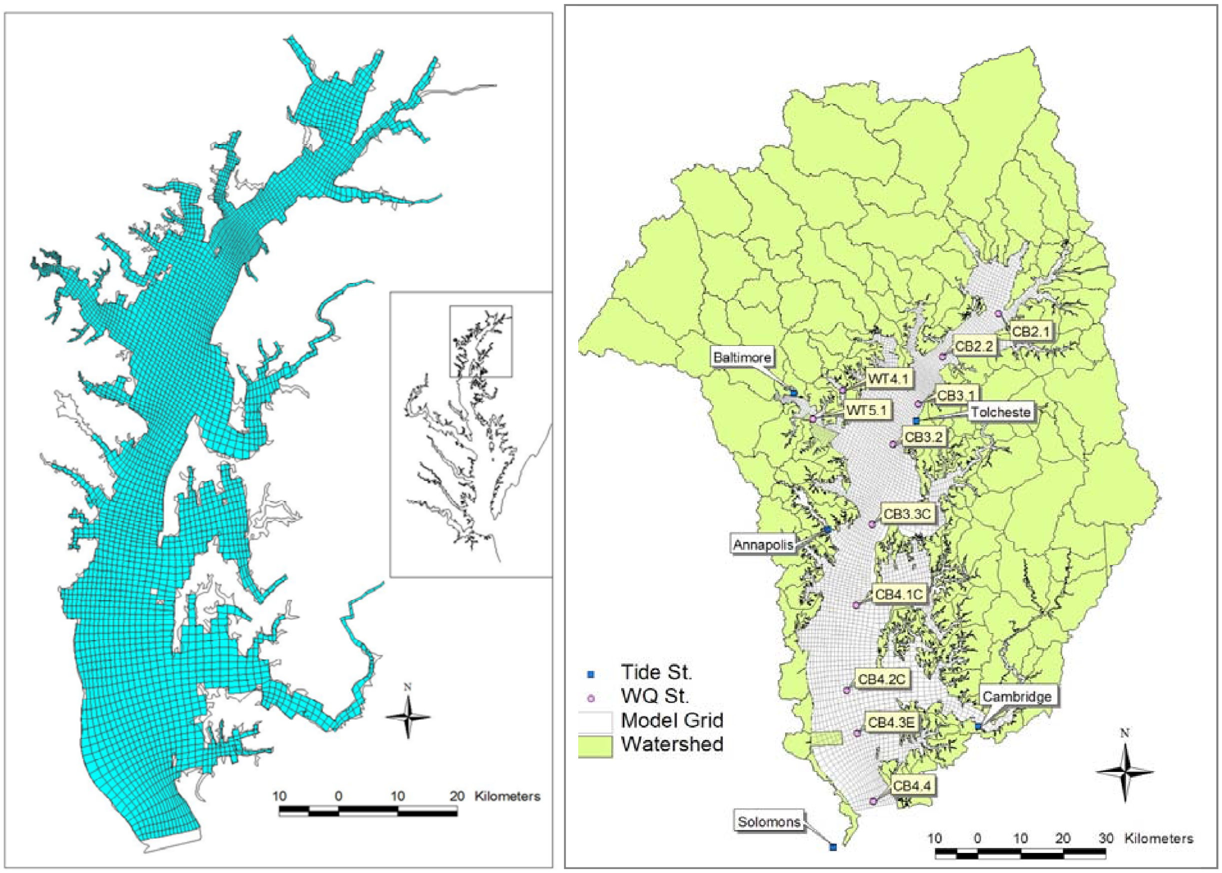


Figure E-3: Model Grid and Sub-Watersheds Adjacent to the Upper Bay

II. Hydrodynamic Model Calibration

The year 2000 was selected for calibration of the hydrodynamic model. The CBP Phase 5 watershed model outputs of flows for rivers and sub-watersheds were discharged to the model grid at their corresponding locations. The drainage area adjacent to the model grids is shown in Figure E-3. NOAA hourly tide observations at Solomons Station were used for the tidal boundary condition (NOAA 2011). The hourly meteorological data including wind, atmospheric pressure, and wet and dry temperatures were also downloaded from the NOAA Solomons Station and Baltimore Airport. The solar radiation data was obtained from the CBP.

The open boundary condition for salinity, temperature, and TSS were prescribed based on the specification of inflowing boundary conditions during the flood tide at the open boundary and recovery time, which has been used to specify the salinity open boundary with a lack of time-varying observations (Yang and Hamrick 2005). When the flow at the open boundary changes from outflow to inflow, the model provides a linear interpolation of inflowing salinity based on the last outflowing salinity and the specified incoming salinity in a predefined recovery time interval. A 1.5-hour time interval was used in the simulation based on the previous model calibration. Once the flooding time exceeds this time interval, the prescribed salinity is used as the boundary condition. The inflow boundary condition is based on observations at station CB4.4.

The linear method is used to interpolate the data between observations. During ebb tide, outflowing salinities and temperatures are calculated using upwind salinities and temperatures immediately inside the open boundary.

The model calibration of tide involves adjusting bottom roughness. The EFDC model is very robust for tidal simulation. A constant bottom roughness of 0.2 cm was used in the modeling domain. A comparison of hourly tide simulations with observations at three stations are shown in Figure E-4. There are some tidal fluctuations for the period of the model simulation, while the surface wind contributes highly for short-term fluctuation of surface elevations. From transport perspective, the sub-tidal variations (~25 hour low-pass filter) are more important. Figure E-5 shows the comparison of sub-tidal variations at three stations. It can be seen that the model simulation of tide is satisfactory.

Model calibration of temperature and salinity are shown in Figures E-6a, E-6b, and E-7, respectively. It can be seen that the model simulates temperature well. For salinity simulation, the model performance is satisfactory, as it simulates the important stratification and destratification processes in the upper Chesapeake Bay.

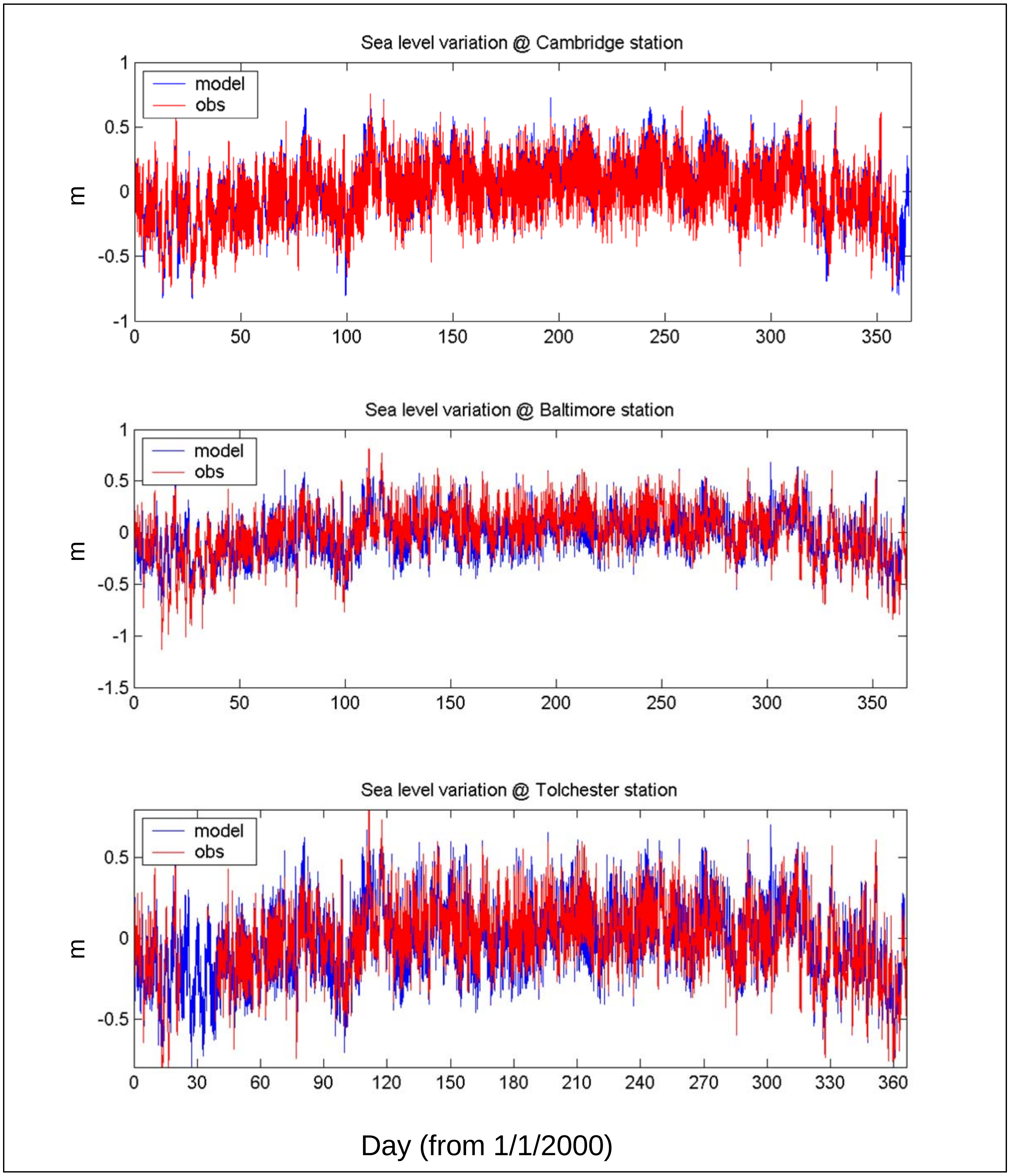


Figure E-4: Comparison of Hourly Tidal Variations at Selected Cambridge, Baltimore, and Tolchester Stations

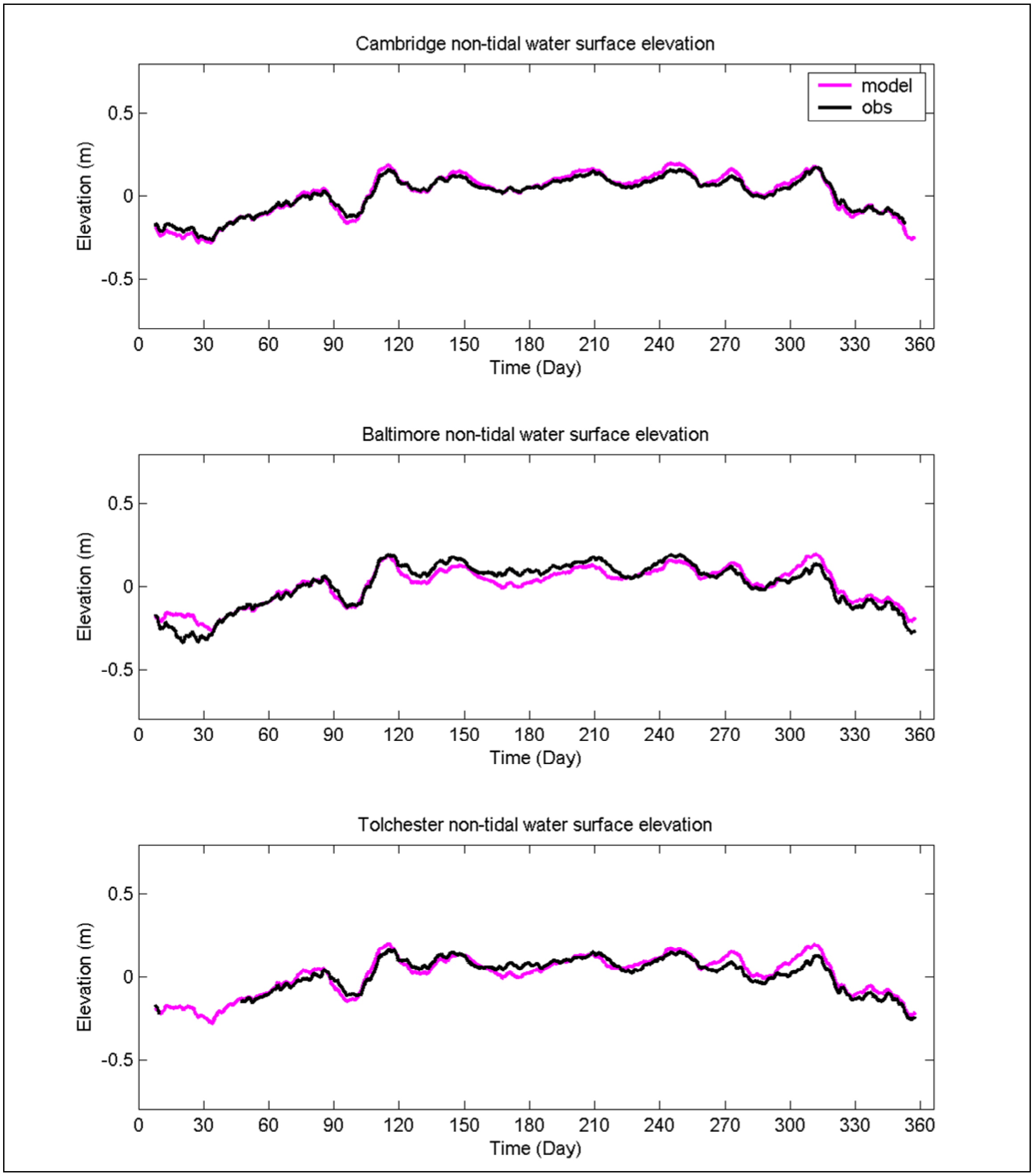


Figure E-5: Comparison of Sub-Tidal Variations at Selected Cambridge, Baltimore, and Tolchester Stations

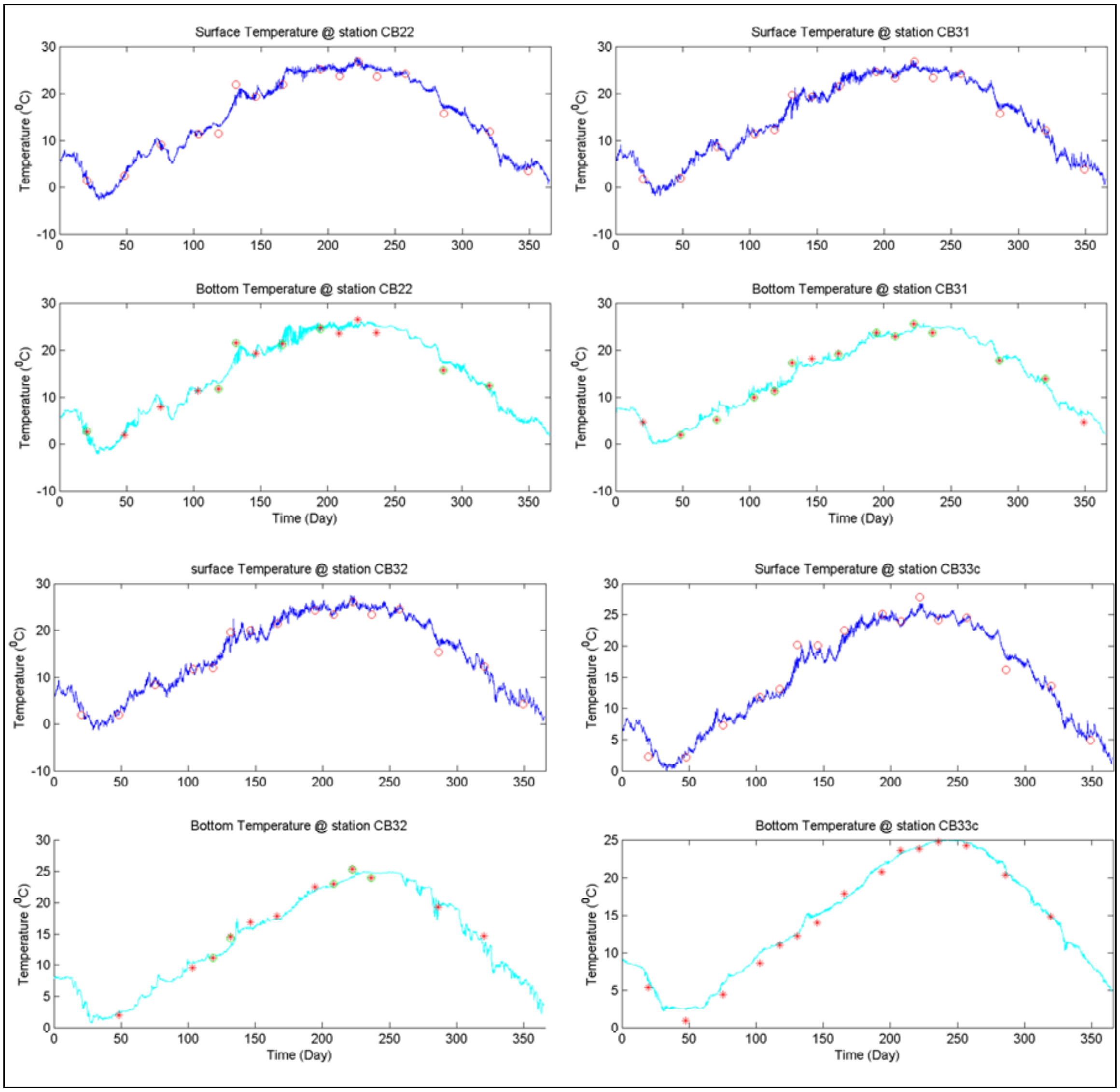


Figure E-6a: Comparison of Temperature Simulation in Year 2000 at Selected Bay Water Quality Stations

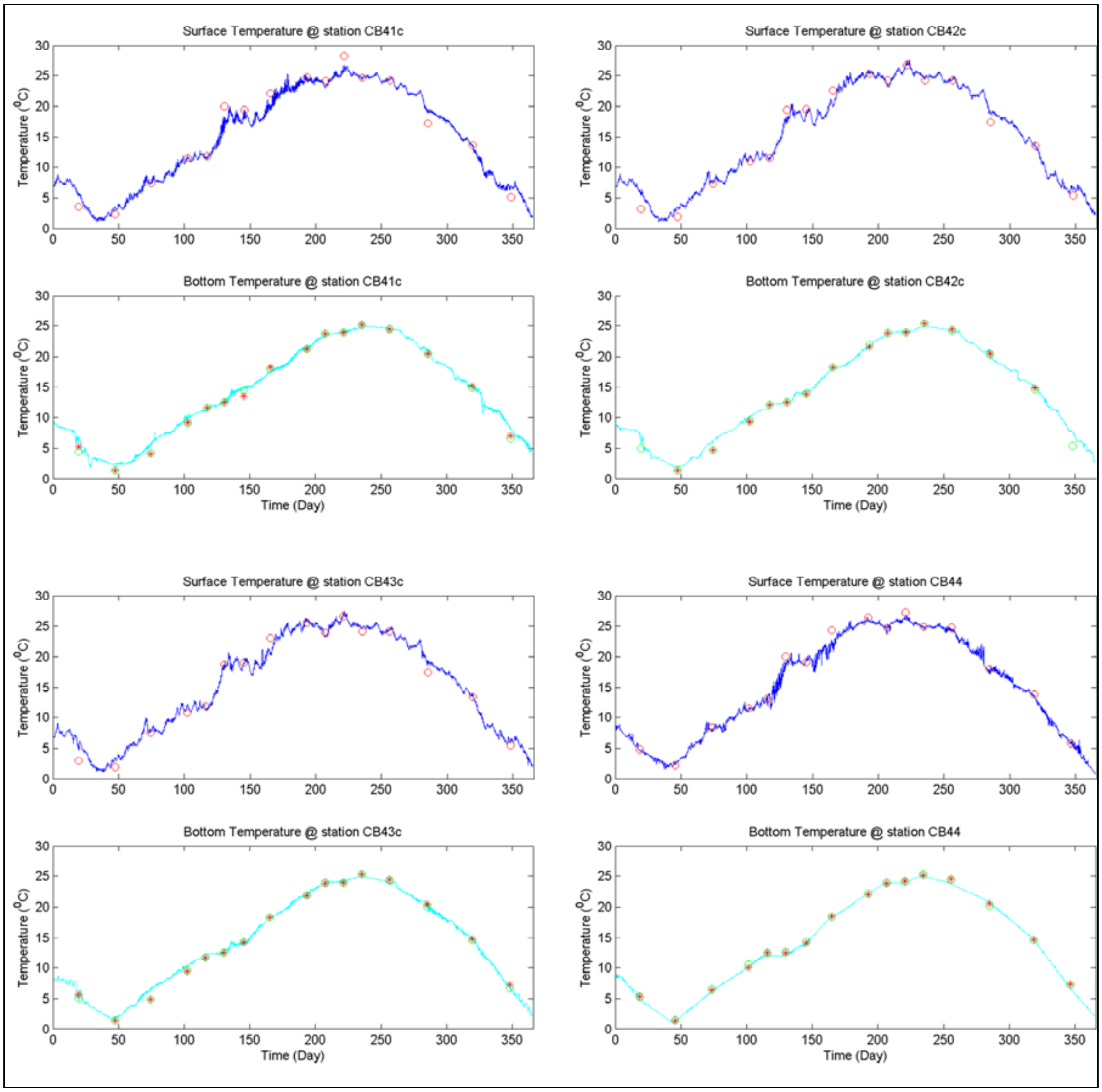


Figure E-6b: Comparison of Temperature Simulation in Year 2000 at Selected Bay Water Quality Stations

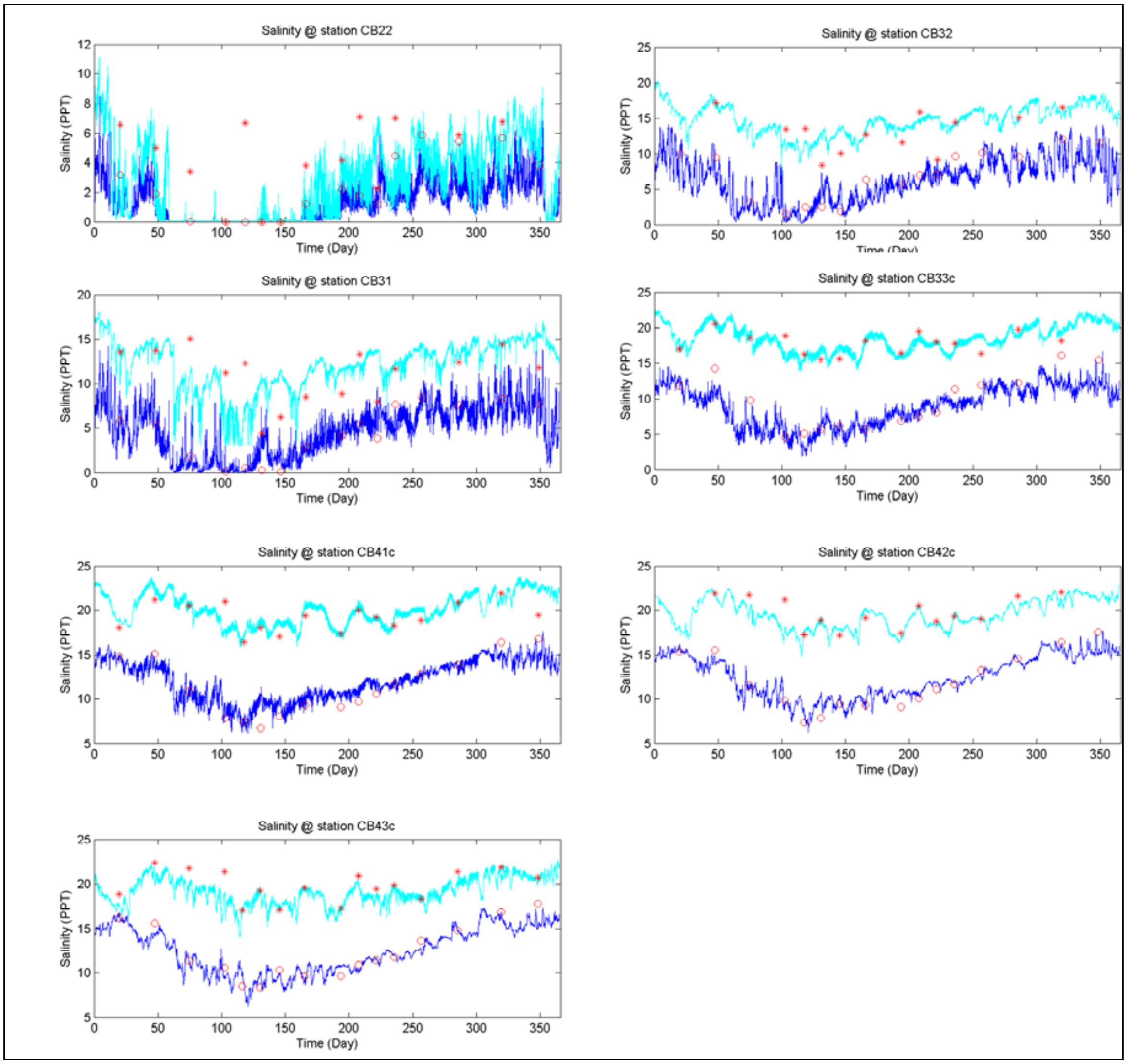
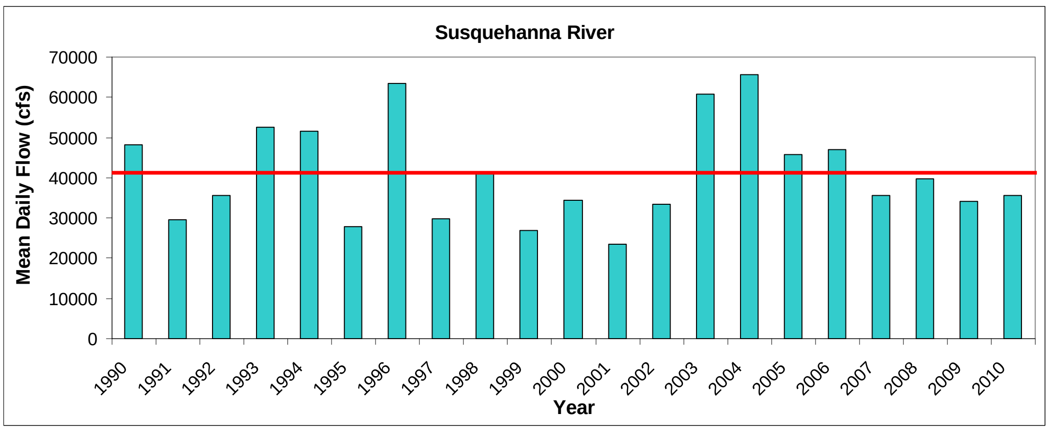


Figure E-7: Comparison of Salinity Simulation of Year 2000 at Selected Bay Water Quality Stations

III. Eutrophication Model Calibration

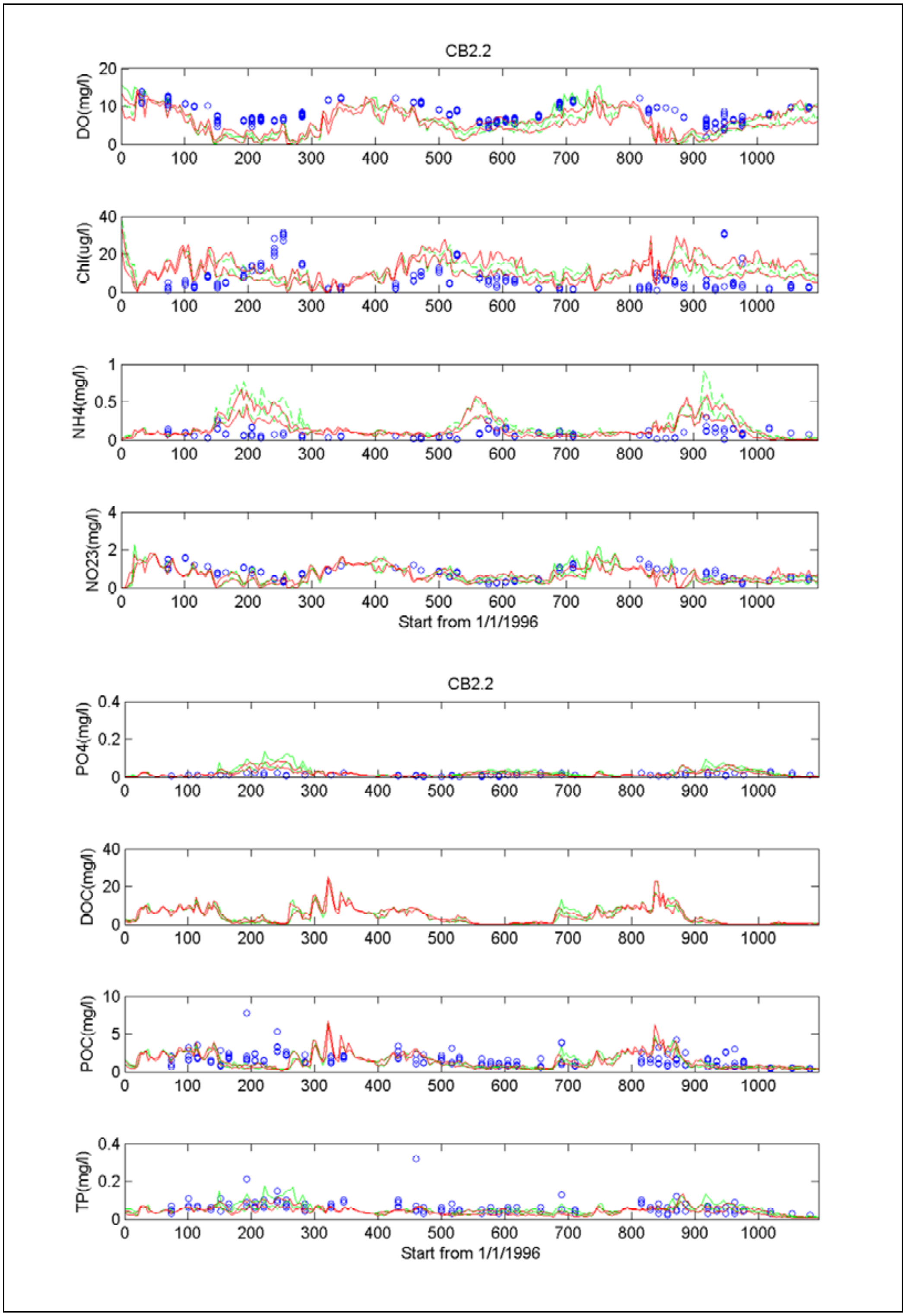
A three-year period from 1996-1998 was selected for the eutrophication model calibration. This simulation period covered dry, wet, and mean hydrological years (see Figure E-8), and it also matched one year intensive PCB measurements in the Baltimore Harbor embayment. The overall objective of the model calibration was to compare the water quality model results to the observed data utilizing a set of model kinetic coefficients and parameters that were consistent with field measurements and were within the general ranges of values accepted by the modeling community, as reported in the literature. The main steps involved in the calibration of the water quality model were: 1) the appropriate boundary condition had to be chosen, 2) the verified external nutrient loads had to be included, 3) the correct initial condition had to be specified, and 4) the suitable parameter values had to be estimated. The Chesapeake Bay observation data at

CB4.4 was used for the model open boundary condition. The CBP Phase 5 watershed model output including TN, TP, PO4, NH4, NO23, DO, and algae were used for nonpoint source loads. For this study, the point source loads were directly discharged to the sub-watershed corresponding to their locations and included in the watershed loads. For modeling purposes, the refractory and labile particulates were grouped into one particulate for OC, nitrogen, and phosphorus. Because the water column eutrophication is coupled to the bottom sediment processes model, the model was cyclically run to 3 years using 1996 load and boundary conditions until the bottom sediments reached a dynamic equilibrium, and the nutrient and carbon concentrations in the bottom sediments were saved and used as an initial condition. Five stations were selected for model calibration, and the results are shown in Figures E-9 to E-13. Model calibrations include algae, DO, NH4, NO23, POC, DOC, and TP. Overall, the model performance is satisfactory. Note that station WT5.1 is located inside the Baltimore Harbor embayment. The model performance of algae and OCs at station WT5.1 is satisfactory, which captures seasonal and annual variations. Although there are some discrepancies of model simulations in some stations in the upper Bay, the results would not affect the PCB simulations, since these stations are located outside of the Baltimore Harbor embayment, while a small domain model was used for PCB simulation in the Baltimore Harbor (see Appendix F). Overall, the model results are suitable for the PCB sub-model.



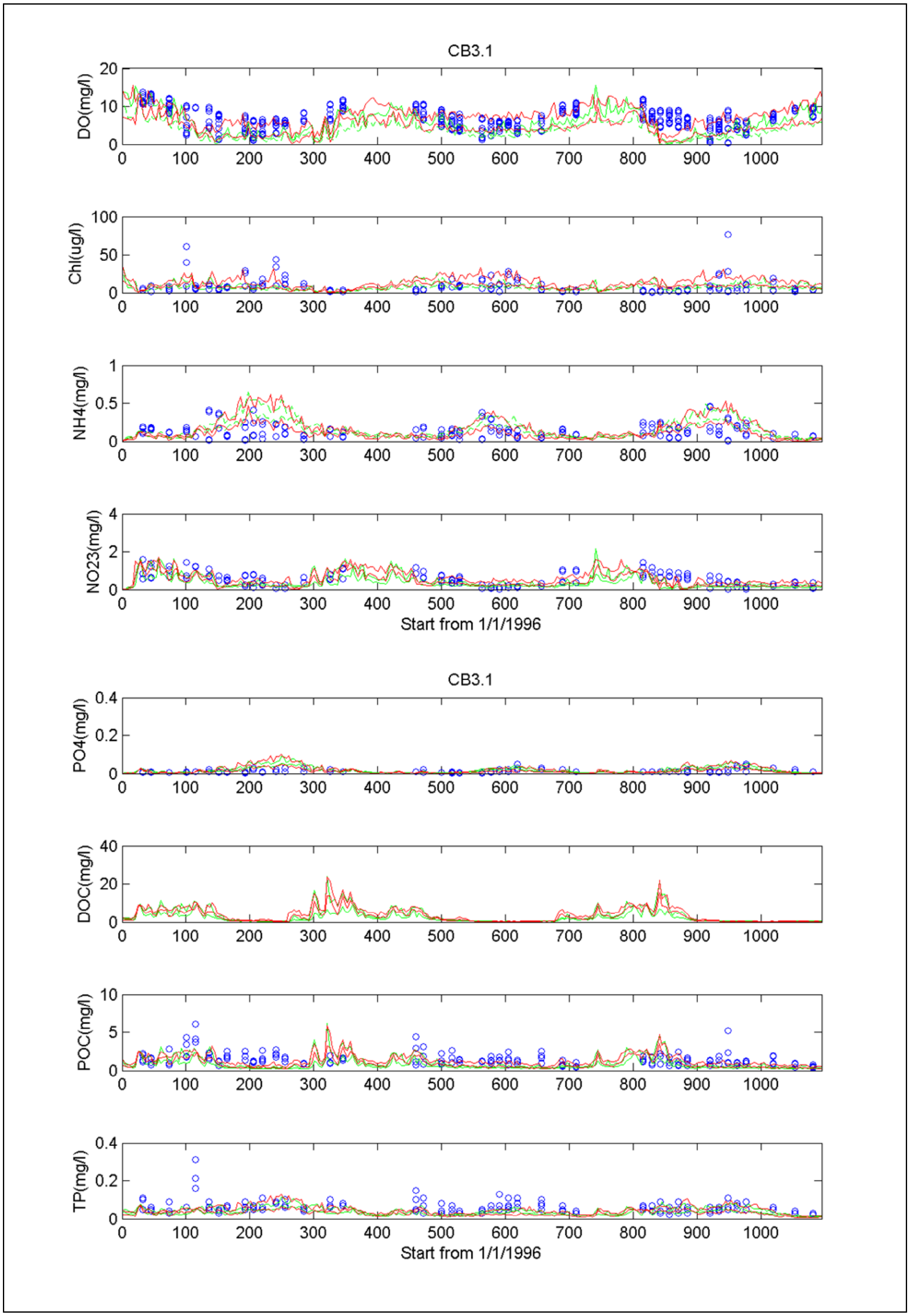
Note: The horizontal line represents the long-term mean flush water discharge

Figure E-8: Mean Freshwater Discharge at the Susquehanna River



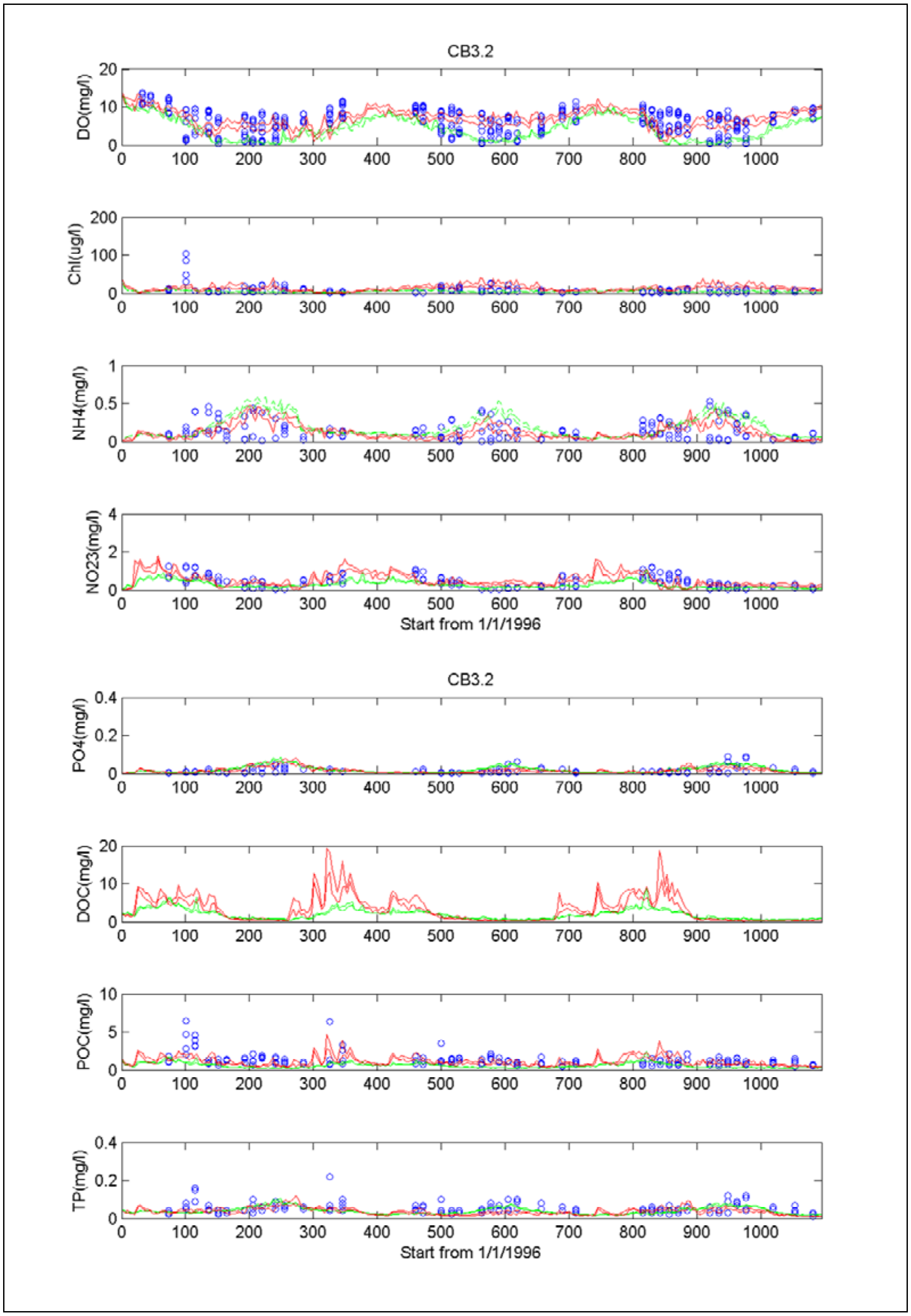
Note: The red and green lines are daily maximum and minimum concentrations at the surface and bottom of the embayment, respectively, and the dots are measurements at different depths.

Figure E-9: Eutrophication Model Calibration at Station CB2.2



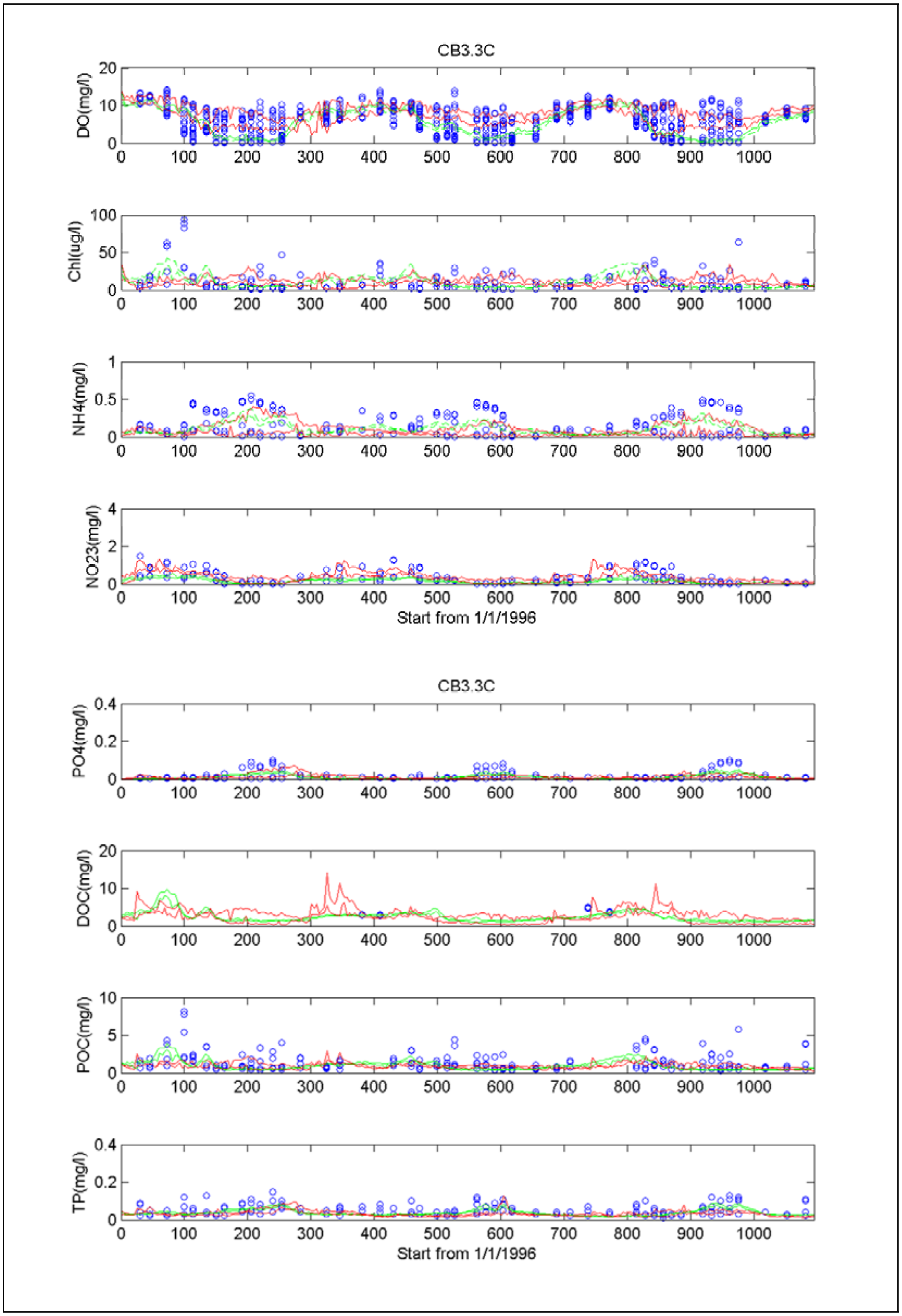
Note: The red and green lines are daily maximum and minimum concentrations at the surface and bottom of the embayment, respectively, and the dots are measurements at different depths.

Figure E-10: Eutrophication Model Calibration at Station CB3.1



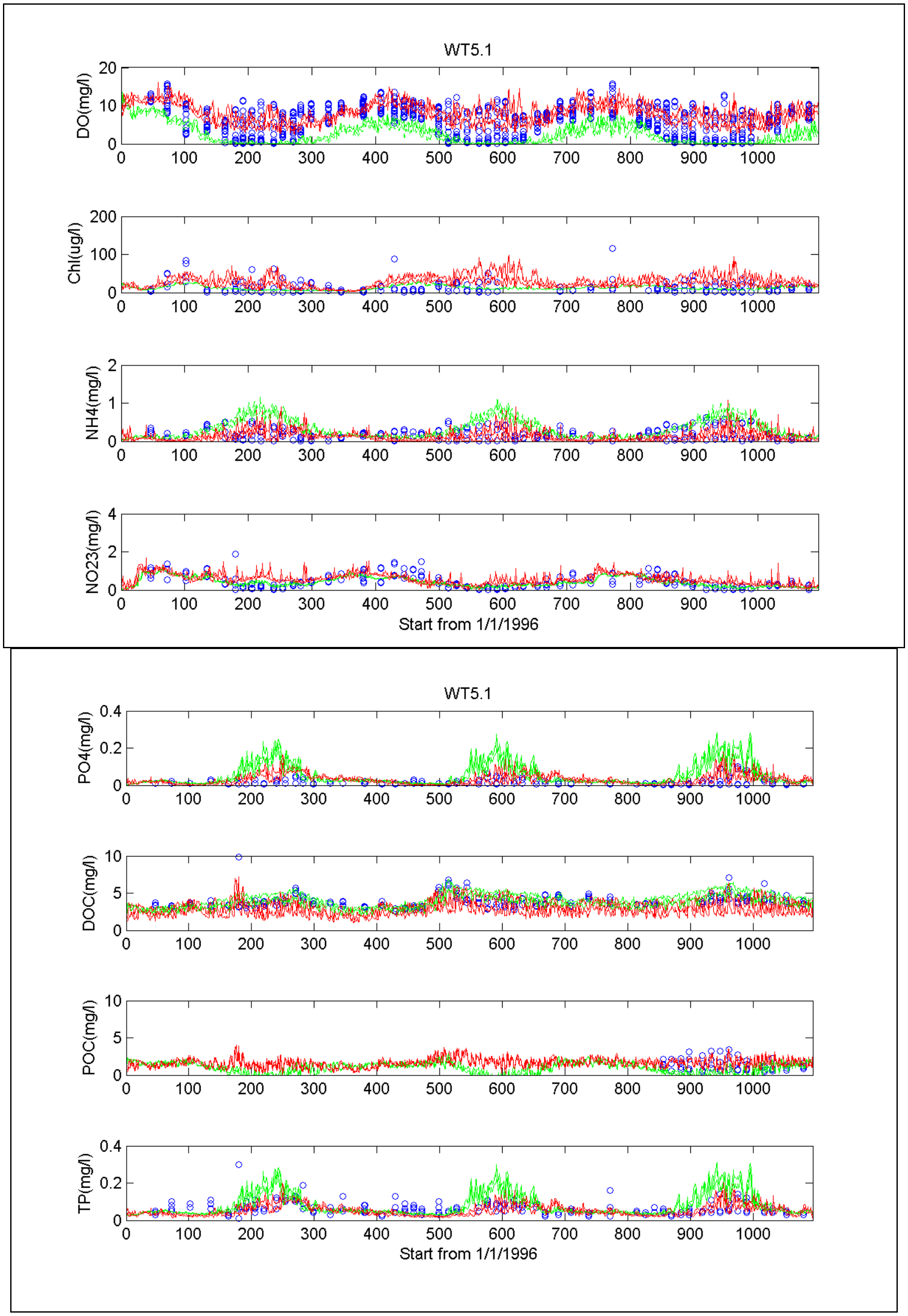
Note: The red and green lines are daily maximum and minimum concentrations at the surface and bottom of the embayment, respectively, and the dots are measurements at different depths.

Figure E-11: Eutrophication Model Calibration at Station CB3.2



Note: The red and green lines are daily maximum and minimum concentrations at the surface and bottom of the embayment, respectively, and the dots are measurements at different depths.

Figure E-12: Eutrophication Model Calibration at Station CB3.3C



Note: The red and green lines are daily maximum and minimum concentrations at the surface and bottom of the embayment, respectively, and the dots are measurements at different depths.

Figure E-13: Eutrophication Model Calibration at Station WT5.1

Appendix F: PCB Model Description and Model Simulation

I. Introduction

Numerical models have been used for developing PCB TMDLs. The PCB TMDL development for tidal portions of the Potomac and Anacostia Rivers in the District of Columbia, Maryland, and Virginia (Haywood and Buchanan 2007) is a successful model application. The Potomac TMDL study used coupled numerical models of OCs and PCBs to simulate the transport and fate of PCBs and conducted load allocation scenario studies to establish load reductions. The carbon-based PCB model is well documented in the document (US EPA 2006; Zhang et al. 2008, 2009). The approach provides a sound methodology to develop TMDLs for tidal rivers and estuaries. The same model framework is used in this TMDL study. The model used the EFDC model as the base model, with a revised PCB sub-model. The model simulates both water column and bottom sediment PCBs. Water column PCBs are modeled as four state variables, which are:

- Particulate organic carbon bound PCB (C_P^1)
- Algal bound PCB (C_P^2)
- Dissolve organic carbon bound PCB (C_D)
- Free dissolved PCB (C_w)

The bottom sediment PCBs are modeled as three state variables:

- Sorbed PCB (include POC-bound + algal bound PCB) (C_{BP})
- Dissolve carbon bound PCB (C_{BD})
- Free dissolved PCB (C_{BW})

A diagram of the PCB model is shown in Figure F-1.

The OC species are simulated using the eutrophication model as described in Appendix E. Both labile and refractory particulate carbons are grouped as particulate carbon. All algae species are grouped into one algal group. The PCB sub-model is coupled to the hydrodynamic model and carbon sub-model (eutrophication model). For each timestep, OC species simulated by carbon model will feed to the PCB sub-model. The tPCBs will be transported by the dynamic fields computed from the hydrodynamic model. The linkage between the hydrodynamic and carbon models is illustrated in Figure F-2.

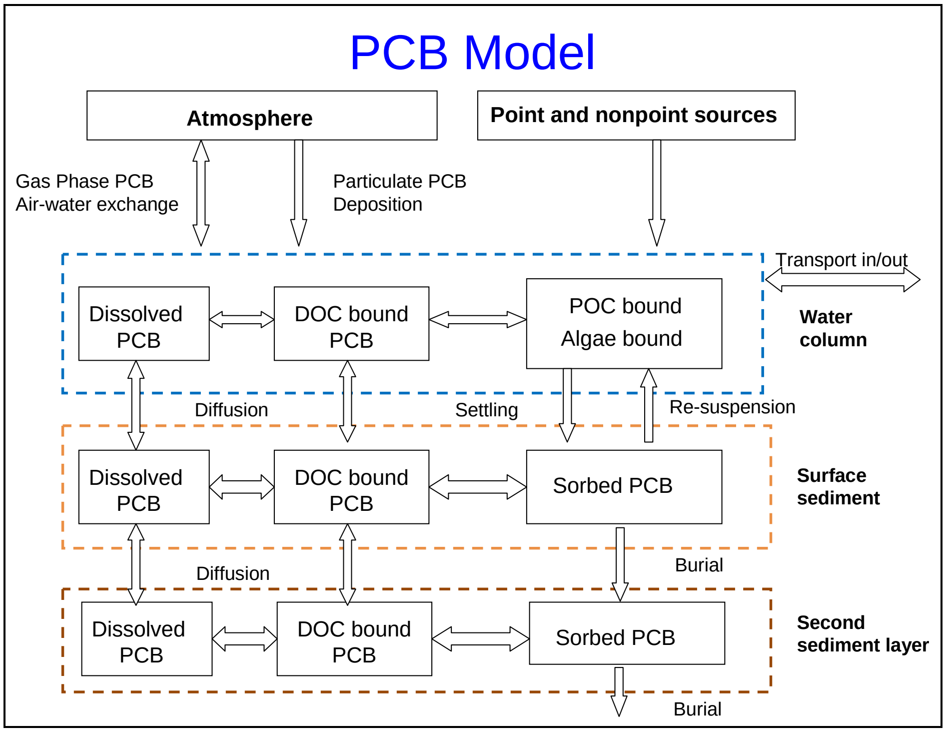


Figure F-1: A Diagram of the PCB Model

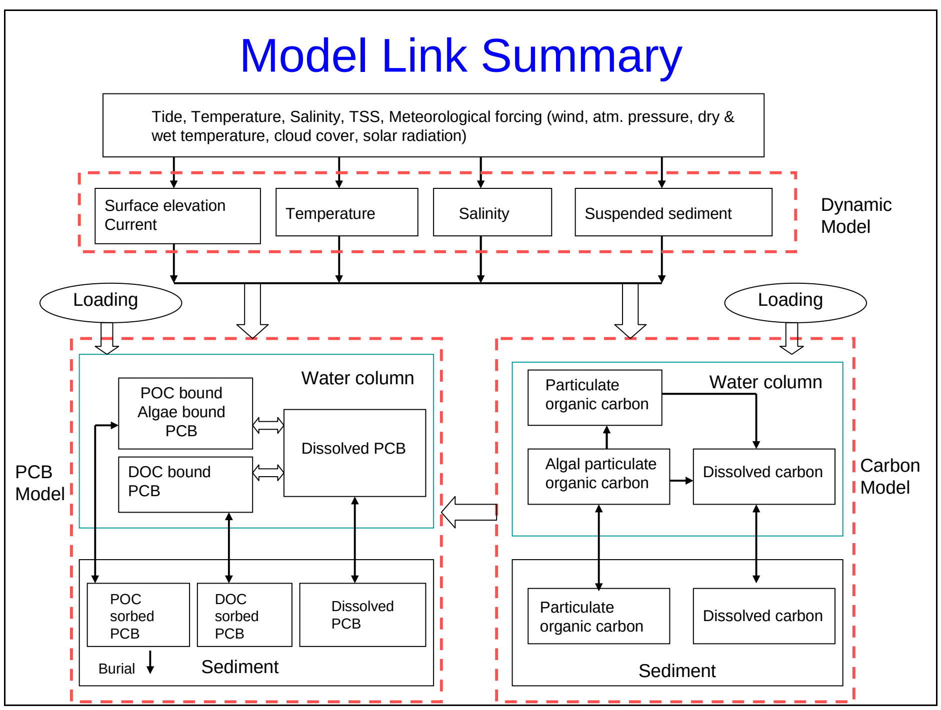


Figure F-2: A diagram of the Linkage of Sub-Models

II. PCB Mass Balance Equation

The EFDC model has a toxic sub-model which uses equilibrium model based sorption/desorption processes between toxic materials and suspended sediment. This sub-model was revised to simulate PCBs based on sorption/desorption between OCs and PCBs. The mass balance and transport equation for simulating PCB transport and fate is similar to those transport equations described in EFDC document (Hamrick 1992; Tetra Tech 2002). Carbon sorption processes are based on the framework of the PCB model applied successfully in the Potomac River (Haywood and Buchanan 2007).

The PCB model uses an equilibrium approach, which assumes linear isotherm equilibrium between sorbed concentrations ν (ng/mg) and dissolved concentrations C_d (ng/L) (Chapra 1997). The processes can be described as

$$\nu = K_d \times C_d \tag{F-1}$$

Where: K_d (L mg^{-1}, or m^{3}g^{-1}) is the partition coefficient. The relationships between tPCB, dissolved PCB, particulate carbon-bound PCB, algal-bound PCB, and dissolved carbon-bound PCB can be computed using fraction coefficients:

Dissolved PCB (C_w): $C_w = f_w \times C$

Particulate Carbon pound PCB (C_P^1): $C_P^1 = f_P^1 \times C$

Algae bound PCB (C_P^2): $C_P^2 = f_P^2 \times C$

Dissolved organic carbon bound PCB (C_D): $C_D = f_D \times C$

Where:

$$f_w + \sum_i f_P^i + f_D = 1 \tag{F-2}$$

$$fw = \frac{Cw}{C} = \frac{\phi}{\phi + \sum_i K_P^i m_P^i + K_D m_D} \tag{F-3}$$

$$f_P^i = \frac{C_P^i}{C} = \frac{K_P^i m_P^i}{\phi + \sum_i K_P^i m_P^i + K_D m_D} \tag{F-4}$$

$$f_D = \frac{C_D}{C} = \frac{K_D m_D}{\phi + \sum_i K_P^i m_P^i + K_D m_D} \tag{F-5}$$

f_w, f_P^1, f_P^2, and f_D are fractions for each species, m_P^1, m_P^2, and m_D are POC, particulate algal carbon, and DOC. K_P^1, K_P^2, and K_D denote the partition coefficients, respectively for the aforementioned three carbon species.

Using equilibrium partitioning relationship, the transport equation for tPCB in the water column in curvilinear-orthogonal horizontal coordinates and a sigma or stretched vertical coordinate system can be written as (Hamrick 1992; Tetra Tech 2002):

$$\partial_t\left(m_x m_y HC\right)+\frac{1}{m_x m_y}\partial_x\left(m_y HuC\right)+\frac{1}{m_x m_y}\partial_y\left(m_x HvC\right)+\partial_x\left(m_x m_y wC\right)$$

$$-\partial_x\left(m_x m_y \sum_i w_s^i f_P^i C\right)=\partial_z\left(m_x m_y \frac{A_b}{H}\partial_z C\right)-\left(m_x m_y H\gamma C\right) \qquad \text{(F-6)}$$

Where: H is water depth, C is tPCB concentration, A_b is eddy diffusivity, w_s^i ($i=1,2$) are settling velocity associated with particulate organic carbon and algal OC, γ is decay constant, u, v, and w are velocities at x-, y-, and z- directions, and m_x and m_y are scale factors of the horizontal coordinates.

The boundary condition at the water column sediment interface, z = 0, is:

$$-\frac{A_b}{H}\partial_z C-\sum_i w_s^i f_s^i C=$$

$$\sum_i\left[\max\left(\frac{J_P^i f_P^i}{m_P^i},0\right)C\right]_S+\sum_i\left[\min\left(\frac{J_P^i f_P^i}{m_P^i},0\right)C\right]_W-q_{dif}\left(\frac{f_w+f_D}{\phi}C\right)_W+q_{dif}\left(\frac{f_w+f_D}{\phi_s}C\right)_S \qquad \text{(F-7)}$$

Where: J_P^i ($i=1,2$) are the OC fluxes between sediment bed and water column (mass per unit area per second), defined as positive from the bed, and ϕ and ϕ_s are porosity in water column and sediment. The subscripts 'w' and 's' denote water column and sediment, respectively, and q_{dif} is diffusion velocity.

The volatilization occurs at the surface and depends on the mass transfer coefficient at the air-water interface and the concentration of PCB in the water column. The boundary condition at the water column and air interface, z = 1, is (Bamford et al. 2002b):

$$-\frac{A_b}{H}\partial_z C-\sum_i w_s^i f_s^i C=\frac{K_V}{\Delta Z}\left[f_w C-\frac{C_a}{K_H'}\right] \qquad \text{(F-8)}$$

Where: K_v is the volatilization mass transfer coefficient [L/T], ΔZ is the thickness of the first layer near the surface, C_a is the vapor phase PCB concentration in air [M/L^3], and K_H' is the dimensionless, temperature-corrected Henry's law constant. K_V can be determined from the field observations or estimated as follows:

$$K_V = \frac{K_g K_l}{K_g + \frac{K_l}{H'}} \qquad \text{(F-9)}$$

Where: K_g is the vapor phase mass transfer constant [L/T] and K_l is the water phase mass transfer constant [L/T]. Mills et al. (1982) provides an empirical formula to convert these transfer constant to O_2 and H_2O.

$$K_{l,PCB} = K_{l,O_2}\left(\frac{32}{M}\right)^{0.25} \qquad \text{(F-10)}$$

$$K_{g,PCB} = K_{gH_2O}\left(\frac{18}{M}\right)^{0.25} \qquad \text{(F-11)}$$

It is relate to current velocity (Mills et al., 1982) by

$$K_{g,PCB} = 168U_w\left(\frac{18}{M}\right)^{0.25} \qquad \text{(F-12)}$$

Where: M is molecular weight. K_{l,O_2} is reareration coefficient (K_a) used in DO model. Several empirical equations can be used including O'Conner-Dobbins, Owens and Gibbs (Chapra 1997). Thomann and Fizpatrick (1982) gave the equation related to wind and surface current

$$K_{l,O2} = K_a = 3.93\frac{\sqrt{U_0}}{H^{3/2}} + \frac{0.0728U_w^{0.5} - 0.317U_w + 0.0372U_w^{25}}{H} \qquad \text{(F-13a)}$$

Where: U_w is wind velocity [L/T] and U_0 is tidal average flow velocity [L/T]. The EFDC model computes the K_a using equation in estuary as follows

$$Ka = \left(k_{ro}\sqrt{\frac{u_{eq}}{h_{eq}} + 0.728U_w^{1/2} - 0.317U_w} + 0.0372U_w^2\right)\frac{1}{\Delta z}\theta^{T-20} \qquad \text{(F-13b)}$$

Where: u_{eq} is weighted velocity over cross-section (m/s), h_{eq} is weighted depth over cross-section (m), U_w is wind speed (m/s) at the height of 10m above surface, θ =constant for temperature adjustment (Park et al. 1995).

PCB gaseous exchange fluxes across the air-water interface are one of the dominant losses of PCBs in the Chesapeake Bay (Bamford et al. 2002a; Nelson et al. 1998). K_H' is a temperature depend parameters (Bamford et al. 2002b). Nelson et al. (1998) provide a formula to correct Henry's law constant as (for temperature at 298 K):

$$\ln H_T = \ln H_{298} + 26.39 - 7868/T \qquad \text{(F-14a)}$$

Where: H_T and H_{298} are the Henry's law constants at temperature T and 298K, respectively. Bamford et al. (2002b), suggests using the following equation:

$$\ln K_H^{'} = -(\Delta H_H / RT) + (\Delta S_H / R) \qquad \text{(F-14b)}$$

Where: ΔH_H and ΔS_H are the entropy of phase change of transfer across the air-water interface and the entropy of phase change. ΔH_H and ΔS_H vary with respect to PCB congeners. The model test shows that Eq. F14b is very sensitive to the temperature and congeners selected. Based on model calibration with different formulas, Nelson's equation was used for the model, which provides better results for the model simulation of individual homolog.

The transport model (Eq. F6) together with boundary condition F7 and F8 is solved using a fractional step procedure which sequentially computes advection, settling, resuspension, and diffusion (Hamrick 1992; Tetra Tech 2002).

III. Sediment PCB Mass Balance Equation

Two-layer bottom sediment model is used for simulate PCBs in the bottom sediment which is similar to the Potomac PCB model. The mass balance equation for the surface layer (layer 1) is written as

$$\partial_t (BC)_1 = -\gamma (BC)_1$$
$$-\sum_i \left[\max\left(\frac{J_P^i f_P^i}{B m_P^i}, 0 \right) BC \right]_{1+} - \sum_i \left[\min\left(\frac{J_P^i f_P^i}{m_P^i}, 0 \right) C \right]_W + \sum_i \left[\min\left(\frac{J_P^i f_P^i}{B m_P^i}, 0 \right) BC \right]_{1-} + \sum_i \left[\max\left(\frac{J_P^i f_P^i}{m_P^i}, 0 \right) BC \right]_{2+}$$
$$+ q_{dif} \left(\frac{f_w + f_D}{\phi} C \right)_W - q_{dif} \left(\frac{f_w + f_D}{B\phi_s} BC \right)_{1+} + q_{dif2} \left(\frac{f_w + f_D}{B\phi_s} BC \right)_{2+} - q_{dif} \left(\frac{f_w + f_D}{B\phi_s} BC \right)_{1-} \qquad \text{(F15)}$$

The bottom layer (layer 2) is written as

$$\partial_t (BC)_2 = -\gamma (BC)_2$$
$$-\sum_i \left[\max\left(\frac{J_P^i f_P^i}{B m_P^i}, 0 \right) BC \right]_{2+} - \sum_i \left[\min\left(\frac{J_P^i f_P^i}{B m_P^i}, 0 \right) BC \right]_{1-} - \sum_i \left[\max\left(\frac{J_P^i f_P^i}{m_P^i}, 0 \right) BC \right]_{2-}$$
$$-q_{dif2} \left(\frac{f_w + f_D}{B\phi_s} BC \right)_{2+} + q_{dif} \left(\frac{f_w + f_D}{B\phi_s} BC \right)_{1-} \qquad \text{(F-16)}$$

Because the porosity changes with time depending on sediment deposition and erosion processes, bulk density and porosity or void ratio of the sediment must be correctly estimated during the model simulation. The porosity can be dynamically computed from inorganic sediment model. Different bed sediment model can be used to simulate the change of bottom sediment thickness and porosity depending on the complexity of the bed sediment model applied. The simplest approach assumes specified time-constant layer thickness and void ratio (Chapra 1997), which is very efficient for long-term simulation as both erosion and resuspension rates can be obtained from field observation and geochemistry method such as Pb^{210} technique (MDE 2009). The second level of bed mass conservation assumes specified time invariant layer thickness, but varying void ratio. A more complex bed mass conservation model uses multiple layers in the bottom and bottom thickness and void ratio are time dependent, and the number of sediment bed layer can be dynamically changed when erosion and deposition occur. However, the complex model is more difficult to calibrate as there is often no sufficient data available.

Note that void ratio (ε) and porosity (ϕ) are related by

$$\phi = \frac{\varepsilon}{1+\varepsilon} \qquad \text{(F-17)}$$

Total sediment on bed can be expressed by sediment density and void ratio and the bed mass conservation for fixed bed thickness can be written as (Tetra Tech 2002)

$$B_k \partial_t \left(\frac{1}{1+\varepsilon_k} \right) = \frac{1}{\rho_s} \left(J_{s,k-} - J_{s,k+} \right) - \delta(k, k_b) \frac{J_{sb}}{\rho_s} \qquad \text{(F-18)}$$

Where: B_k is the thickness of the k[th] layer, ε_k is void ratio at k[th] layer, ρ_s is sediment density, J_{sk+}, J_{sk-} are sediment fluxes with k- and k+ defining the bottom and top boundaries of the k[th] layer, J_{sb} is sediment deposition at the top layer k_b, where

$$\delta(k, kb) = \begin{cases} 1 & k = k_b \\ 0 & k \neq k_b \end{cases}$$

An alternative way to model sediment is to assume that the ratio of total particulate carbon and sediment is a constant. Therefore, sediment deposition can be estimated by carbon deposition (DRBC 2003). Let TPOC and IS represents all particulate matters (m) in the sediment, Assuming TPOC/IS=η, then the concentration TPOC and IS are $m \cdot \eta/(\eta+1)$ and $m/(\eta+1)$. Total sediment associated with settling of TPCO is $1/\eta \cdot$TPOC. This deposition is balanced by resuspension and burial in the sediment bed.

For the EFDC model, the resuspension of sediment is computed based on critical shear stress near the bottom. When shear stress is larger than critical shear stress, resuspension occurs. The sediment porosity changes as deposition and resuspension occurs. The carbon to sediment ratio (or carbon fraction) is used to estimate the amount of OC to be resuspended associated with the resuspended sediment, and the corresponding resuspended PCB can be computed and added to PCB pool in the water column.

IV. PCB Model Configuration

It is not feasible to model 209 PCB congeners. For Lake Michigan PCB application, 56 congeners were simulated (Zhang et al. 2008). An alternative way is to simulate homologs, which groups congeners according to the number of chlorine. In Delaware estuary, penta-PCB was selected as surrogate for tPCB (DRBC 2003). For Potomac TMDL, PCB3+ was selected as the surrogate for tPCB. Based on data analysis, high correlations exist between tetra-, penta-, and hexa-PCBs and tPCB. It is logical to model these homologs and the sum of the three can be used to compute the tPCB. Data analysis and regression results are presented in Appendix C. Regression with intersection set to zero was used to convert model results of sum of tetra-, penta-, and hexa- PCBs to tPCB (Table C2). Tetra-, penta-, and hexa- PCB homologs were selected for the model simulation. Data needed to set the model include:

- Nonpoint source load
    - Directly Controllable
        - Watershed Sources
            - Tributaries
            - Non-regulated Watershed Runoff (Direct Drainage)
        - Contaminated Sites
        - Atmospheric deposition
    - Resusepnsion from Bottom Sediments
    - Tidal Influence from Chesapeake Bay Mainstem
- Point source load
    - Directly Controllable
        - Process Water
            - WWTPs
            - Industrial Process Water
            - DMCFs
        - NPDES Regulated Stormwater

Previous studies show the Baltimore Harbor embayment is highly influenced by the Chesapeake Bay mainstem (Hong et al. 2010). A large portion of PCBs from the Bay mainstem can be transported into the embayment. However, there is no sufficient data available to estimate the load of the Bay mainstem and estimate the water column PCB concentrations at the mouth of Baltimore Harbor embayment. For the current TMDL, an intensive survey was conducted to measure seasonal PCB concentrations near the mouth. For modeling purposes, a small domain model which only includes the Baltimore Harbor embayment was used to simulate PCBs inside the embayment. The model grids inside the embayment are identical to the upper Chesapeake Bay model. The nested grid approach was used for the simulation, which enabled the boundary condition to be specified and long-term model simulation to be conducted efficiently. The output of hourly surface elevation, salinity, temperature, and suspended sediments from the upper Bay model were saved and used for the open boundary condition for the small domain model. For OC, two options can be used for the modeling. The first option is to use hourly output from the upper

Bay eutrophication model as the open boundary conditions for the small domain model. The eutrophication model will be run for the small domain model simultaneously with the PCB model. The second option is to save all the OC species in both water column and sediment including settling in each layer and exchanges between water column and bottom sediment. To improve the efficiency of the long-term simulation, the best calibrated OC results and associated fluxes were saved on the hard drive and used for the small domain PCB model. The small domain model for Baltimore Harbor embayment is shown in Figure F-3.

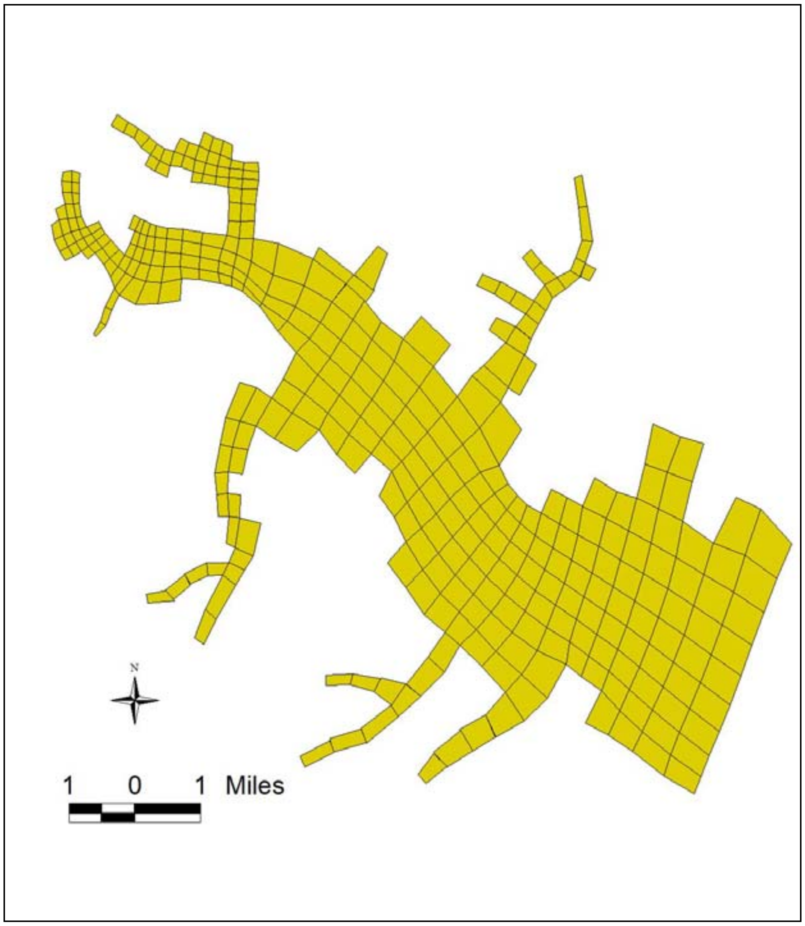


Figure F-3: Small Domain Models for Baltimore Harbor Embayment

Nonpoint Source Watershed Loads and NPDES Regulated Stormwater

For the nonpoint source watershed loads and NPDES regulated stormwater loads, the regression method, as described in Appendix D, was applied. These loads were estimated as an eggregate and then merely apportioned subsequently based on the proportion of urban land use within the direct drainage to the embayment. The upstream drainage areas and subwatersheds in the direct drainage to the Baltimore Harbor embayment include:

- Upstream

- Jones Falls
- Gwynns Falls
- Patapsco River

- Direct Drainage
  - Sawmill Creek (upstream Furnace Creek)
  - Remainder of watershed adjacent to the embayment

The Sawmill Creek at Grain Highway is a small drainage area, which is primarily urban, and was therefore assumed to be representative of the highly urbanized watershed area adjacent to the embayment. The regression function established for flow and tPCB load for Sawmill Creek was used to calculate the background load for the other sub-watersheds adjacent to the embayment as well. An estimation of tPCB watershed loads is listed in Table D-2. Using water column homolog distributions (see Table C-1), the nonpoint source watershed loads of tPCBs was redistributed to the three homologues.

Process Water *Point Source Load*

There are five permitted industrial process water sources, two WWTPs, and two DMCfs in the Baltimore Harbor embayment's watershed. The tPCB loads from these facilities were estimated from the measured PCB concentrations and average flows (see Table 7 and Appendix L). The total load from these facilities is approximately 859.4 g/year.

Contaminated Sites

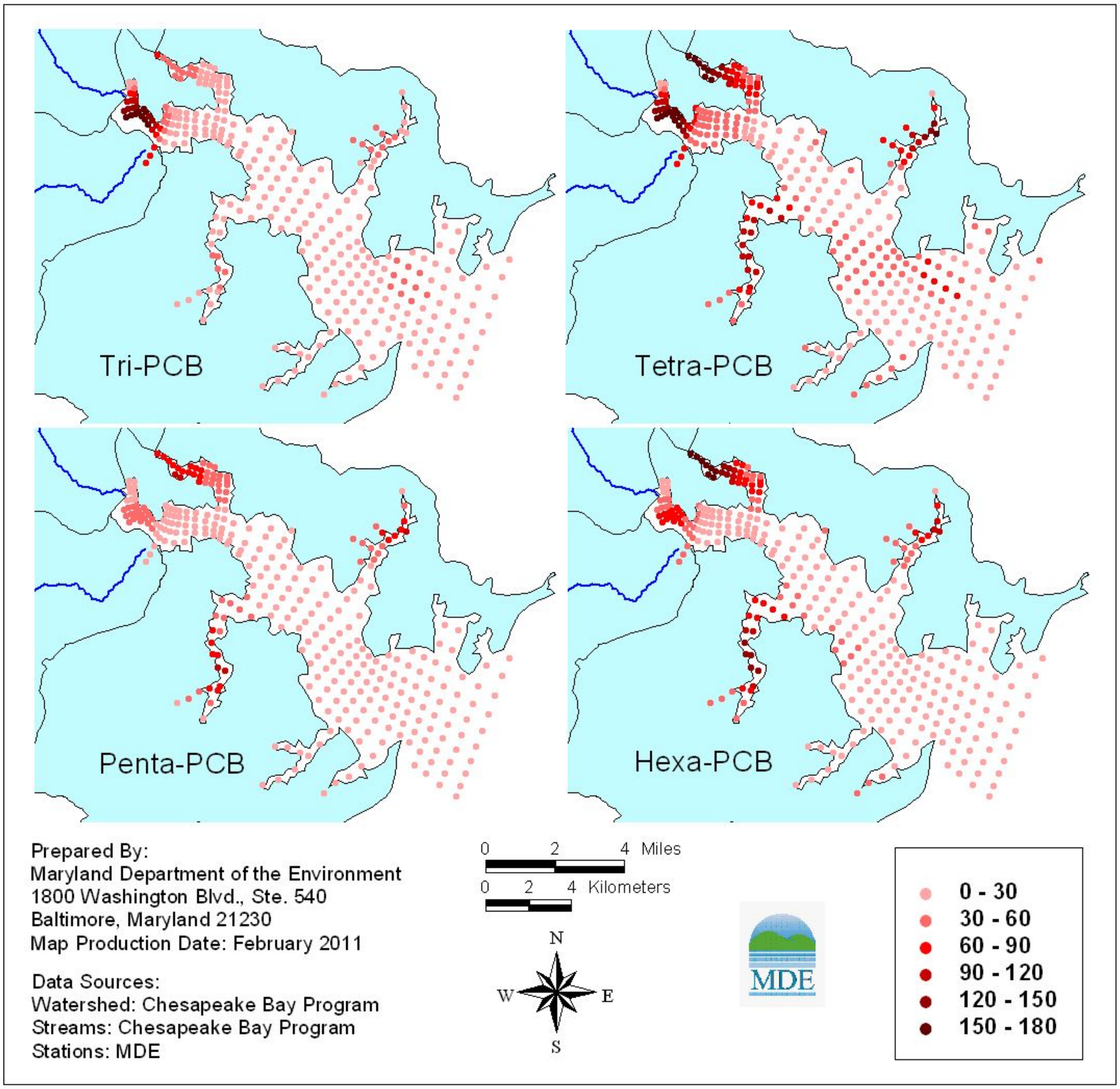
The estimated load from contaminated sites is about 14.5 g/year, which is small compared to the overall nonpoint source load. Because these sites are located in the direct drainage area of the watershed, their load needs to be removed from the total nonpoint source watershed load from the direct drainage portion of the watershed, as they are inherently a background load in this source.

Atmospheric Deposition and Air-Water Exchange

As described in Section 4.2, the CBP Atmospheric Deposition Study (CBP 1999) estimated a net deposition of 16.3 ug/m^2/year tPCB for urban areas and a net deposition of 1.6 ug/m^2/yr tPCB for regional (non urban) areas. The value of 16.3 ug/m^2/year was used for the model input of atmospheric deposition rate for this study. In the Chesapeake Bay, Nelson et al. (1998) estimated PCB gaseous exchange fluxes across the air-water interface of the mainstem of the Bay and determined that the annual loss of PCBs by volatilization was more than 10 times larger than inputs to the Bay from wet and dry deposition. Total PCB gaseous concentrations in Baltimore Harbor vary seasonally ranging from 67-1,400 picograms/meter cubed (pg/m^3) with mean concentration of 330 pg/m^3 (Bamford et al. 2002a). Net loss of PCBs ranges from 19-1240 ng/m^2/day, with mean flux of 350 ng/m^2/day. Because there is no sufficient time series data of PCB gaseous observations, a mean gaseous concentration of 330 pg/m^3 was used for model simulation. As the model simulation focus on long-term variation, this approach is appropriate.

Initial Condition

The residence time of Baltimore Harbor embayment is about 20-40 days (Hong et al. 2010). For long term simulation, the initial condition in the water column is not critical, which will be updated within a month. However, a large amount of PCBs are deposited on the bottom sediment, which is one of the dominate sources of the PCBs in water column. A comprehensive survey was conducted in year 2000, which covered a large area. Several surveys were conducted before 2000 and after 2000. By comparing the PCB sediment data, it is reasonable to use the 2000 data set as an initial condition, and use the current data set as model verification, assuming the sediment PCB concentrations are dynamically in a steady state. Figure F-4 shows the distribution of tri-, tetra-, penta-, and hexa-PCBs in the Baltimore Harbor embayment sediment based on year 2000 data. It can be seen that high concentrations were observed in Northern Harbor, Middle Branch, Curtis Creek, and Bear Creek. The interpolated results for tetra-, penta-, and hexa-PCBs were used for the model initial condition. The interpolation method was also used to obtain water column initial condition.



Note: units are in ng/g

Figure F-4: Predicted Distribution of Tri-, Tetra-, Penta-, and Hexa-PCBs in the Bottom Sediment of Baltimore Harbor Embayment Based on 2000 Data

Open Boundary Condition

The pervious study shows that a large portion of the materials from Chesapeake Bay mainstem are transported into the embayment (Hong et al. 2010). Bi-monthly data were collected at the Baltimore Harbor embayment's mouth and used to estimate loads from the Chesapeake Bay mainstem. A high order polynomial function was used to fit the data over a year. Different functions have been tested. The best-fit (with R^2=0.95) function could be used for the model boundary condition. An estimated tPCB distribution at the Baltimore Harbor embayment is shown in Figure F-5. By examining the distribution of observations and comparing with the regression results, it was decided to use linear interpolation between observed data points as the open boundary condition. This approach can avoid errors introduced due to the selection of functions to fit the data. It is assumed that the boundary condition have not changed much in recent years and will be repeatedly used for multiple year simulations.

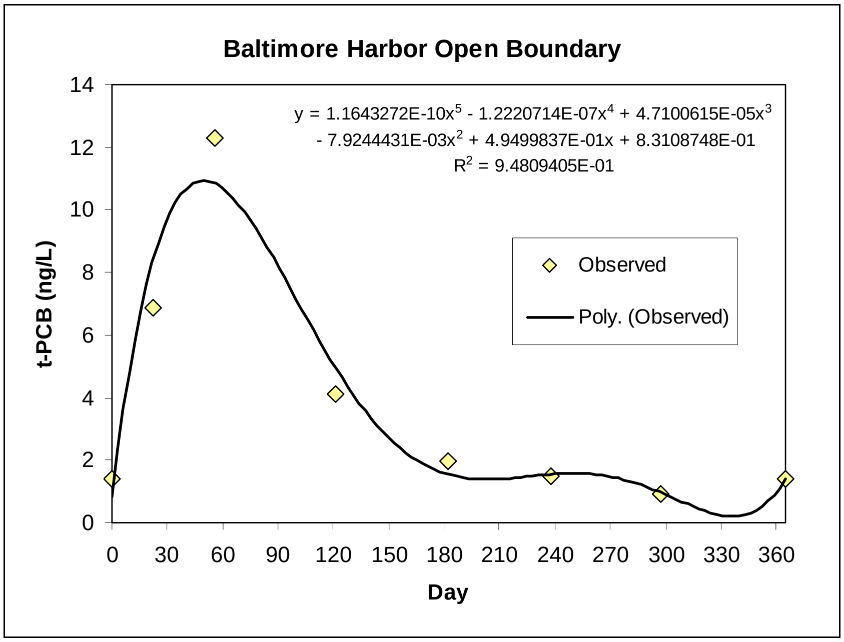


Figure F-5: Open Boundary Condition for tPCB in Baltimore Harbor Embayment

IV. *PCB Model Validation*

A three year period (1996-1998) was selected for the model calibration. During this period, an intensive survey at Key Bridge Station in the Baltimore Harbor embayment was conducted (Bamford et al. 2002a). This data set has both particulate and dissolved PCBs available, which can be used for model calibration. The reason of the selection of 1996-1998 periods was that this period covered wet, dry, and mean hydrological years and enabled us to test the model response to hydrological variations. The purpose for model calibration to simulate PCBs was to match this one year observations. It is reasonable to assume that this area does not undergo significant change in terms of both sediment and water column in a short team. Therefore, the modeled range of PCB variation should be within the range of measurements collected in recent years. Another assumption was that the sediment PCB concentration is dynamically in steady state and gradually decreases. The modeled PCB variations at each station where current samples are available will be examined for the simulation period. These data were mainly used to ensure the variations of PCB simulations are within the range of the observations.

Model calibration of the three homologs at the Key Bridge Station (near WT5.2 Figure E3) is presented in Figures F-6a through F-6c. It can be seen that the model captures the variation of the PCB over the year. Particulate, dissolved, and total PCBs all agree with the observations reasonably. Total PCB was computed by summing the three homologs and multiplying the conversion ratio of 1.48. It can be seen that high PCB concentrations occur during spring when run off is high. For the nonpoint source load distribution, high loads also occur in spring.

Because a large amount of water is transported into the embayment from the Chesapeake Bay mainstem, the observations at the embayment's boundary show the same pattern. It can be expected that seasonal PCB variations are highly controlled by nonpoint sources from the watershed and the Chesapeake Bay mainstem. Inter-annual variations can also be observed as high concentrations of PCB occurring in wet years (i.e.,1996). The model simulated the seasonal variations for both dissolved and particulate PCBs well. Since there is large uncertainty associated with boundary condition, load, atmospheric deposition, and observations, we do not expect model simulation matches observation for every data point. A cross check was conducted to compare model simulations and field observations at stations where recently data are available (see Figures F-7a through F-7c). The data were collected between 2008-2009. The purpose of comparison is to ensure that the modeled PCBs are within an acceptable range.

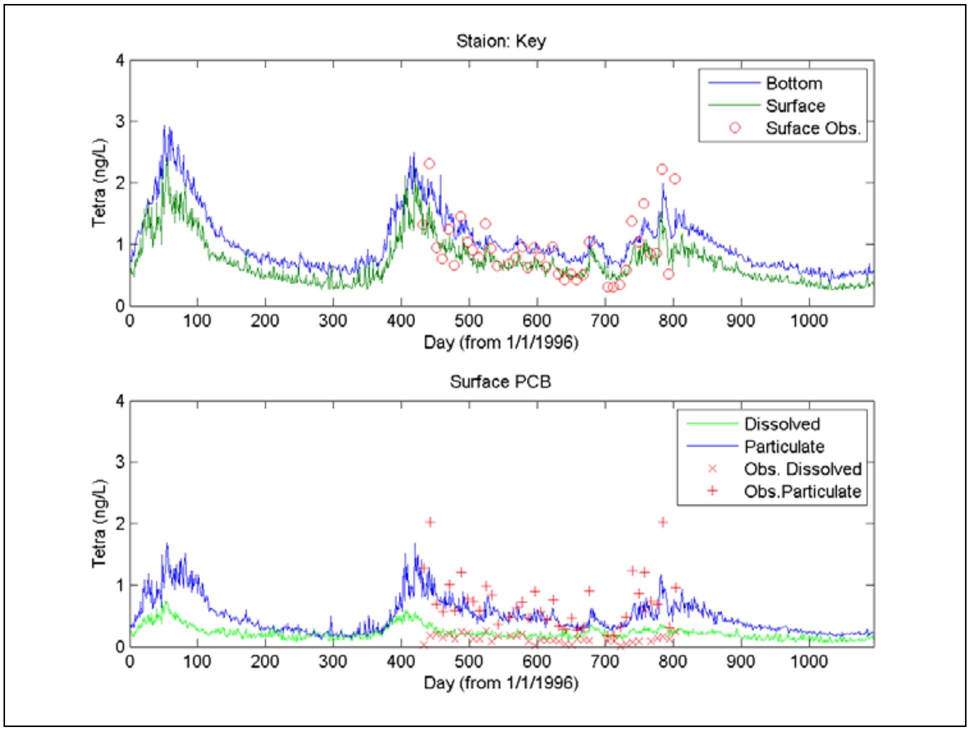


Figure F-6a: Comparison of Modeled Tetra-PCBs and Observed Data

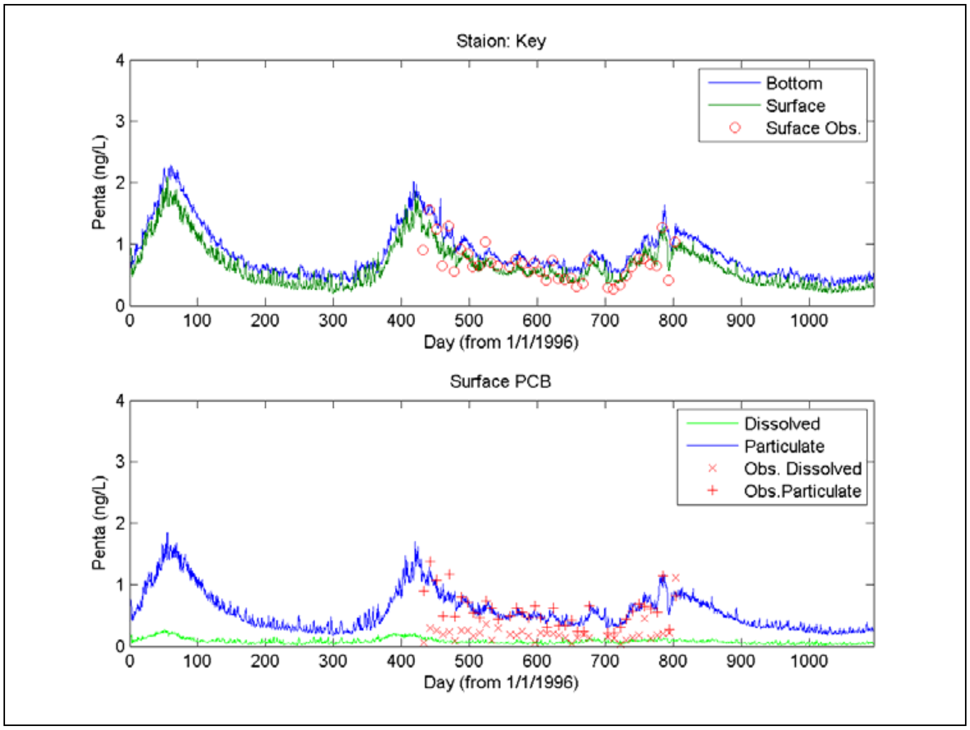


Figure F-6b: Comparison of Modeled Penta-PCBs and Observed Data

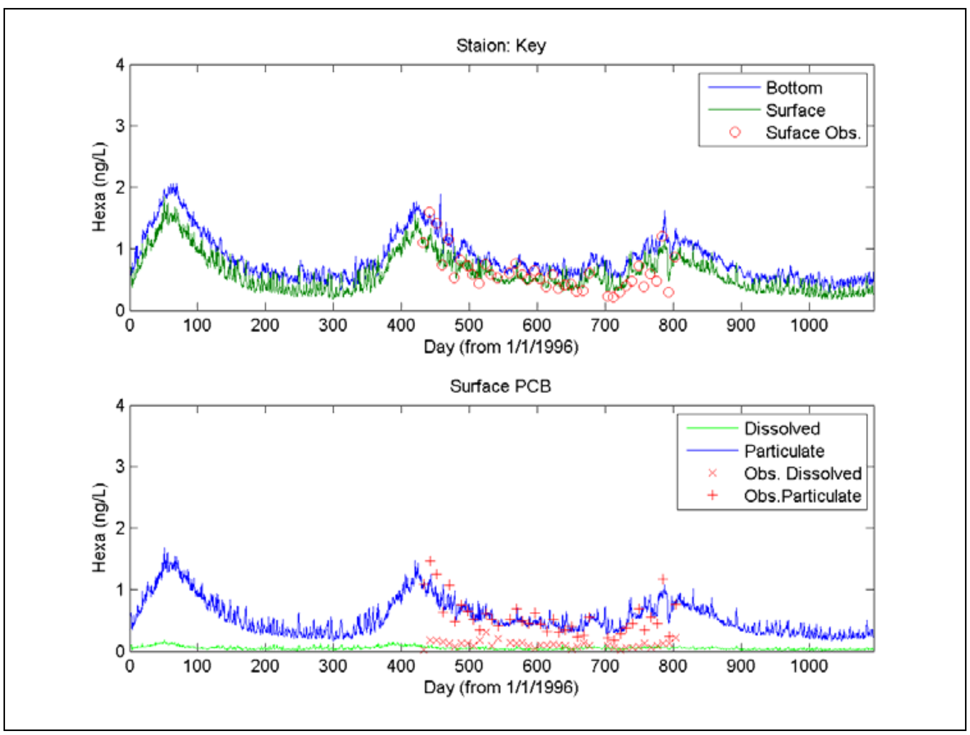
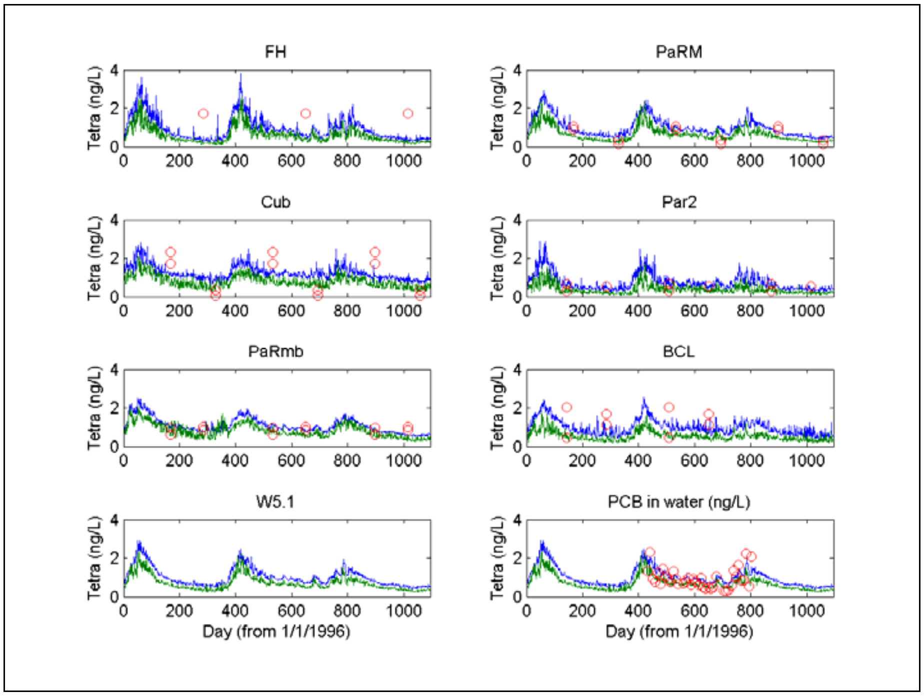
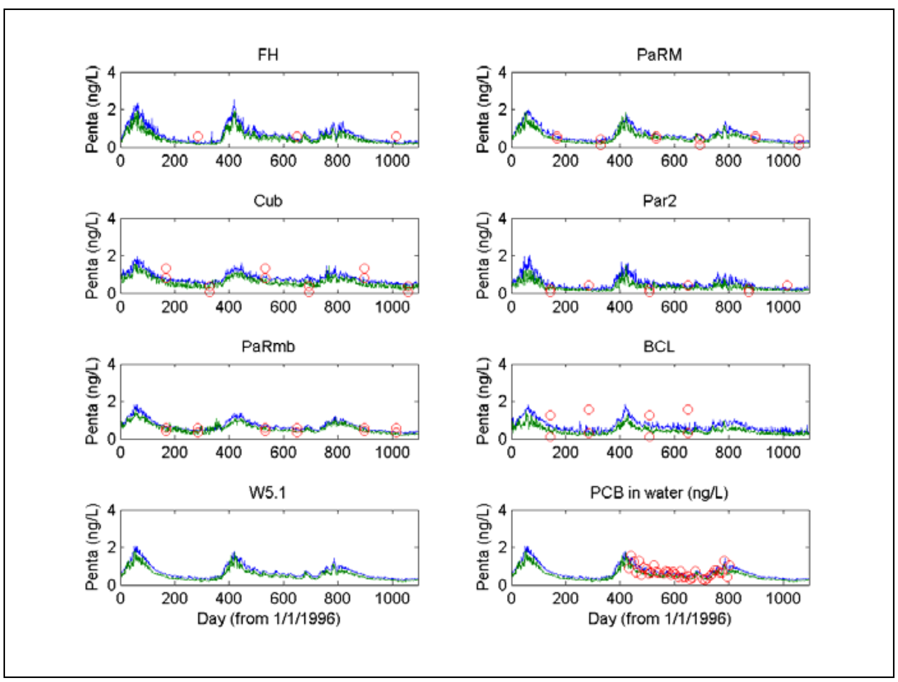


Figure F-6c: Comparison of Modeled Hexa-PCBs and Observed Data



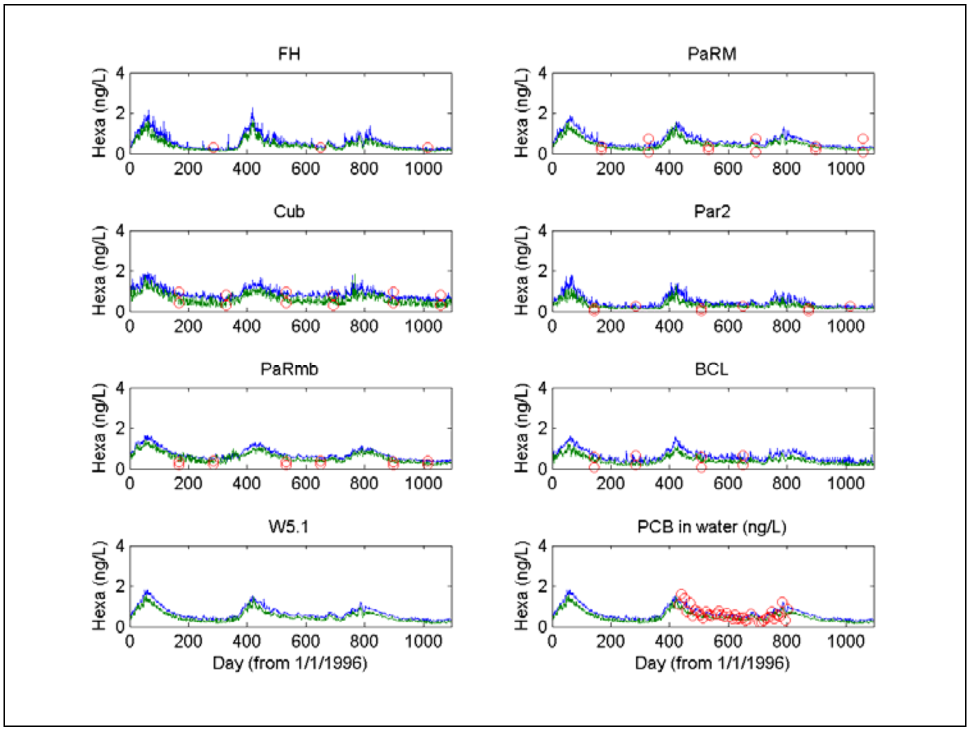
Note: The red circles represent field observations in 1997, the blue lines are bottom concentrations, and the green lines are surface concentrations

Figure F-7a: Model Simulation of Tetra-PCBs in Selected Stations



Note: The red circles represent field observations in 1997, the blue lines are bottom concentrations, and the green lines are surface concentrations

Figure F-7b: Model Simulation of Penta-PCBs in Selected Stations

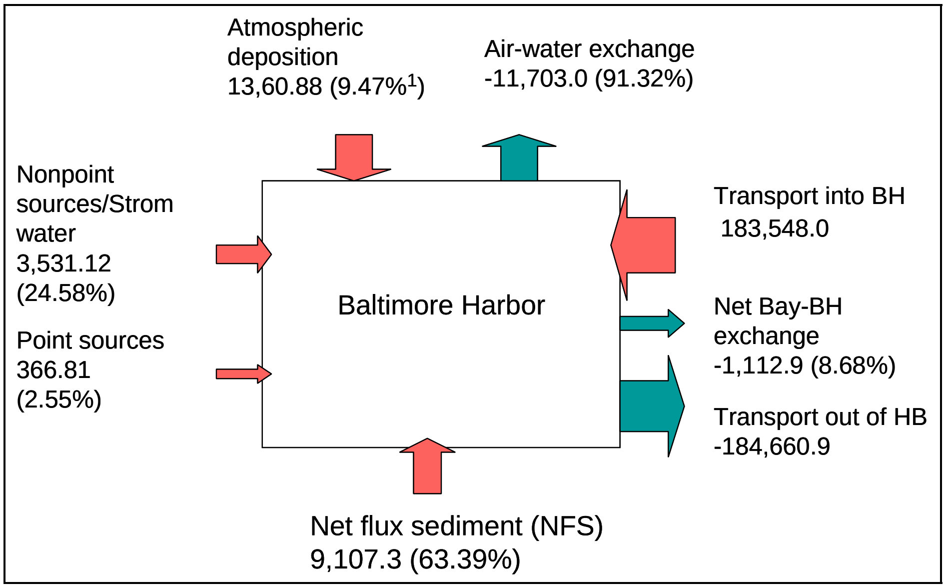


Note: The red circles represent field observations in 1997, the blue lines are bottom concentrations, and the green lines are surface concentrations

Figure F-7c: Model Simulation of Hexa-PCB in Selected Stations

V. PCB Budget

Using model simulations, point and nonpoint source loads, and air-water exchange flux, the tPCB budget can be obtained. The total load for computing the percentage of sources is the sum of nonpoint source, point source, atmospheric deposition, and net flux from sediment. The total loss for computing percentage of losses is the sum of volatilization and net transport out of the Hembayment. Although a large amount of tPCB is transported into the embayment from the Chesapeake Bay mainstem during flood tide, more tPCB is transported out of the embayment during ebb tide due to higher tPCB concentration inside the embayment. Air-water exchange through volatilization is about 11,703 g/year, which is about 340.2 ng/m^2/day. This value is in the same range of the measured mean flux of 350 ng/m^2/day in the embayment (Bamford et al. 2002a). Volatilization is the major loss of PCB from the embayment. A large amount of PCBs comes from the bottom sediment due to resuspension. Most of them are lost through volatilization or are transported out of the embayment. A diagram of tPCB budget is shown in Figure F-8.



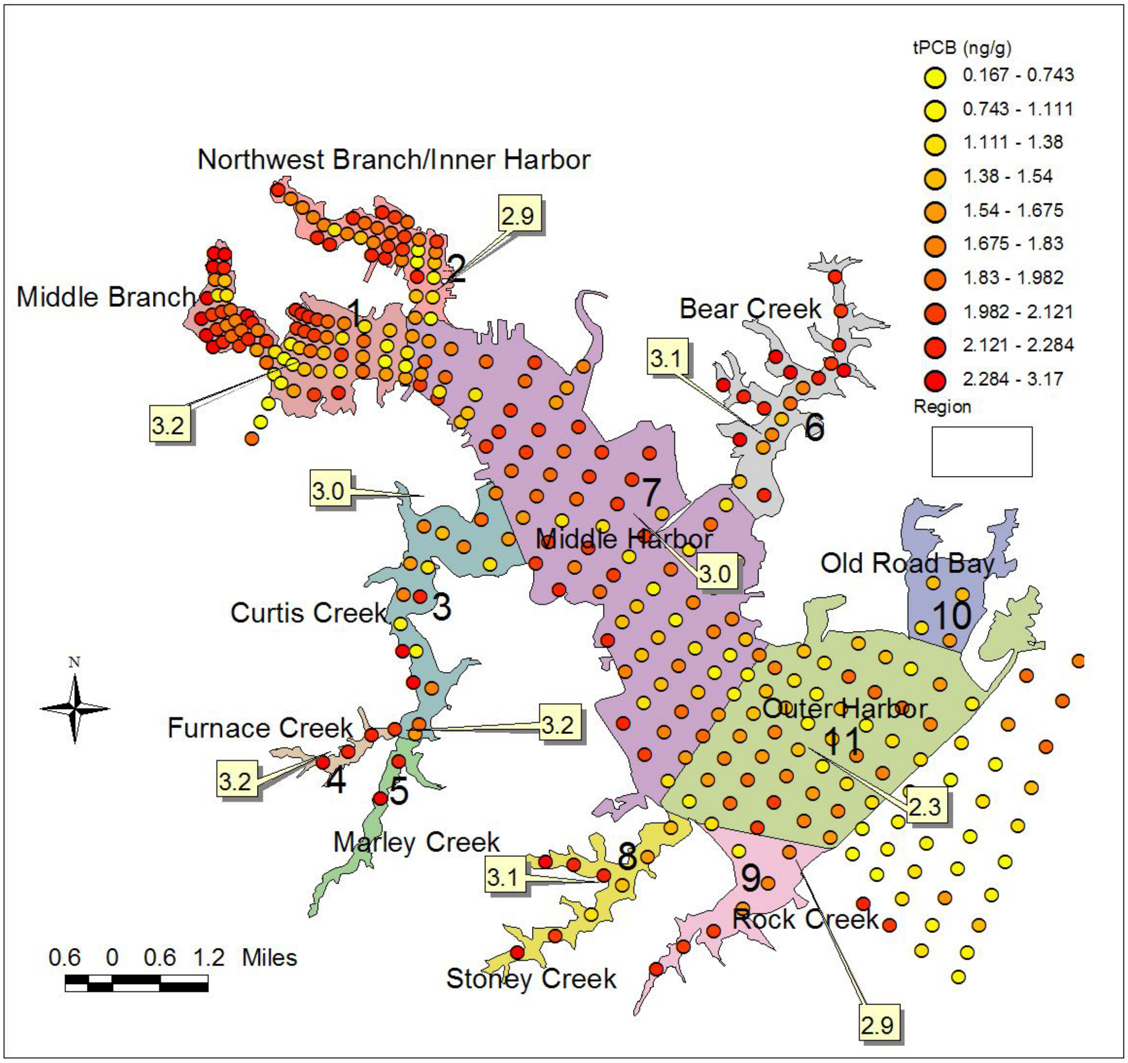
Note: Units are g/year

Figure F-8: Budget of tPCBs for the Calibration Year (1996-1998)

VI. PCB TMDL Calculation

The sources PCBs to the Baltimore Harbor embayment consist of point and nonpoint sources Nonpoint sources include atmospheric deposition, resuspension from the bottom sediments, tidal influence from the Chesapeake Bay mainstem, contaminated sites, tributary drainage, and nonregulated watershed runoff within the direct drainage portion of the watershed. Point sources include WWTPs, DMCFs, industrial process water sources, and NPDES regulated stormwater. Although a large amount of PCBs are transported into the embayment from the Chesapeake Bay mainstem, PCBs are mainly transported out to the Bay mainstem during ebb tide, resulting in a net loss of PCBs from the embayment. The dominant source of PCBs to the embayment is resuspension from the bottom sediments, and the major loss is through volatilization. It is expected that with the decrease of directly controllable point and nonpoint source loads, the conditions in the embayment will be gradually improved in both the water column and sediments. Because PCBs in the Chesapeake Bay mainstem can be transported in the embayment, sensitivity tests with clean sediments and no other sources of PCBs show that the embayment will not achieve water quality standards without reducing the PCB load from the Bay mainstem. Diagnostic model runs show that sediment response to load changes is slow. Therefore, the flow of the mean hydrological year was repeatedly run for 80 years until the water column and bottom sediment layers achieved a dynamic equilibrium. For this cyclic run, the loads for both point and nonpoint sources were reduced, and the same percentage reduction was applied to the open boundary. The PCB concentration varied at the open boundary. The delivered water column tPCB endpoint was used as the lower bound, and the concentration was not allowed to be lower than the endpoint. It was assumed that the atmospheric load would be reduced 57.6% in the model simulation. The entire embayment was divided into 11 segments. The maximum monthly mean tPCB concentration of each segment in the final year was computed and compared to both water column and sediment TMDL endpoint tPCB concentrations. Scenario runs show that a 91.5% reduction for all nonpoint source watershed loads and NPDES regulated stormwater will meet water quality standards. The load after the 91.5% reduction was determined to be the

TMDL for the embayment. A distribution of bottom sediments in the embayment after a 91.5% reduction is shown in Figure F-9. It can be seen relative high sediment concentrations occur near the very upper parts of the Middle Branch and Northwest Branches of the Harbor embayment.



Note: The numbers marked in the boxes represent the mean value tPCB value in the segment.

Figure F-9: The tPCB Distribution of the Final Month of the Scenario Runs

Appendix G: Model Sensitivity Test

I. Introduction

A large uncertainty in model predictions can be expected due to the uncertainties inherited in model parameters, forcing conditions in the model, and the limited data set applied within the model. To assess model uncertainty, a sensitivity analysis was conducted to evaluate the effects of changes in model forcing, model parameters, and external loads on the model results. The sensitivity analysis can provide information on whether or not model predictions are reliable given the uncertainties in the model parameters, model forcing conditions, and loads.

Sensitivity analysis simulations were conducted to identify individual forcing and parameters on model predications. A total of 5 sensitivity simulations were conducted. Penta-PCB was selected for the sensitivity run. The mean flow year of 1998 was selected for the simulations. Vertical mean concentrations of penta-PCB were compared to the existing conditions at selected stations distributed inside the embayment. The simulations are listed below:

(1) Impact of directly controllable point and nonpoint sources on PCB concentrations in the embayment, assuming clean bottom sediments and no PCB transport into the embayment from the Chesapeake Bay mainstem.

(2) Impact of open boundary conditions with the Chesapeake Bay mainstem, assuming clean sediments and without directly controllable point and nonpoint sources.

(3) Impact of atmospheric deposition.

(4) Impact of changing the partition coefficient.

(5) Impact of organic carbon (OC).

II. Sensitivity Test of Directly Controllable Point and Nonpoint Sources

With only directly controllable point and nonpoint source loads, assuming clean bottom sediments and no PCB transport into the embayment from the Chesapeake Bay mainstem, the vertically averaged penta-PCB concentration was very low. However, it was still higher than the water column TMDL endpoint of 0.27 ng/L (see Figure G-1). PCB concentrations in the bottom sediment were building up gradually. Therefore, a reduction in directly controllable point and nonpoint source loads is required for the embayment to meet the water column TMDL endpoint tPCB concentration.

III. Sensitivity Test of Open Boundary Condition with the Chesapeake Bay Mainstem

The Baltimore Harbor embayment is highly influenced by the Chesapeake Bay mainstem, and a three-layer circulation is often developed during the spring. The Bay mainstem and embayment exchange transports a large amount of water and pollutants into the embayment. It can be expected that the specification of the open boundary has a large influence on the embayment. A sensitivity run was conducted assuming clean sediments without directly controllable point and nonpoint sources. Figure G-2 shows the model results. It is evident that the model is highly controlled by the Chesapeake Bay mainstem conditions. The results agree with the previous study, as the residence time of the embayment is controlled by both freshwater and saltwater from the Bay mainstem (Hong et al. 2010). Although a large portion of the PCBs transported into the embayment will leave during ebb tides, settling can cause PCBs to accumulate in the bottom sediments. A reduction from the Bay mainstem is needed to achieve the TMDL endpoint tPCB concetrations. Based on observations, the Susquehanna River tPCB inputs to the Chesapeake Bay are decreasing (Ko and Baker 2004). An estimated rate of decrease is about 5.5-6.5% per year. As the Susquehanna River dominates the freshwater inputs to the Bay mainstem, it is expected that tPCB concentration will decrease approximately 90% over a 55 year period.

IV. Sensitivity Test of Atmospheric Deposition

Loss of PCBs due to volatilization is the major pathway of PCB loss inside the embayment, when PCB concentrations in the water column are higher than gaseous PCBs. The model sensitivity of the impact of atmospheric deposition on the embayment was conducted, assuming clean sediments without other directly controllable point and nonpoint sources or inputs from the Chesapeake Bay mainstem. Model results are shown in Figure G-3. It can be seen that atmospheric deposition has less impact on the embayment than other sources. A portion of the atmospherically deposited PCBs will be adsorb to the bottom sediments.

V. Sensitivity Test of the Partition Coefficient

Homolog partition coefficients are key parameters. The estimated K_d value based on field data can vary by several orders of magnitude. The model uses the equation based on (Chapra 1997) to convert K_{ow} to partition coefficient for each homolog:

$$K_d = (6.17 \times 10^{-7} K_{ow})\, f_{oc}$$

The partition coefficients are larger than the values estimated based on the empirical equations obtained from observations (Baker et al. 2002), but the model calibration gives better performance. Because the K_d values estimated from field data vary by several orders of magnitude (see Figure G-8), the sensitivity run was conducted using CHARM's empirical equation to obtain K_d (log (K_d)=5.68) for particulate carbon. The K_d for dissolved carbon is an order of magnitude smaller than the K_d for particulate carbon (Zhang et al. 2009; DRBC 2003). The model used a 10% of POC K_d value for the DOC K_d value. The results are shown in Figure G-4. Overall, there is no significant difference in the water column, while a difference can be seen in the sediment. As lower K_d value were used, less PCB deposition occured in the bottom sediments. However, error is less than 13%. An additional model simulation with a 20% increase of the K_d value was also conducted and is shown in Figure G-5. The increase of K_d by 20% did not result in significant differences.

VI. Sensitivity Test of Organic Carbon

Organic carbon including particulate, algae, and dissolved carbon were simulated by the eutrophication model. The eutrophication model depends on the accuracy of nonpoint source loads, algae, and nutrient dynamics simulations. Errors inherited in carbon simulation can affect the tPCB simulation. A model sensitivity test was conducted by increasing the particulate carbons (particulate and algae) by 20%, and the results are presented in Figure G-6. It is evident that particulate carbon has less of an impact on the water column and more of an impact on sediment deposition. Because of the increase of POC, more settlement of PCBs occurred, resulting in a decrease of PCB concentration in the sediment, as newly settled carbon were associated with lower PCB concentrations. However, the error introduced in the sediment was less that 3%. A sensitivity run was also conducted by increasing the DOC by 20%, resulting in a slight increase of water column PCB concentration (see Figure G-7). This indicates that its impact on sediment is negligible.

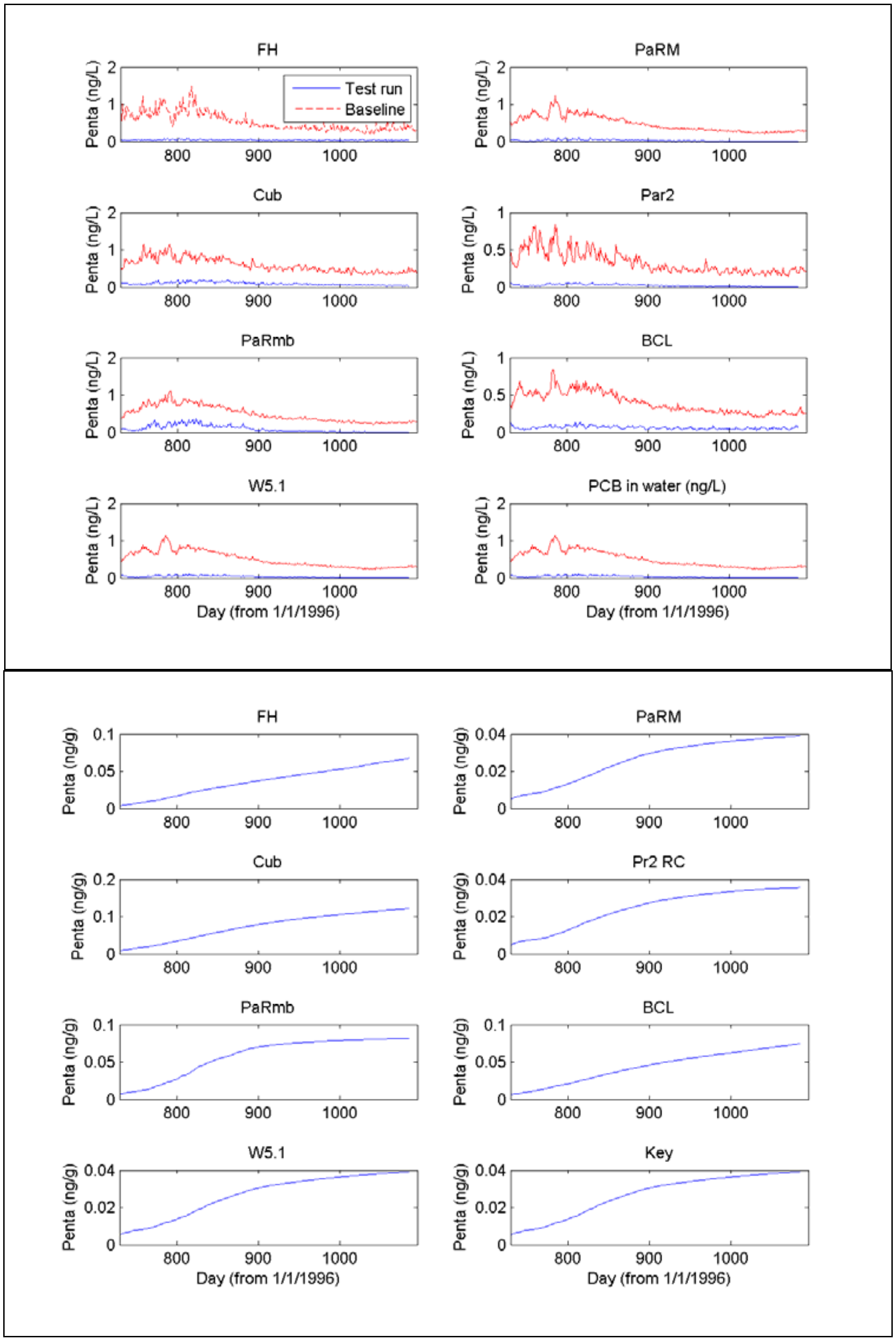


Figure G-1: Sensitivity Simulation of the Directly Controllable Nonpoint and Point Sources of Penta-PCBs in the Water Column (Upper Panel) and Sediment (Lower Panel)

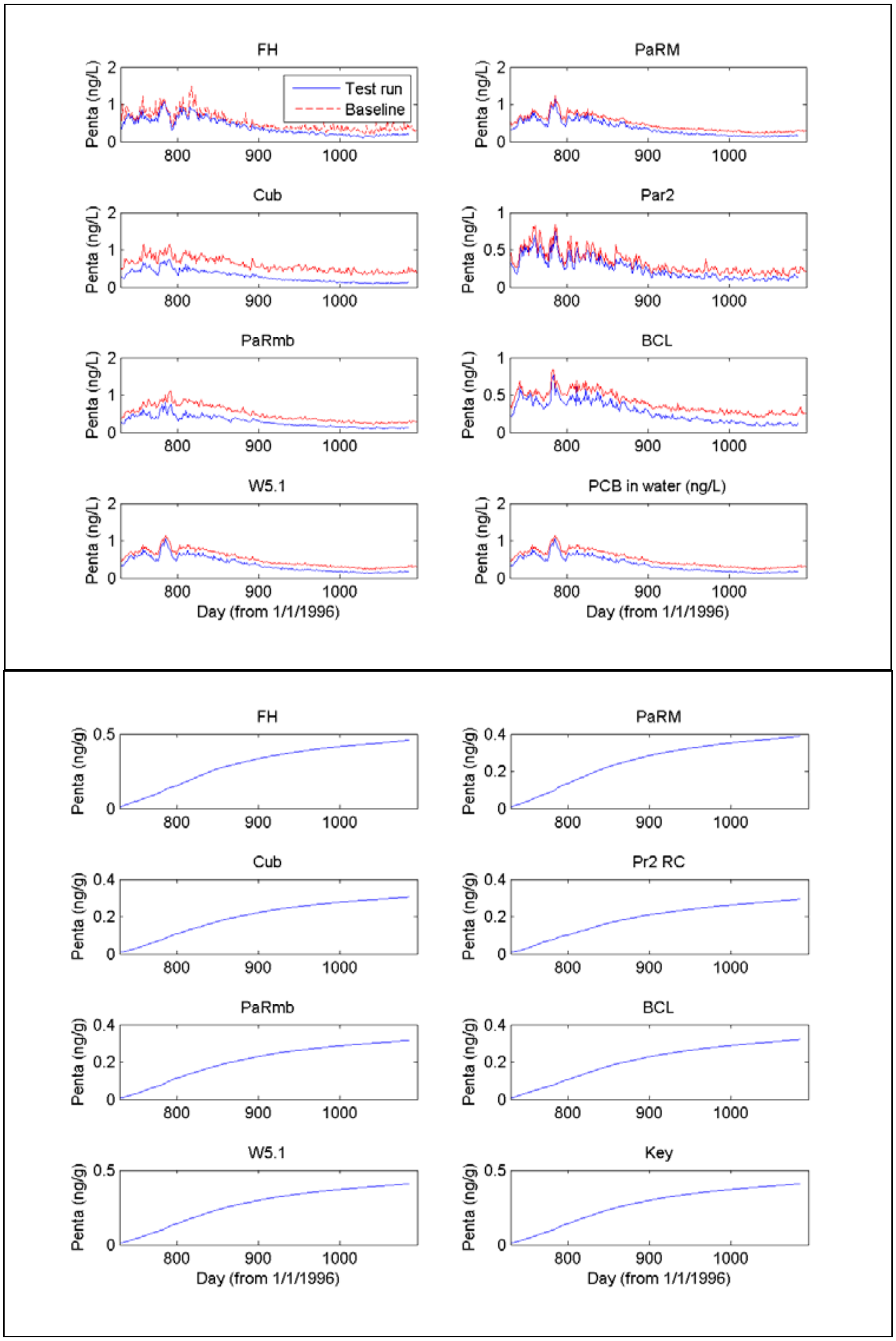


Figure G-2: Sensitivity Simulation of the Open Boundary Condition with the Chesapeake Bay Mainstem of Penta-PCBs in the Water Column (Upper Panel) and Sediments (Lower Panel)

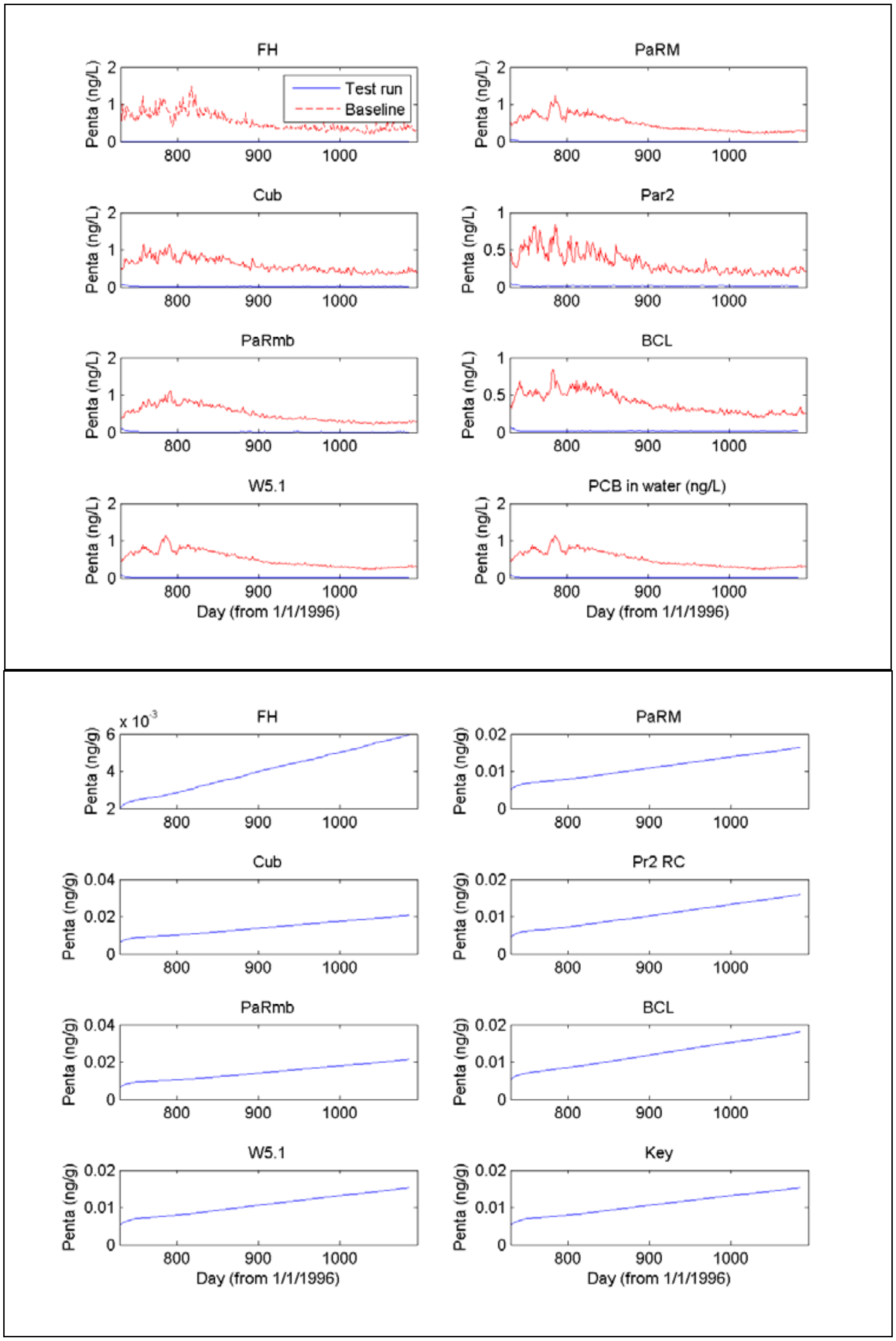


Figure G-3: Sensitivity Simulation of the Atmospheric Deposition of Penta-PCBs in the Water Column (Upper Panel) and Sediments (Lower Panel)

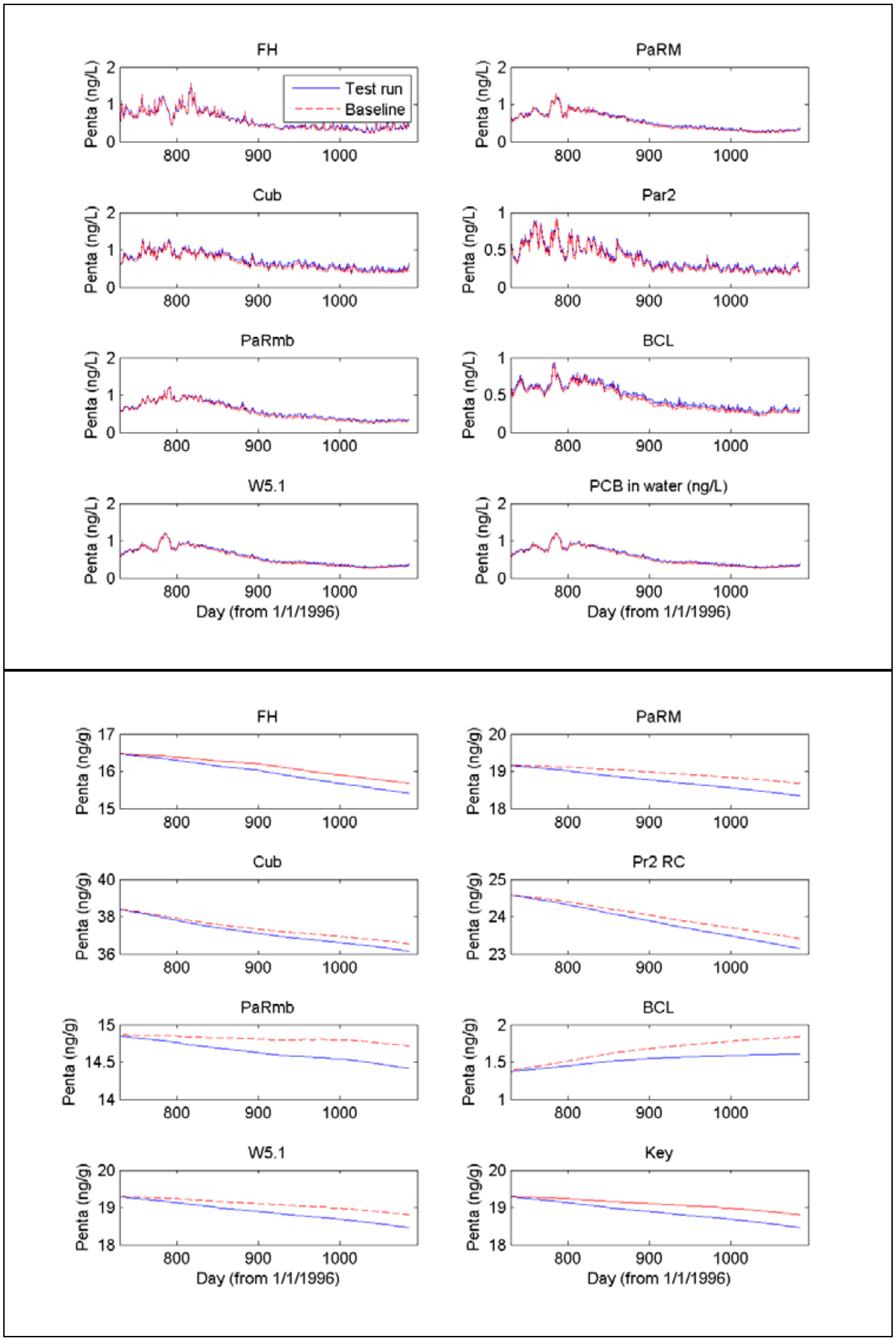


Figure G-4: Sensitivity Simulation Using Estimated K_d Value of Penta-PCB (log(K_d)=5.39) in the Water Column (Upper Panel) and Sediments (Lower Panel)

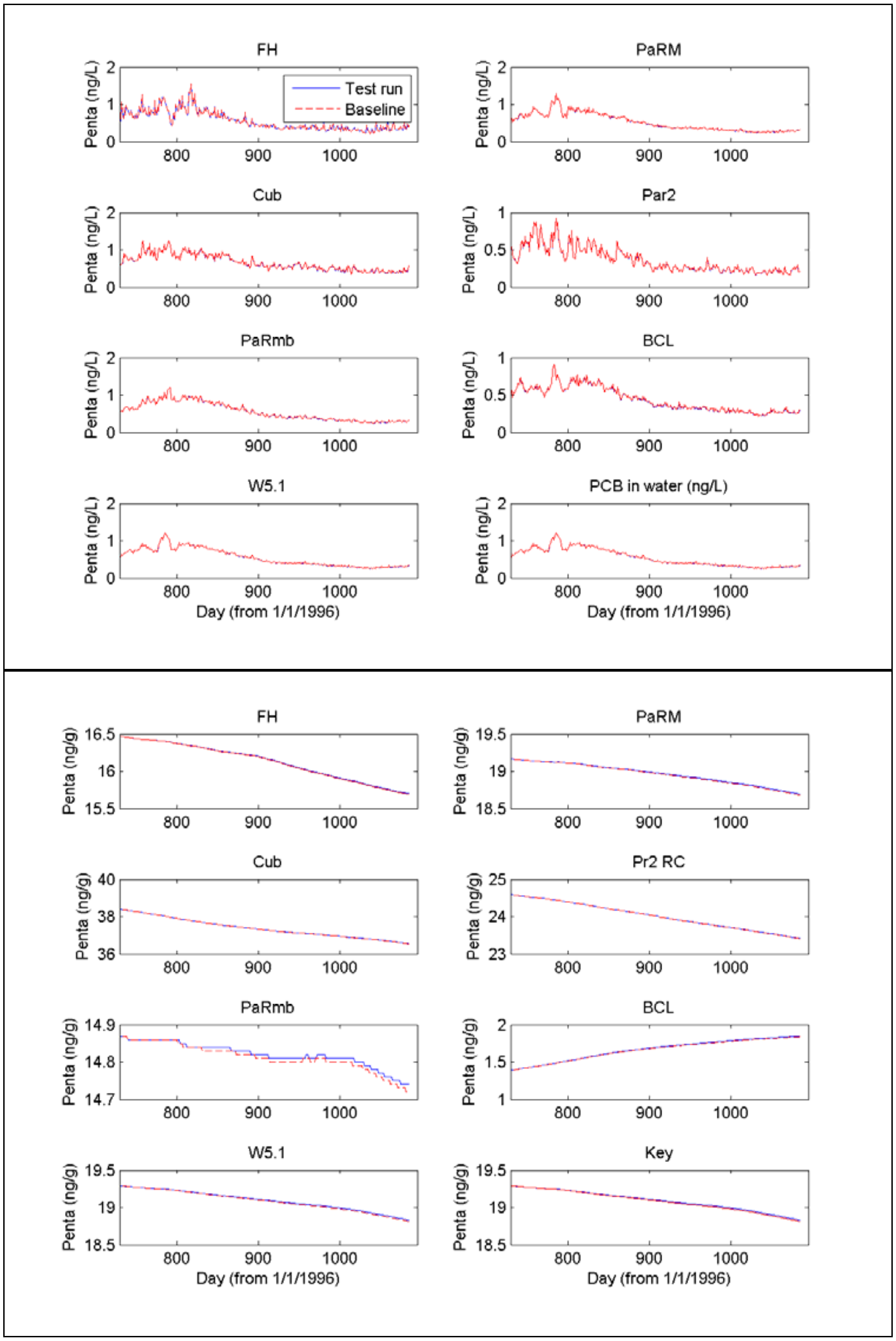


Figure G-5: Sensitivity Simulation with Increase of 20% of K_d Value of Penta-PCB in the Water Column (Upper Panel) and Sediments (Lower Panel)

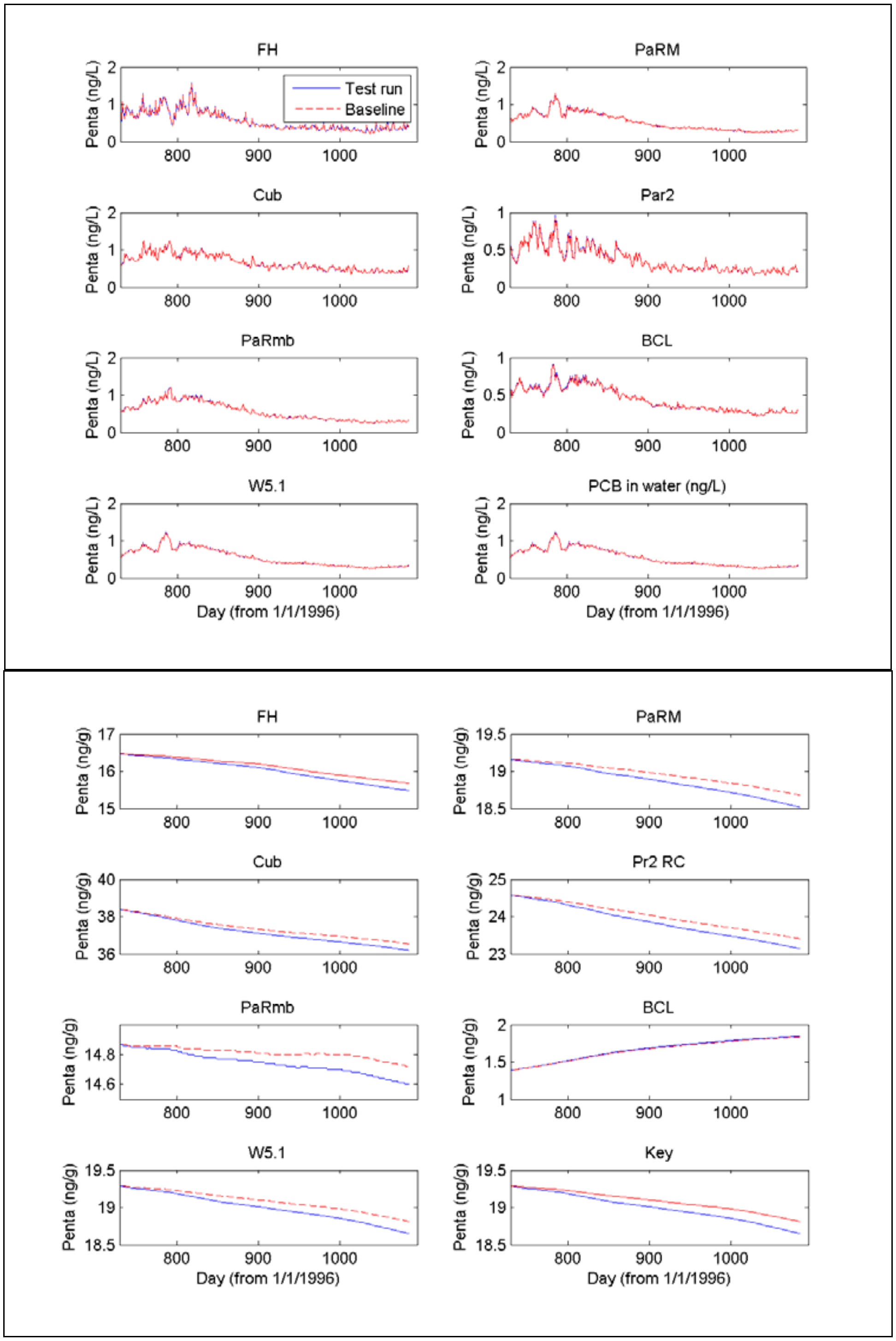


Figure G-6: Sensitivity Simulation of Increase 20% of Particulate Carbons in the Water Column (Upper Panel) and Sediments (Lower Panel)

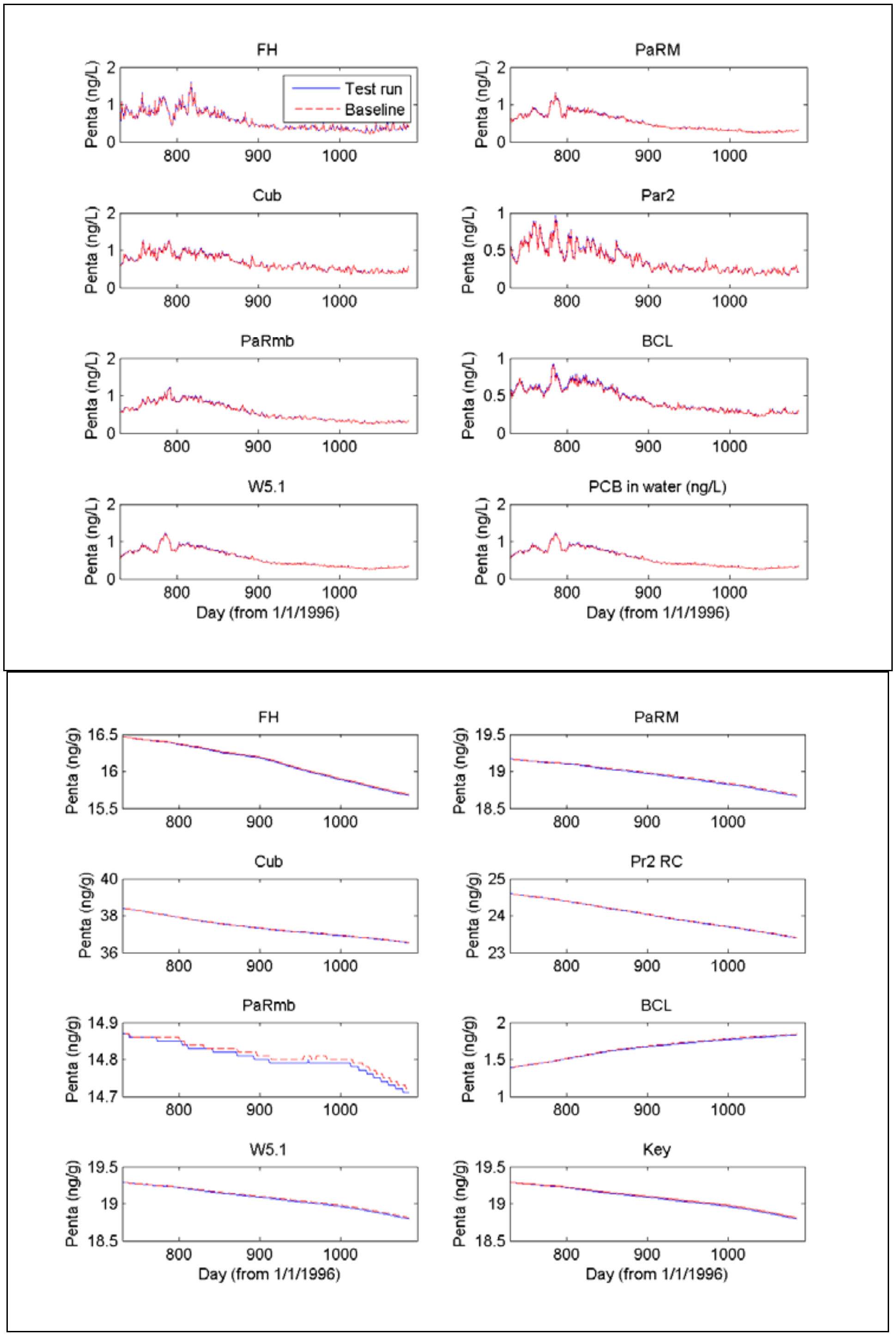


Figure G-7: Sensitivity Simulation of Increase 20% of Dissolved Organic Carbon in the Water Column (Upper Panel) and Sediments (Lower Panel)

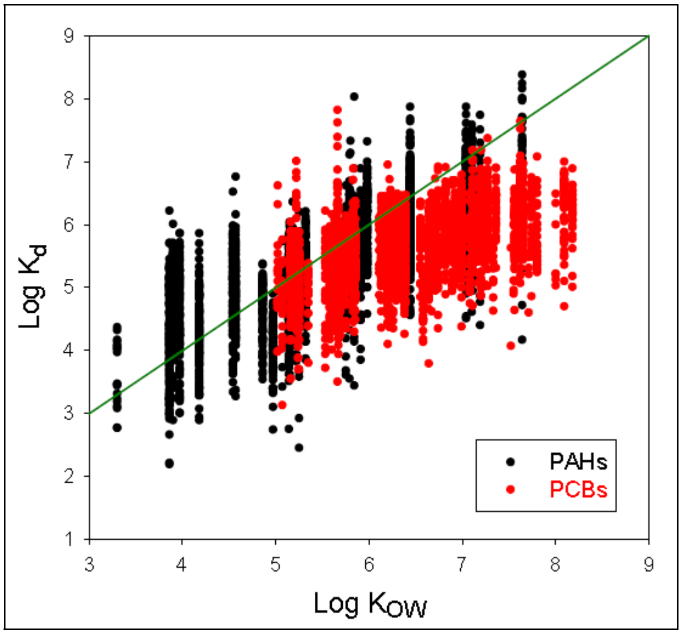


Figure G-8: Observed Distribution Coefficients of Individual PAHs and PCB Congeners in Baltimore Harbor Embayment Survey Water versus Their Octanol-Water Partition Coefficients (Baker et al. 2002)

Appendix H: List of NPDES Regulated Stormwater Permits

Table H-1: NPDES Regulated Stormwater Permit Summary for the Baltimore Harbor Embayment Watershed[1]

MDE Permit	NPDES	Facility	City	County	Type	TMDL
04DP3313	MD0068276	STATE HIGHWAY ADMINISTRATION (MS4)	STATE-WIDE	ALL PHASE I (Baltimore City, Baltimore County, Anne Arundel)	WMA6	STORMWATER WLA
	MDR100000	MDE GENERAL PERMIT TO CONSTRUCT	ALL	ALL		STORMWATER WLA
02SW0036		ADVANCED THERMAL HYDRONICS, INC.	DUNDALK	BALTIMORE	WMA5SW	STORMWATER WLA
02SW0037		MONTEBELLO BRANDS, INC.	DUNDALK	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW0038		TECHALLOY COMPANY, INC. - BALTIMORE WELDING DIV.	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW0039		TNEMEC COMPANY, INCORPORATED	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW0040		VULCAN HART COMPANY	BALTIMORE	BALTIMORE	WMA5SW	STORMWATER WLA
02SW0048		H.R. SIMON AND COMPANY, INC.	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW0075		NEW NGC, INC, D/B/A NATIONAL GYPSUM COMPANY	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW0083		AMG RESOURCES CORPORATION	BALTIMORE	BALTIMORE	WMA5SW	STORMWATER WLA
02SW0094		BALTIMORE SCRAP CORPORATION	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW0227		SMURFIT-STONE CONTAINER CORPORATION - BALTIMORE	BALTIMORE	ANNE ARUNDEL	WMA5SW	STORMWATER WLA
02SW0234		BESTWAY TRANSPORT, INC.	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW0251		DELTA CHEMICAL CORPORATION	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW0252		REEDBIRD AVENUE LANDFILL	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW0253		PENNINGTON AVENUE LANDFILL	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW0256		MONUMENT STREET LANDFILL	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW0257		QUARANTINE ROAD LANDFILL	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW0298		GLEN BURNIE LANDFILL AND CONVENIENCE CENTER	GLEN BURNIE	ANNE ARUNDEL	WMA5SW	STORMWATER WLA
02SW0308		BALTIMORE SUN - SUN PARK	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW0415		DUNDALK MARINE TERMINAL	DUNDALK	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW0419		MARYLAND PORT ADMINISTRATION - WALLACE ST.	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW0420		SOUTH LOCUST POINT MARINE TERMINAL	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW0421		CLINTON STREET MARINE TERMINAL	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW0422		MARYLAND PORT ADMIN. - HAWKINS POINT MARINE TERMINAL	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW0432		PQ CORPORATION	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW0449		DAILY EXPRESS, INC.	BALTIMORE	BALTIMORE	WMA5SW	STORMWATER WLA
02SW0456		E. STEWART MITCHELL, INC.	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW0500		CURTIS BAY ENERGY LIMITED PARTNERSHIP	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW0564		EASTERN PLATING COMPANY - BAYLIS	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW0589		IST CORPORATION DBA ARCADE MARKETING CP	BALTIMORE	ANNE ARUNDEL	WMA5SW	STORMWATER WLA
02SW0625		SOLLEY ROAD SANITARY LANDFILL	GLEN BURNIE	ANNE ARUNDEL	WMA5SW	STORMWATER WLA
02SW0629		PATAPSCO WWTP	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW0650		SOUTHERN GALVANIZING	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA

02SW0681		CLEAN HARBORS OF BALTIMORE	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW0682		CAMBRIDGE IRON & METAL COMPANY, INC.	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW0684		BFI QUARANTINE ROAD LANDFILL	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW0692		DLA/DNSC CURTIS BAY DEPOT	BALTIMORE	ANNE ARUNDEL	WMA5SW	STORMWATER WLA
02SW0709		BALTIMORE CITY DPW - FIRE MAINTENANCE	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW0711		ANSAM METALS CORPORATION	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW0760		ANNE ARUNDEL COUNTY - COX CREEK WATER RECLAMATION FACILITY	BALTIMORE	BALTIMORE	WMA5SW	STORMWATER WLA
02SW0787		HOUFF TRANSFER, INC.	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW0823		HUBERS BUS SERVICE, INC.	GLEN BURNIE	ANNE ARUNDEL	WMA5SW	STORMWATER WLA
02SW0832		H & S BAKERY	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW0885		P. T. O'MALLEY LUMBER COMPANY, INC.	BALTIMORE	BALTIMORE	WMA5SW	STORMWATER WLA
02SW0923		YELLOW TRANSPORTATION, INC. (BLT)	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW0925		J & R BUS SERVICE, INC.	GLEN BURNIE	ANNE ARUNDEL	WMA5SW	STORMWATER WLA
02SW0938		WESTWAY TERMINAL COMPANY	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW0939		BELT'S BUSINESS CENTER - BALTIMORE	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW0949		TRANSFLOW TERMINAL SERVICES, INC.	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW0961		THE NELSON COMPANY	BALTIMORE	BALTIMORE	WMA5SW	STORMWATER WLA
02SW0962		MAISEL BROTHERS, INC.	GLEN BURNIE	ANNE ARUNDEL	WMA5SW	STORMWATER WLA
02SW0964		RELIABLE CONTRACTING COMPANY, INC.	GLEN BURNIE	ANNE ARUNDEL	WMA5SW	STORMWATER WLA
02SW0978		JOHNSON'S TRANSFER, INC.	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1002		TOM'S AUTO PARTS	BALTIMORE	BALTIMORE	WMA5SW	STORMWATER WLA
02SW1007		BOB'S TRANSPORT & STORAGE CO., INC.	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1018		BALTIMORE CITY DPW - CENTRAL GARAGE	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1020		COX AUTO PARTS, INC.	BALTIMORE	BALTIMORE	WMA5SW	STORMWATER WLA
02SW1025		DEXT COMPANY D/BA RECONSERVE OF MARYLAND	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1028		BALTERM - DUNDALK	DUNDALK	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1029		CSX INTERMODAL, INC. - BALTIMORE	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1031		BALTIMORE QUALITY ASSURANCE	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1040		FAIRFIELD TRUCK AND TANK CENTER, INC.	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1057		DREVER HEAT TREATING	BALTIMORE	ANNE ARUNDEL	WMA5SW	STORMWATER WLA
02SW1071		RUKERT TERMINALS CORPORATION	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1080		INTERSTATE BRANDS CORP. - GLEN BURNIE	GLEN BURNIE	ANNE ARUNDEL	WMA5SW	STORMWATER WLA
02SW1085		BFI WASTE SERVICES, LLC - BALTIMORE	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1087		ATLANTIC TERMINALLING, LLC	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1109		BALTIMORE RECYCLING CENTER, LLC	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1110		BALTERM LLP. - SOUTH LOCUST POINT MARINE TERMINAL	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1111		PORTS AMERICA BALTIMORE, INC.	DUNDALK	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1143		G & H AUTO PARTS	BALTIMORE	BALTIMORE	WMA5SW	STORMWATER WLA
02SW1161		THE OWL CORPORATION	BALTIMORE	BALTIMORE	WMA5SW	STORMWATER WLA
02SW1176		ANNE ARUNDEL COUNTY - NORTHERN DISTRICT ROADS	GLEN BURNIE	ANNE ARUNDEL	WMA5SW	STORMWATER WLA
02SW1181		ANNE ARUNDEL COUNTY ROADS - NORTHERN	PASADENA	ANNE ARUNDEL	WMA5SW	STORMWATER WLA

02SW1187		CURTIS RECYCLERS, INC.	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1210		THE DIRT EXPRESS COMPANY	GLEN BURNIE	ANNE ARUNDEL	WMA5SW	STORMWATER WLA
02SW1213		MARYLAND PORT ADMINISTRATION - CHILDS STREET	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1240		BALTIMORE PROCESSING & TRANSFER CENTER	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1260		D.M.T. TRUCKING, INC.	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1262		BALTIMORE PIPE, INC.	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1274		KAUFMAN PRODUCTS, INC	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1283		EJ ENTERPRISES, INC.	GLEN BURNIE	ANNE ARUNDEL	WMA5SW	STORMWATER WLA
02SW1285		MARYLAND RECYCLE COMPANY, INC. - GLEN BURNIE	GLEN BURNIE	ANNE ARUNDEL	WMA5SW	STORMWATER WLA
02SW1298		THE SUN PRODUCTS CORPORATION	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1308		DIETRICH INDUSTRIES, INC.	BALTIMORE	BALTIMORE	WMA5SW	STORMWATER WLA
02SW1308		DIETRICH INDUSTRIES, INC.	BALTIMORE	BALTIMORE	WMA5SW	STORMWATER WLA
02SW1332		SHA - GLEN BURNIE SHOP	GLEN BURNIE	ANNE ARUNDEL	WMA5SW	STORMWATER WLA
02SW1356		PEMCO CORPORATION	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1360		PCS SALES, INC.	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1373		VANE TERMINAL, INC. - PIER 12	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1384		CANTON MARINE TERMINAL - PIER 13	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1395		COMPLEMENTARY COATINGS CORPORATION D/B/A INSL-X	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1402		THE BERG BROTHERS RECYCLING COMPANY	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1411		VALLEY PROTEINS - BALTIMORE DIVISION	BALTIMORE	ANNE ARUNDEL	WMA5SW	STORMWATER WLA
02SW1414		EASTALCO ALUMINUM COMPANY - BALTIMORE PIER	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1418		DOLPHIN ASSOCIATES, INC.	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1427		INFRA-METALS COMPANY	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1428		HOLCIM (US) INC. - BALTIMORE TERMINAL	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1487		DEPSCO SERVICES, INC.	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1494		LAURA A. LUCKERT TRUCKING, INC.	BALTIMORE	BALTIMORE	WMA5SW	STORMWATER WLA
02SW1499		A. H. GARDNER & SON, INC.	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1504		GABLE SIGNS & GRAPHICS, INC.	BALTIMORE	ANNE ARUNDEL	WMA5SW	STORMWATER WLA
02SW1506		MODEL MACHINE COMPANY, INC.	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1545		ASSOCIATED CARGO, INC.	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1589		DOVCO INDUSTRIAL FABRICATORS, INC.	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1593		THE FURST BROTHERS COMPANY	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1620		A & L TRANSPORT, INC.	BALTIMORE	BALTIMORE	WMA5SW	STORMWATER WLA
02SW1622		VAC PAC MANUFACTURING COMPANY, INC.	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1633		PATTERNS UNLIMITED, INC.	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1634		B & G QUALITY MACHINE & TOOL COMPANY, INC.	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1635		LIQUID TRANSFER TERMINALS, INC. - PENNINGTON	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1658		AMERICAN LIMOUSINES, INC.	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1669		WAGNER BROTHERS CONTAINERS, INC.	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1674		MTA - EASTERN BUS DIVISION	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1695		BRUCE MACHINE & TOOL COMPANY, INC.	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1753		FORT AVENUE REALTY, LLC	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA

02SW1764		BALTERM, LLP - NORTH LOCUST POINT	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1774		THE VANE BROTHERS COMPANY	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1784		UNIVERSITY OF MARYLAND MEDICAL CENTER	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1785		MTA - WASHINGTON BLVD. BUS DIVISION	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1792		ACTIVE TRANSPORTATION COMPANY	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1814		HAWKINS POINT LANDFILL	HAWKINS POINT	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1873		AIR PRODUCTS & CHEMICALS, INC. - BALTIMORE	SPARROWS POINT	BALTIMORE	WMA5SW	STORMWATER WLA
02SW1880		FREESTATE AUTO RECYCLING, INC.	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1881		OPTA MINERALS BALTIMORE	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1885		MID ATLANTIC BAKING COMPANY	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1907		CONSTELLATION ENERGY GROUP - GOULD STREET GENERATING STATION	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1917		COMMUNITY COLLEGE OF BALTIMORE COUNTY - DUNDALK	BALTIMORE	BALTIMORE	WMA5SW	STORMWATER WLA
02SW1919		THE ABBEY DRUM COMPANY	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1939		THE ABBEY DRUM COMPANY - BALTIC AVENUE	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1951		MTA - CROMWELL LIGHT RAIL MAINTENANCE FACILITY	GLEN BURNIE	ANNE ARUNDEL	WMA5SW	STORMWATER WLA
02SW1958		GEO SPECIALTY CHEMICALS	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1973		BALTIMORE COUNTY BUREAU OF HIGHWAYS - SHOP 9	BALTIMORE	BALTIMORE	WMA5SW	STORMWATER WLA
02SW1977		DILLONS BUS SERVICE, INC. - BALTIMORE	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1990		BERRY PLASTICS CORPORATION	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1991		CHESAPEAKE AGRO-IRON, INC.	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW1993		DANA CONTAINER, INC.	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW2011		SIGNODE EASTERN OPERATIONS	BALTIMORE	BALTIMORE	WMA5SW	STORMWATER WLA
02SW2034		FRITZ ENTERPRISES, INC.	SPARROWS POINT	BALTIMORE	WMA5SW	STORMWATER WLA
02SW2041		BGE- SPRING GARDENS	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW2045		MDTA - BALTIMORE HARBOR TUNNEL	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW2046		MDTA - FORT MCHENRY TUNNEL	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW2050		MDTA - FRANCIS SCOTT KEY BRIDGE	DUNDALK	BALTIMORE	WMA5SW	STORMWATER WLA
02SW2058		CERES TERMINALS	DUNDALK	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW2060		MARINE TERMINALS CORPORATION EAST	DUNDALK	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW2064		BALTIMORE PACKAGING, LLC	DUNDALK	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW2065		MULTIMARINE REFRIGERATION	DUNDALK	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW2071		BEVERAGE CAPITAL CORPORATION PLANT #2	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW2073		MILLENNIUM SPECIALTY CHEMICALS - ST. HELENA	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW3026		EDGEMERE TERMINALS, INC.	BALTIMORE	BALTIMORE CITY	WMA5SW	STORMWATER WLA
02SW3034		LAFARGE BUILDING MATERIALS, INC.	SPARROWS POINT	BALTIMORE	WMA5SW	STORMWATER WLA
04DP3315	MD0068292	BALTIMORE CITY MS4	BALTIMORE	BALTIMORE CITY	WMA6	STORMWATER WLA
04DP3316	MD0068306	ANNE ARUNDEL COUNTY MS4	COUNTY-	ANNE ARUNDEL	WMA6	STORMWATER WLA

			WIDE			
05DP3317	MD0068314	BALTIMORE COUNTY MS4	COUNTY-WIDE	BALTIMORE	WMA6	STORMWATER WLA

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

Appendix I: Technical Approach Used to Generate Maximum Daily Load

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 Baltimore Harbor embayment. 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 a daily output.

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

VI. Options Considered

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

This section describes the range of options that were considered when developing methods to calculate the MDL for the Baltimore Harbor Embayment.

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 Baltimore Harbor embayment:

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

Probability Level

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

1. Water quality criteria consist of components describing acceptable magnitude, duration, and frequency. The frequency component addresses how often conditions can allowably surpass the combined magnitude and duration components.
2. Pollutant loads, especially from wet weather sources, typically exhibit a large degree of variability over time. It is rarely practical to specify a "never to be exceeded value" for a daily load, as essentially any load value has some finite probability of being exceeded.

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

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

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

V. Selected Approach

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

- Approach for Nonpoint Sources and NPDES Regulated Stormwater Point Sources
- Approach for WWTPs, Industrial Process Water Point Sources, and DMCFs

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

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

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

The CV was calculated using the arithmetic mean and standard deviation of the baseline ambient water column tPCB concentrations in the Baltimore Harbor embayment. The resulting CV of 0.90 was calculated using the following equation:

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

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

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

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

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

Using a z-score associated with the 99th percent probability of 2.33, a CV of 0.90, and consistent units, the resulting dimensionless conversion factor from long-term average loads to a maximum daily value is 3.34. The average annual Baltimore Harbor Embayment PCB TMDL is reported in g/year, and the conversion from g/year to a maximum daily load in g/day is 0.0092 (e.g. 3.34/365)

VIII. Approach for WWTPs, Industrial Process Water Point Sources, and DMCFs

The TMDL also considers contributions from NPDES permitted WWTPs, industrial process water point sources, and DMCFs that discharge quantifiable concentrations of tPCBs to the Baltimore Harbor embayment. The MDLs were calculated for these sources based on the guidance provided in the Technical Support Document (TSD) for Water Quality-based Toxics Control (US EPA 1991). The long-term average annual TMDL was converted to maximum daily limits using Table 5-2 of the TSD assuming a coefficient of variation of 0.6 and a 99th percentile probability. This results in a dimensionless multiplication factor of 3.11. The average annual Baltimore Harbor Embayment TMDL of PCBs is reported in g/year, and the conversion from g/year to a maximum daily load in g/day is 0.0085 (i.e. 3.11/365).

IX. Results of Approach

This section lists the results of the selected approach to define the Baltimore Harbor Embayment MDLs.

- Calculation Approach for Nonpoint Sources (Direct Atmospheric Deposition, Tributaries, Non-regulated Watershed Runoff, and Contaminated Sites) and NPDES Regulated Stormwater Point Sources.

  Direct Atmospheric Deposition LA (g/day) = Average Annual TMDL Direct Atmospheric Deposition LA (g/year) * 0.0092

  Tributary LA (g/day) = Average Annual TMDL Tributary LA (g/year) * 0.0092

  Non-regulated Watershed Runoff LA (g/day) = Average Annual TMDL Non-regulated Watershed Runoff LA (g/year) * 0.0092

  Contaminated Site LA (g/day) = Average Annual TMDL Contaminated Site LA (g/year) * 0.0092

  NPDES Stormwater WLA (g/day) = Average Annual TMDL NPDES Regulated Stormwater WLA (g/year) * 0.0092

- Calculation Approach for WWTPs, Industrial Process Water Point Sources, and DMCFs

  WWTP WLA (g/day) = Average Annual TMDL WWTP WLA (g/year)* 0.0085

Industrial Process Water WLA (g/day) = Average Annual TMDL Industrial Process Water WLA (g/year)* 0.0085

DMCF WLA (g/day) = Average Annual TMDL DMCF WLA (g/year)* 0.0085

Table I-1: Summary of tPCB MDLs in the Baltimore Harbor Embayment

PCB Source	**MDL (g/day)**
Direct Atmospheric Deposition (to the Surface of the Embayment)	5.30
Tributaries[1]	
Jones Fall	0.24
Gwynns Fall	0.43
Patapsco River Lower North Branch	0.54
Non-regulated Watershed Runoff[2]	0.29
Contaminated Sites	0.13
Nonpoint Sources	***6.93***
Industrial Process Water	4.24
WWTPs	0.28
DMCFs	0.66
NPDES Regulated Stormwater[2,3]	
Anne Arundel County	0.62
Baltimore County	0.27
Baltimore City	0.28
Point Sources	***6.34***
Total	**13.96**

Notes: [1] Although the tributary loads are reported here as a single nonpoint source value, they could include both point and nonpoint source loads.
[2] Load applies to the direct drainage portion of the applicable watershed only.
[3] Load per jurisdiction applies to all NPDES stormwater dischargers within the direct drainage area of the jurisdiction to the Baltimore Harbor embayment. These dischargers are identified in Appendix H.

Table I-2: Summary of tPCB MDLs in Curtis Creek/Bay

PCB Source[1]	**MDL (g/day)**
Direct Atmospheric Deposition (to the Surface of the Embayment)	0.47
Non-regulated Watershed Runoff[2]	0.06
Contaminated Sites	0.07
Nonpoint Sources	***0.61***
Industrial Process Water[3]	-
WWTPs[3]	-
DMCFs[3]	-
NPDES Regulated Stormwater[2,4]	
Anne Arundel County	0.21
Baltimore City	0.03
Point Sources	***0.24***
Total	**0.89**

Notes: [1] None of the upstream tributaries (i.e., Jones Falls, Gwynns Falls, and the Patapsco River Lower North Branch) drain directly into Curtis Creek/Bay.
[2] Load applies to the direct drainage portion of the applicable watershed only.
[3] No industrial process water facilities, WWTPs, or DMCFs have been identified in the applicable watershed.
[4] Load per jurisdiction applies to all NPDES stormwater dischargers within the direct drainage area of the jurisdiction to Curtis Creek/Bay. These dischargers are identified in Appendix H.

Table I-3: Summary of tPCB MDLs in Bear Creek

PCB Source[1]	MDL (g/day)
Direct Atmospheric Deposition (to the Surface of the Embayment)	0.31
Non-regulated Watershed Runoff[2]	0.02
Contaminated Sites[4]	-
Nonpoint Sources	***0.33***
Industrial Process Water[3]	-
WWTPs[4]	-
DMCFs[4]	-
NPDES Regulated Stormwater[2,5]	
Baltimore County	0.25
Point Sources	***0.25***
Total	**0.61**

Notes: [1] None of the upstream tributaries (i.e., Jones Falls, Gwynns Falls, and the Patapsco River Lower North Branch) drain directly into Bear Creek.
[2] Load applies to the direct drainage portion of the applicable watershed only.
[3] One outfall from the RG Steel facility discharges to Bear Creek. However, this facility falls under an aggregate WLA for all industrial process water discharges, which is accounted for in the TMDL for the Baltimore Harbor embayment. An individual WLA for this outfall will therefore not be presented in this table.
[4] No WWTPs, DMCFs, or contaminated sites have been identified in the applicable watershed.
[5] Load applies to all NPDES stormwater dischargers within the direct drainage area of the jurisdiction to Bear Creek. These dischargers are identified in Appendix H.

Appendix J: Contaminated Site Load Calculation Methodology

The term 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 have been screened for, reported, and detected during formal site investigations. MDE has identified four contaminated sites within the direct drainage area of the Baltimore Harbor portion of the Patapsco River embayment's watershed, for which EOF tPCB baseline loads have been estimated. These sites (see Table J-1) were identified based on information gathered from MDE's LRP-MAP database (MDE 2011c) and have 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.

tPCB EOF loads from these sites have been calculated, and subsequently, these EOF loads would usually be converted to EOS loads using methods applied within Maryland's nontidal sediment TMDLs, thirteen of which have been approved by the EPA since 2006. The modeling assumption behind the conversion to EOS loads is that not all of the contaminated site tPCB loads are expected to reach the impaired waterbody. Thus, EOS loads are thought to be a more accurate representation of tPCB loads from these sites. However, due in large part to the fact that the TMDL analysis only considered contaminated sites located within the direct drainage area of the embayment's watershed, all of the identified contaminated sites are immediately adjacent to the tidal embayment. Therefore, a delivery factor of one is applied, and the resultant EOS loads are equivalent to the base EOF loads.

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

I. tPCB Soil Concentration Data Processing

The Contaminated Site tPCB Baseline Loads were only characterized for those sites (contained within MDE's LRP-MAP database and located within the direct drainage area of the Patapsco River embayment's watershed) and 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. 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 value of the tPCB concentrations from each site was calculated (see Table J-1).

Table J-1: Median tPCB Soil Concentrations at Contaminated Sites in the Direct Drainage Area of the Patapsco River Embayment's Watershed

Site Name	Site Description	Median tPCB (μg/kg)	n[1] [%][2]
B&O Railroad Landfill	No Soil Remediation	2,815	4 [25%]
Crown Central Petroleum	Minimal Soil Remediation	120	1 [100%]
Old Fairfield	No Soil Remediation	1,325	22 [47%]
Olin Corporation	Post Soil Remediation	79	4 [24%]

Notes: [1] n = number of samples above method detection limits.
[2] % = percentage of all samples that are above method detection limits.

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 each site with the use of the Maryland state climate database, county soil databases, and management databases that can be downloaded from the following website: http://fargo.nserl.purdue.edu/rusle2_dataweb/RUSLE2_Index.htm. The site characteristics (i.e., 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. For sites with 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.

[1] RUSLE2 is an advanced, user-friendly software model developed by the University of Tennessee Biosystems Engineering & Soil Science Department, in cooperation with 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.

5. **<u>Management:</u>** 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 concentrations were converted to pounds of tPCBs per pound of soil (lbs/lb). The EOF contaminated site tPCB loads are reported in Table J-2 in g/year.

Table J-2: Summary of Contaminated Site Soil Loss Values and EOF tPCB Loads

Site Name	Site Description	Median tPCB (µg/kg)	Soli Loss (lbs/year)	EOF PCB Loads (g/year)
B&O Railroad Landfill	No Soil Remediation	2,815	4,825	6.16
Crown Central Petroleum	Minimal Soil Remediation	120	9,356	0.51
Old Fairfield[1]	No Soil Remediation	1,325	12,575	7.56
Olin Corporation[1]	Post Soil Remediation	79	7,864	0.28
Total				**14.5**

Note: [1] Old Fairfield and Olin Corporation are specifically located within the watershed draining to the Curtis Creek/Bay portion of the Patapsco River embayment. Thus, the total contaminated site loading to the Curtis Creek/Bay portion of the Patapsco River embayment is 7.8 g/year.

IV. Calculating EOS tPCB loads

The TMDL analysis only considered contaminated sites located within the direct drainage area of the embayment's watershed. Due in large part to this assessment, all of the identified contaminated sites happen to be located immediately adjacent to the tidal embayment. 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 loads are therefore equivalent to the initial EOF loads.

V. Contaminated Site Baseline Load Summary

The Contaminated Site tPCB Baseline Load from the identified sites in the direct drainage area of the Patapsco River embayment's watershed is estimated to be 14.5 g/year (see Table J-2). This load is the summation of the individual tPCB loads from four contaminated sites within direct drainage area to the embayment, two of which have undergone some degree of remediation. Two of the sites, Old Fairfield and Olin Corporation, are specifically located with the watershed draining to the Curtis Creek/Bay portion of the Patapsco River embayment. The total contaminated site loading to the Curtis Creek/Bay portion of the Patapsco River embayment is therefore 7.8 g/year. The average tPCB concentrations at the remediated sites are below levels detected at the sites that have not yet been remediated.

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

Tables K-1 through K-7 list the tPCB concentrations in the water column, sediment, stormwater, and fish tissue samples in the Baltimore Harbor embayment, Bear Creek, and Curtis Creek/Bay. Figures K-1 through K-4 show the locations of these monitoring stations.

Table K-1: Sediment tPCB Concentrations (ng/g) in the Baltimore harbor Embayment, Bear Creek, and Curtis Creek/Bay - Sediment Mapping Study

Station	Date	Concentration	Location	Station	Date	Concentration	Location
BSM1	6/3/96	0.0	Baltimore Harbor	BSM60	6/4/96	163.4	Baltimore Harbor
BSM10	6/3/96	199.2	Baltimore Harbor	BSM61	6/4/96	197.1	Baltimore Harbor
BSM11	6/3/96	80.3	Baltimore Harbor	BSM62	6/4/96	81.6	Baltimore Harbor
BSM12	6/3/96	82.5	Baltimore Harbor	BSM63	6/4/96	88.8	Baltimore Harbor
BSM13	6/3/96	116.8	Baltimore Harbor	BSM64	6/4/96	701.2	Baltimore Harbor
BSM14	6/3/96	102.5	Baltimore Harbor	BSM65	6/4/96	922.1	Baltimore Harbor
BSM15	6/3/96	183.8	Baltimore Harbor	BSM66	6/4/96	6.2	Baltimore Harbor
BSM16	6/3/96	153.5	Baltimore Harbor	BSM67	6/4/96	364.2	Baltimore Harbor
BSM17	6/3/96	44.4	Baltimore Harbor	BSM68	6/4/96	176.7	Baltimore Harbor
BSM18	6/3/96	94.2	Baltimore Harbor	BSM69	6/4/96	307.7	Baltimore Harbor
BSM19	6/3/96	33.2	Baltimore Harbor	BSM7	6/3/96	114.9	Baltimore Harbor
BSM2	6/3/96	110.1	Baltimore Harbor	BSM70	6/4/96	445.5	Baltimore Harbor
BSM20	6/3/96	91.8	Baltimore Harbor	BSM71	6/4/96	1056.0	Baltimore Harbor
BSM21	6/3/96	124.8	Baltimore Harbor	BSM72	6/4/96	759.6	Baltimore Harbor
BSM22	6/3/96	66.2	Baltimore Harbor	BSM73	6/4/96	3.6	Baltimore Harbor
BSM23	6/3/96	153.3	Baltimore Harbor	BSM74	6/4/96	227.0	Baltimore Harbor
BSM24	6/3/96	155.0	Baltimore Harbor	FB	6/15/95	507.9	Baltimore Harbor
BSM25	6/3/96	202.8	Baltimore Harbor	IH	6/1/95	603.6	Baltimore Harbor
BSM26	6/3/96	35.3	Baltimore Harbor	RB	6/1/95	127.0	Baltimore Harbor
BSM27	6/3/96	8.5	Baltimore Harbor	BSM28	6/3/96	0.1	Bear Creek
BSM3	6/3/96	37.3	Baltimore Harbor	BSM29	6/3/96	120.7	Bear Creek
BSM37	6/4/96	78.9	Baltimore Harbor	BSM30	6/3/96	325.8	Bear Creek
BSM38	6/4/96	175.3	Baltimore Harbor	BSM31	6/3/96	347.1	Bear Creek
BSM39	6/4/96	119.4	Baltimore Harbor	BSM32	6/3/96	204.0	Bear Creek
BSM4	6/3/96	26.5	Baltimore Harbor	BSM33	6/3/96	316.1	Bear Creek
BSM40	6/4/96	94.1	Baltimore Harbor	BSM34	6/3/96	1175.9	Bear Creek
BSM41	6/4/96	87.5	Baltimore Harbor	BSM35	6/3/96	16.1	Bear Creek
BSM42	6/4/96	190.9	Baltimore Harbor	BSM44	6/5/96	556.7	Curtis Bay
BSM43	6/4/96	1.4	Baltimore Harbor	BSM45	6/5/96	524.4	Curtis Bay
BSM5	6/3/96	DL	Baltimore Harbor	BSM46	6/5/96	534.9	Curtis Bay
BSM53	6/4/96	114.3	Baltimore Harbor	BSM47	6/5/96	508.3	Curtis Bay

BSM54	6/4/96	52.8	Baltimore Harbor	BSM48	6/5/96	827.1	Curtis Bay
BSM55	6/4/96	94.7	Baltimore Harbor	BSM49	6/5/96	373.4	Curtis Bay
BSM56	6/4/96	100.7	Baltimore Harbor	BSM50	6/5/96	172.7	Curtis Bay
BSM57	6/4/96	131.8	Baltimore Harbor	BSM51	6/5/96	192.9	Curtis Bay
BSM58	6/4/96	93.7	Baltimore Harbor	BSM52	6/5/96	1.6	Curtis Bay
BSM59	6/4/96	114.6	Baltimore Harbor	CB	6/15/95	181.6	Curtis Bay
BSM6	6/3/96	82.3	Baltimore Harbor				

Table K-2: Sediment tPCB Concentrations (ng/g) in the Baltimore Harbor Embayment, Bear Creek, and Curtis Creek/Bay - New Sediment Study

Station	Date	Concentration	Location	Station	Date	Concentration	Location
FH	5/13/08	22.8	Baltimore Harbor	RC	10/2/08	36.5	Baltimore Harbor
FH	10/2/08	10.2	Baltimore Harbor	RC	10/2/08	20.9	Baltimore Harbor
PaRM	6/5/08	133.4	Baltimore Harbor	BCL	5/13/08	116.1	Bear Creek
PaRM	11/12/08	40.3	Baltimore Harbor	BCL	5/13/08	127.0	Bear Creek
PaRMB	6/5/08	42.5	Baltimore Harbor	BCL	10/2/08	56.7	Bear Creek
PaRMB	10/2/08	1.6	Baltimore Harbor	CuB	6/5/08	10.6	Curtis Bay
RC	5/13/08	0.4	Baltimore Harbor	CuB	11/12/08	28.6	Curtis Bay

Table K-3: Water Column tPCB Concentrations (ng/L) in the Baltimore Harbor Embayment, Bear Creek, and Curtis Creek/Bay - CHARM Study

Station	Type	Date	Concentration	Location	Station	Type	Date	Concentration	Location
00	Tidal	10/12/99	1.26	Baltimore Harbor	G2	Non-Tidal	3/29/00	2.91	Baltimore Harbor
00	Tidal	10/12/99	2.01	Baltimore Harbor	G2	Non-Tidal	4/4/00	7.90	Baltimore Harbor
00	Tidal	10/26/99	4.24	Baltimore Harbor	G2	Non-Tidal	4/6/00	7.95	Baltimore Harbor
00	Tidal	10/26/99	2.39	Baltimore Harbor	G2	Non-Tidal	7/27/00	8.18	Baltimore Harbor
00	Tidal	3/16/00	0.95	Baltimore Harbor	J1	Non-Tidal	3/14/00	4.31	Baltimore Harbor
00	Tidal	3/16/00	1.25	Baltimore Harbor	J1	Non-Tidal	3/17/00	1.99	Baltimore Harbor
00	Tidal	3/21/00	5.02	Baltimore Harbor	J1	Non-Tidal	3/21/00	70.67	Baltimore Harbor
00	Tidal	3/29/00	2.09	Baltimore Harbor	J1	Non-Tidal	3/29/00	6.68	Baltimore Harbor
00	Tidal	4/4/00	2.27	Baltimore Harbor	J1	Non-Tidal	4/4/00	10.22	Baltimore Harbor
00	Tidal	4/4/00	3.54	Baltimore Harbor	J1	Non-Tidal	4/6/00	4.11	Baltimore Harbor
00	Tidal	7/20/00	2.63	Baltimore Harbor	J1	Non-Tidal	7/27/00	9.65	Baltimore Harbor
00	Tidal	7/20/00	3.48	Baltimore Harbor	J1	Non-Tidal	8/1/00	20.00	Baltimore Harbor
00	Tidal	8/3/00	3.25	Baltimore Harbor	J2	Non-Tidal	3/14/00	4.37	Baltimore Harbor
00	Tidal	8/3/00	1.12	Baltimore Harbor	J2	Non-Tidal	3/17/00	1.55	Baltimore Harbor
01	Tidal	3/16/00	5.42	Baltimore Harbor	J2	Non-Tidal	3/21/00	10.36	Baltimore Harbor
01	Tidal	8/1/00	3.70	Baltimore Harbor	J2	Non-Tidal	3/29/00	2.95	Baltimore Harbor
02	Tidal	10/12/99	2.48	Baltimore Harbor	J2	Non-Tidal	4/4/00	1.85	Baltimore Harbor
02	Tidal	3/16/00	2.82	Baltimore Harbor	J2	Non-Tidal	4/6/00	2.19	Baltimore Harbor

02	Tidal	7/20/00	4.50	Baltimore Harbor	J2	Non-Tidal	7/27/00	5.43	Baltimore Harbor
02	Tidal	8/1/00	2.14	Baltimore Harbor	J2	Non-Tidal	8/3/00	5.46	Baltimore Harbor
02	Tidal	8/3/00	4.15	Baltimore Harbor	key	Tidal	3/8/97	6.88	Baltimore Harbor
04	Tidal	10/12/99	1.04	Baltimore Harbor	key	Tidal	3/17/97	8.49	Baltimore Harbor
04	Tidal	3/16/00	1.83	Baltimore Harbor	key	Tidal	3/27/97	5.27	Baltimore Harbor
04	Tidal	3/21/00	2.15	Baltimore Harbor	key	Tidal	4/5/97	3.81	Baltimore Harbor
04	Tidal	7/20/00	7.19	Baltimore Harbor	key	Tidal	4/14/97	5.79	Baltimore Harbor
04	Tidal	8/3/00	5.65	Baltimore Harbor	key	Tidal	4/23/97	2.98	Baltimore Harbor
05	Tidal	10/12/99	1.48	Baltimore Harbor	key	Tidal	5/2/97	5.43	Baltimore Harbor
05	Tidal	3/16/00	1.84	Baltimore Harbor	key	Tidal	5/12/97	4.32	Baltimore Harbor
05	Tidal	8/3/00	3.04	Baltimore Harbor	key	Tidal	5/20/97	3.41	Baltimore Harbor
06	Tidal	10/12/99	1.67	Baltimore Harbor	key	Tidal	5/29/97	2.70	Baltimore Harbor
06	Tidal	10/12/99	3.12	Baltimore Harbor	key	Tidal	6/7/97	4.84	Baltimore Harbor
06	Tidal	3/16/00	2.17	Baltimore Harbor	key	Tidal	6/16/97	3.69	Baltimore Harbor
06	Tidal	8/1/00	1.99	Baltimore Harbor	key	Tidal	6/25/97	3.23	Baltimore Harbor
07	Tidal	3/16/00	1.86	Baltimore Harbor	key	Tidal	7/13/97	3.24	Baltimore Harbor
07	Tidal	8/1/00	2.26	Baltimore Harbor	key	Tidal	7/22/97	3.96	Baltimore Harbor
08	Tidal	3/16/00	1.51	Baltimore Harbor	key	Tidal	7/31/97	3.53	Baltimore Harbor
08	Tidal	8/1/00	1.88	Baltimore Harbor	key	Tidal	8/9/97	2.70	Baltimore Harbor
11	Tidal	3/16/00	1.50	Baltimore Harbor	key	Tidal	8/18/97	3.79	Baltimore Harbor
11	Tidal	3/21/00	2.39	Baltimore Harbor	key	Tidal	8/27/97	3.02	Baltimore Harbor
11	Tidal	3/29/00	3.46	Baltimore Harbor	key	Tidal	9/5/97	2.25	Baltimore Harbor
11	Tidal	4/4/00	3.30	Baltimore Harbor	key	Tidal	9/14/97	3.55	Baltimore Harbor
11	Tidal	8/1/00	2.17	Baltimore Harbor	key	Tidal	9/23/97	2.32	Baltimore Harbor
12	Tidal	3/16/00	1.82	Baltimore Harbor	key	Tidal	10/2/97	1.75	Baltimore Harbor
12	Tidal	8/1/00	1.57	Baltimore Harbor	key	Tidal	10/11/97	2.26	Baltimore Harbor
13	Tidal	3/16/00	1.40	Baltimore Harbor	key	Tidal	10/20/97	2.16	Baltimore Harbor
13	Tidal	8/1/00	1.57	Baltimore Harbor	key	Tidal	10/29/97	2.11	Baltimore Harbor
14	Tidal	3/16/00	2.07	Baltimore Harbor	key	Tidal	11/7/97	4.68	Baltimore Harbor
14	Tidal	3/21/00	2.96	Baltimore Harbor	key	Tidal	12/4/97	1.48	Baltimore Harbor
14	Tidal	8/1/00	2.70	Baltimore Harbor	key	Tidal	12/13/97	2.23	Baltimore Harbor
15	Tidal	3/16/00	2.00	Baltimore Harbor	key	Tidal	12/22/97	2.09	Baltimore Harbor
15	Tidal	8/1/00	3.74	Baltimore Harbor	key	Tidal	12/31/97	2.65	Baltimore Harbor
16	Tidal	10/12/99	2.11	Baltimore Harbor	key	Tidal	1/9/98	4.55	Baltimore Harbor
16	Tidal	3/16/00	1.89	Baltimore Harbor	key	Tidal	1/19/98	4.23	Baltimore Harbor
16	Tidal	8/1/00	4.25	Baltimore Harbor	key	Tidal	1/27/98	5.44	Baltimore Harbor
16	Tidal	8/3/00	3.83	Baltimore Harbor	key	Tidal	2/5/98	3.94	Baltimore Harbor
19	Tidal	10/12/99	5.76	Baltimore Harbor	key	Tidal	2/14/98	3.96	Baltimore Harbor
19	Tidal	10/26/99	5.80	Baltimore Harbor	key	Tidal	2/23/98	8.96	Baltimore Harbor
19	Tidal	11/2/99	8.98	Baltimore Harbor	key	Tidal	3/4/98	2.24	Baltimore Harbor
19	Tidal	3/16/00	2.70	Baltimore Harbor	key	Tidal	3/13/98	6.20	Baltimore Harbor
20	Tidal	10/12/99	1.64	Baltimore Harbor	pr1	Tidal	6/3/96	2.58	Baltimore Harbor

20	Tidal	3/16/00	2.61	Baltimore Harbor	pr1	Tidal	6/4/96	3.76	Baltimore Harbor
20	Tidal	7/31/00	4.29	Baltimore Harbor	pr1	Tidal	6/5/96	3.21	Baltimore Harbor
20	Tidal	8/3/00	3.86	Baltimore Harbor	pr1	Tidal	6/9/96	5.02	Baltimore Harbor
21	Tidal	11/2/99	4.39	Baltimore Harbor	pr1	Tidal	2/20/97	2.06	Baltimore Harbor
21	Tidal	11/3/99	3.55	Baltimore Harbor	pr2	Tidal	6/3/96	3.04	Baltimore Harbor
21	Tidal	3/16/00	1.75	Baltimore Harbor	pr2	Tidal	6/4/96	Below DL	Baltimore Harbor
21	Tidal	3/16/00	3.32	Baltimore Harbor	pr2	Tidal	6/5/96	Below DL	Baltimore Harbor
21	Tidal	3/21/00	31.53	Baltimore Harbor	pr2	Tidal	6/9/96	Below DL	Baltimore Harbor
21	Tidal	3/29/00	4.98	Baltimore Harbor	pr2	Tidal	2/20/97	2.48	Baltimore Harbor
21	Tidal	4/4/00	4.41	Baltimore Harbor	pr3	Tidal	6/3/96	2.48	Baltimore Harbor
21	Tidal	4/6/00	3.71	Baltimore Harbor	pr3	Tidal	6/4/96	2.94	Baltimore Harbor
21	Tidal	7/31/00	1.08	Baltimore Harbor	pr3	Tidal	6/5/96	3.36	Baltimore Harbor
22	Tidal	11/2/99	13.77	Baltimore Harbor	pr3	Tidal	6/9/96	4.13	Baltimore Harbor
22	Tidal	11/3/99	10.12	Baltimore Harbor	pr3	Tidal	2/20/97	2.96	Baltimore Harbor
22	Tidal	3/16/00	3.18	Baltimore Harbor	pr4	Tidal	6/3/96	6.38	Baltimore Harbor
22	Tidal	3/21/00	3.19	Baltimore Harbor	pr4	Tidal	6/4/96	6.45	Baltimore Harbor
22	Tidal	3/29/00	5.43	Baltimore Harbor	pr4	Tidal	6/5/96	4.64	Baltimore Harbor
22	Tidal	4/4/00	5.09	Baltimore Harbor	pr4	Tidal	6/9/96	5.74	Baltimore Harbor
22	Tidal	4/5/00	13.23	Baltimore Harbor	pr4	Tidal	2/20/97	4.77	Baltimore Harbor
22	Tidal	4/6/00	2.87	Baltimore Harbor	pr5	Tidal	6/3/96	4.65	Baltimore Harbor
22	Tidal	8/1/00	7.07	Baltimore Harbor	pr5	Tidal	6/4/96	5.40	Baltimore Harbor
22	Tidal	8/3/00	5.91	Baltimore Harbor	pr5	Tidal	6/5/96	3.81	Baltimore Harbor
23	Tidal	8/1/00	7.39	Baltimore Harbor	pr5	Tidal	6/9/96	4.25	Baltimore Harbor
B331	Non-Tidal	4/3/02	1.05	Baltimore Harbor	pr5	Tidal	2/20/97	3.59	Baltimore Harbor
B331	Non-Tidal	4/25/02	1.66	Baltimore Harbor	pr6	Tidal	6/3/96	4.93	Baltimore Harbor
B332	Non-Tidal	4/3/02	0.16	Baltimore Harbor	pr6	Tidal	6/4/96	4.23	Baltimore Harbor
B332	Non-Tidal	4/25/02	0.32	Baltimore Harbor	pr6	Tidal	6/5/96	4.31	Baltimore Harbor
B351	Non-Tidal	4/3/02	1.30	Baltimore Harbor	pr6	Tidal	6/9/96	3.75	Baltimore Harbor
B351	Non-Tidal	4/25/02	37.59	Baltimore Harbor	pr6	Tidal	2/20/97	3.75	Baltimore Harbor
B421	Non-Tidal	4/3/02	1.42	Baltimore Harbor	pr7	Non-Tidal	6/3/96	DL	Baltimore Harbor
B421	Non-Tidal	4/25/02	8.41	Baltimore Harbor	pr7	Non-Tidal	6/4/96	4.74	Baltimore Harbor
B423	Non-Tidal	4/3/02	1.07	Baltimore Harbor	pr7	Non-Tidal	6/5/96	Below DL	Baltimore Harbor
B423	Non-Tidal	4/25/02	1.39	Baltimore Harbor	pr7	Non-Tidal	6/9/96	3.23	Baltimore Harbor
CHARM_B	Tidal	4/1/03	4.70	Baltimore Harbor	pr7	Non-Tidal	2/20/97	Below DL	Baltimore Harbor
CHARM_D	Tidal	2/24/03	1.98	Baltimore Harbor	09_1	Tidal	7/31/00	7.17	Bear Creek
CHARM_D	Tidal	4/1/03	6.47	Baltimore Harbor	09_2	Tidal	7/31/00	23.22	Bear Creek
G1	Non-Tidal	3/14/00	1.44	Baltimore Harbor	09_3	Tidal	7/31/00	9.22	Bear Creek
G1	Non-Tidal	3/17/00	1.28	Baltimore Harbor	09_4	Tidal	7/31/00	11.70	Bear Creek
G1	Non-Tidal	2/25/01	4.32	Baltimore Harbor	09_5	Tidal	7/31/00	9.91	Bear Creek
G1.5	Non-Tidal	10/19/99	0.74	Baltimore Harbor	09_6	Tidal	7/31/00	14.99	Bear Creek
G1.5	Non-Tidal	11/2/99	0.62	Baltimore Harbor	09_7	Tidal	7/31/00	14.65	Bear Creek
G1.5	Non-Tidal	11/3/99	1.75	Baltimore Harbor	09_8	Tidal	7/31/00	18.32	Bear Creek

G1.5	Non-Tidal	3/29/00	1.71	Baltimore Harbor	09_9	Tidal	7/31/00	9.48	Bear Creek
G1.5	Non-Tidal	4/4/00	2.48	Baltimore Harbor	09	Tidal	10/12/99	1.12	Bear Creek
G1.5	Non-Tidal	4/6/00	1.67	Baltimore Harbor	09	Tidal	3/16/00	2.24	Bear Creek
G1.5	Non-Tidal	7/27/00	4.21	Baltimore Harbor	10	Tidal	3/16/00	1.74	Bear Creek
G2	Non-Tidal	10/19/99	1.61	Baltimore Harbor	17	Tidal	10/12/99	2.98	Curtis Bay
G2	Non-Tidal	11/2/99	1.85	Baltimore Harbor	17	Tidal	3/16/00	3.03	Curtis Bay
G2	Non-Tidal	11/3/99	4.50	Baltimore Harbor	17	Tidal	8/3/00	5.73	Curtis Bay
G2	Non-Tidal	3/14/00	2.53	Baltimore Harbor	17	Tidal	8/3/00	3.84	Curtis Bay
G2	Non-Tidal	3/17/00	2.37	Baltimore Harbor	18	Tidal	3/16/00	2.00	Curtis Bay
G2	Non-Tidal	3/21/00	17.89	Baltimore Harbor	18	Tidal	8/1/00	3.22	Curtis Bay

Table K-4: Water Column tPCB Concentrations (ng/L) in the Baltimore Harbor Embayment, Bear Creek, and Curtis Creek/Bay - New Study

Station	Type	Date	Concentration	Location	Station	Type	Date	Concentration	Location
B351	Non-Tidal	4/29/08	3.18	Baltimore Harbor	BD-1-B	Tidal	10/23/2008	1.36	Baltimore Harbor
B351	Non-Tidal	5/12/08	0.79	Baltimore Harbor	BD-1-B	Tidal	12/8/2008	1.23	Baltimore Harbor
B351	Non-Tidal	6/24/08	3.50	Baltimore Harbor	BD-1-B	Tidal	2/25/2009	2.51	Baltimore Harbor
B351	Non-Tidal	7/14/08	0.45	Baltimore Harbor	BD-1-S	Tidal	4/30/2008	6.91	Baltimore Harbor
B351	Non-Tidal	8/28/08	3.54	Baltimore Harbor	BD-1-S	Tidal	6/30/2008	2.41	Baltimore Harbor
B351	Non-Tidal	9/26/08	1.70	Baltimore Harbor	BD-1-S	Tidal	8/25/2008	1.27	Baltimore Harbor
B351	Non-Tidal	10/30/08	1.51	Baltimore Harbor	BD-1-S	Tidal	10/23/2008	0.99	Baltimore Harbor
B351	Non-Tidal	11/14/08	0.69	Baltimore Harbor	BD-1-S	Tidal	2/25/2009	0.79	Baltimore Harbor
B351	Non-Tidal	12/10/08	10.03	Baltimore Harbor	BD2-B	Tidal	6/30/2008	1.60	Baltimore Harbor
B351	Non-Tidal	1/7/09	7.11	Baltimore Harbor	BD2-B	Tidal	8/25/2008	0.76	Baltimore Harbor
B351	Non-Tidal	2/26/09	1.66	Baltimore Harbor	BD2-B	Tidal	10/23/2008	0.79	Baltimore Harbor
B351	Non-Tidal	3/26/09	2.24	Baltimore Harbor	BD2-B	Tidal	2/25/2009	15.52	Baltimore Harbor
B421	Non-Tidal	4/29/08	3.44	Baltimore Harbor	BD2-S	Tidal	6/30/2008	1.49	Baltimore Harbor
B421	Non-Tidal	5/12/08	19.44	Baltimore Harbor	BD2-S	Tidal	8/25/2008	2.50	Baltimore Harbor
B421	Non-Tidal	6/24/08	1.31	Baltimore Harbor	BD2-S	Tidal	10/23/2008	0.59	Baltimore Harbor
B421	Non-Tidal	7/14/08	5.91	Baltimore Harbor	BD2-S	Tidal	2/25/2009	9.09	Baltimore Harbor
B421	Non-Tidal	8/28/08	4.53	Baltimore Harbor	BD3-B	Tidal	4/30/2008	1.71	Baltimore Harbor
B421	Non-Tidal	9/26/08	1.75	Baltimore Harbor	BD4-B	Tidal	4/30/2008	6.16	Baltimore Harbor
B421	Non-Tidal	10/30/08	1.08	Baltimore Harbor	BD4-B	Tidal	6/30/2008	3.96	Baltimore Harbor
B421	Non-Tidal	11/14/08	1.99	Baltimore Harbor	BD4-B	Tidal	8/25/2008	5.45	Baltimore Harbor
B421	Non-Tidal	12/10/08	7.27	Baltimore Harbor	BD4-B	Tidal	10/23/2008	1.54	Baltimore Harbor
B421	Non-Tidal	1/7/09	20.74	Baltimore Harbor	BD4-B	Tidal	2/25/2009	5.55	Baltimore Harbor
B421	Non-Tidal	2/26/09	3.04	Baltimore Harbor	BD4-S	Tidal	4/30/2008	0.61	Baltimore Harbor
B421	Non-Tidal	3/26/09	0.87	Baltimore Harbor	BD4-S	Tidal	6/30/2008	2.03	Baltimore Harbor
B423	Non-Tidal	4/29/08	2.48	Baltimore Harbor	BD4-S	Tidal	8/25/2008	2.07	Baltimore Harbor
B423	Non-Tidal	5/12/08	8.63	Baltimore Harbor	BD4-S	Tidal	10/23/2008	1.28	Baltimore Harbor
B423	Non-Tidal	6/24/08	9.39	Baltimore Harbor	BD4-S	Tidal	12/8/2008	2.91	Baltimore Harbor

B423	Non-Tidal	7/14/08	5.36	Baltimore Harbor
B423	Non-Tidal	9/26/08	0.68	Baltimore Harbor
B423	Non-Tidal	10/30/08	0.76	Baltimore Harbor
B423	Non-Tidal	11/14/08	1.34	Baltimore Harbor
B423	Non-Tidal	12/10/08	6.11	Baltimore Harbor
B423	Non-Tidal	1/7/09	8.19	Baltimore Harbor
B423	Non-Tidal	2/26/09	1.52	Baltimore Harbor
B423	Non-Tidal	3/26/09	3.58	Baltimore Harbor
B425	Non-Tidal	4/29/08	3.72	Baltimore Harbor
B425	Non-Tidal	5/12/08	2.73	Baltimore Harbor
B425	Non-Tidal	6/24/08	1.87	Baltimore Harbor
B425	Non-Tidal	7/14/08	4.87	Baltimore Harbor
B425	Non-Tidal	8/28/08	1.76	Baltimore Harbor
B425	Non-Tidal	9/26/08	0.97	Baltimore Harbor
B425	Non-Tidal	10/30/08	1.28	Baltimore Harbor
B425	Non-Tidal	11/14/08	1.27	Baltimore Harbor
B425	Non-Tidal	12/10/08	2.90	Baltimore Harbor
B425	Non-Tidal	1/7/09	5.88	Baltimore Harbor
B425	Non-Tidal	2/26/09	0.74	Baltimore Harbor
B425	Non-Tidal	3/26/09	2.41	Baltimore Harbor
BD-1-B	Tidal	4/30/2008	1.28	Baltimore Harbor
BD-1-B	Tidal	8/25/2008	1.45	Baltimore Harbor
BD4-S	Tidal	2/25/2009	0.76	Baltimore Harbor
FH-B	Tidal	10/2/08	3.47	Baltimore Harbor
FH-B	Tidal	5/13/2008	0.88	Baltimore Harbor
FH-S	Tidal	5/13/2008	2.53	Baltimore Harbor
PaRM-B	Tidal	6/5/2008	2.61	Baltimore Harbor
PaRM-B	Tidal	11/12/08	4.12	Baltimore Harbor
PaRMB-B	Tidal	6/5/2008	1.53	Baltimore Harbor
PaRMB-B	Tidal	10/2/08	2.62	Baltimore Harbor
PaRMB-S	Tidal	6/5/2008	2.36	Baltimore Harbor
PaRMB-S	Tidal	10/2/08	2.82	Baltimore Harbor
PaRM-S	Tidal	6/5/2008	2.01	Baltimore Harbor
PaRM-S	Tidal	11/12/08	0.54	Baltimore Harbor
RC-B	Tidal	5/13/2008	1.44	Baltimore Harbor
RC-B	Tidal	10/2/08	2.02	Baltimore Harbor
BCL-B	Tidal	5/13/2008	2.12	Bear Creek
BCL-B	Tidal	10/2/08	5.21	Bear Creek
BCL-S	Tidal	10/2/2008	5.06	Bear Creek
CuB-B	Tidal	6/5/2008	7.22	Curtis Bay
CuB-B	Tidal	11/12/08	2.35	Curtis Bay
CuB-S	Tidal	6/5/2008	3.52	Curtis Bay
CuB-S		11/12/08	1.41	Curtis Bay

Table K-5: Stormwater tPCB Concentrations (ng/L) in the Baltimore Harbor Embayment's Watershed

Station	Date	Concentration
SW1	5/12/08	8.51
SW1	7/14/08	3.98
SW1	9/26/08	1.76
SW1	11/14/08	2.49
SW1	1/7/09	1.39
SW1	3/26/09	7.01
SW2	5/12/08	16.36
SW2	7/14/08	9.17
SW2	9/26/08	1.16
SW2	11/14/08	10.68
SW2	1/7/09	13.56
SW2	3/26/09	1.90
SW3	5/12/08	7.75
SW3	7/14/08	6.48
SW3	9/26/08	13.39
SW3	11/14/08	2.06
SW3	1/7/09	14.24
SW3	3/26/09	3.87
SW4	5/12/08	4.30
SW4	7/14/08	8.06
SW4	9/26/08	4.71
SW4	11/14/08	7.96
SW4	1/7/09	7.76
SW4	3/26/09	1.53
SW5	5/12/08	26.66
SW5	7/14/08	16.42
SW5	9/26/08	20.24
SW5	11/14/08	36.45
SW5	1/7/09	31.49
SW5	3/26/09	24.56

Table K-6: Fish Tissue tPCB Concentrations (ng/g) in the Baltimore Harbor Embayment, Bear Creek, and Curtis Creek/Bay

Site	Date	Concentration	Species	Location
CC	9/13/01	625.1	White Perch	Baltimore Harbor
CuB	5/21/08	412.1	White Perch	Baltimore Harbor
FH	9/17/01	613.4	White Perch	Baltimore Harbor
FH	5/13/08	163.5	White Perch	Baltimore Harbor
GFSFMT	8/27/03	590.7	White Perch	Baltimore Harbor
PaR	4/17/02	224.2	Brown Bullhead Catfish	Baltimore Harbor
PaR	4/17/02	527.5	Brown Bullhead Catfish	Baltimore Harbor
PaR	4/17/02	1000.2	White Catfish	Baltimore Harbor
PaRHSB	4/29/03	113.2	Brown Bullhead Catfish	Baltimore Harbor
PaRHSB	4/29/03	126.4	Brown Bullhead Catfish	Baltimore Harbor
PaRHSB	4/29/03	1283.5	Channel Catfish	Baltimore Harbor
PaRHSB	4/29/03	1774.1	Channel Catfish	Baltimore Harbor
PaRHSB	4/29/03	93.0	White Sucker	Baltimore Harbor
PaRHSB	4/29/03	78.6	White Sucker	Baltimore Harbor
PaRL	9/17/01	472.7	White Perch	Baltimore Harbor
PaRL	8/23/02	720.3	White Perch	Baltimore Harbor
PaRM	9/19/01	556.2	White Perch	Baltimore Harbor
PaRM	9/19/01	519.0	White Perch	Baltimore Harbor
PaRM	5/13/08	77.4	White Perch	Baltimore Harbor
PaRM	5/13/08	259.4	White Perch	Baltimore Harbor
PaRMB	9/6/01	881.8	White Perch	Baltimore Harbor
PaRMB	9/19/01	990.4	White Perch	Baltimore Harbor
PaRMB	9/19/01	1037.0	White Perch	Baltimore Harbor
PaRMB	5/22/08	269.6	White Perch	Baltimore Harbor
PaRMB	9/17/08	198.6	White Perch	Baltimore Harbor
PaRMB	9/17/08	185.3	White Perch	Baltimore Harbor
PaRMB	9/23/08	326.5	White Perch	Baltimore Harbor
PaRMB	9/23/08	442.1	White Perch	Baltimore Harbor
PaRNWH	9/5/01	673.2	White Perch	Baltimore Harbor
RC	9/10/01	333.6	White Perch	Baltimore Harbor
SC	9/19/01	588.5	White Perch	Baltimore Harbor
UPaR	8/23/02	541.9	White Perch	Baltimore Harbor
BCL	9/18/01	571.0	White Perch	Bear Creek
BCL	5/13/08	199.2	White Perch	Bear Creek
BCL	9/17/08	147.8	White Perch	Bear Creek
BCL	9/17/08	281.5	White Perch	Bear Creek
BCU	9/13/01	374.5	White Perch	Bear Creek
CCS	7/27/03	366.5	White Perch	Curtis Bay
MC	9/18/01	632.4	White Perch	Curtis Bay

PaRU	9/10/01	640.3	White Perch	Curtis Bay
UCC	9/10/01	353.2	White Perch	Curtis Bay

Table K-7: Bottom Water Column tPCB Concentrations (ng/L) in the Baltimore Harbor Embayment

Station	Sample Type	Date	Concentration
00	Bottom Water	10/12/1999	2.02
00	Bottom Water	10/26/1999	2.40
00	Bottom Water	11/2/1999	1.71
02	Bottom Water	10/26/1999	3.18
06	Bottom Water	10/12/1999	3.12
16	Bottom Water	10/12/1999	3.22
17	Bottom Water	8/3/2000	3.78
21	Bottom Water	3/16/2000	3.33
Average			**3.11**

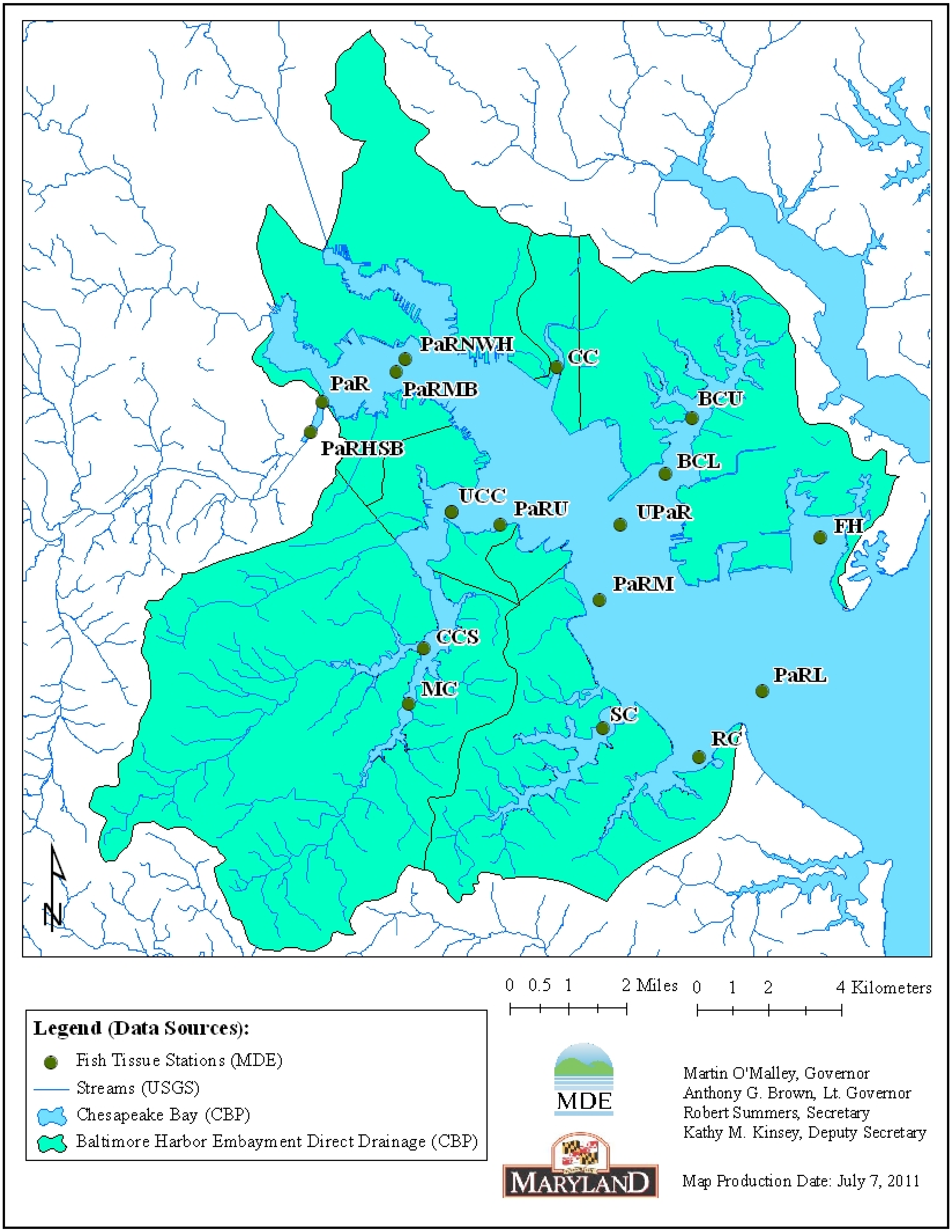


Figure K-1: PCB Fish Tissue Monitoring Stations in the Baltimore Harbor Embayment

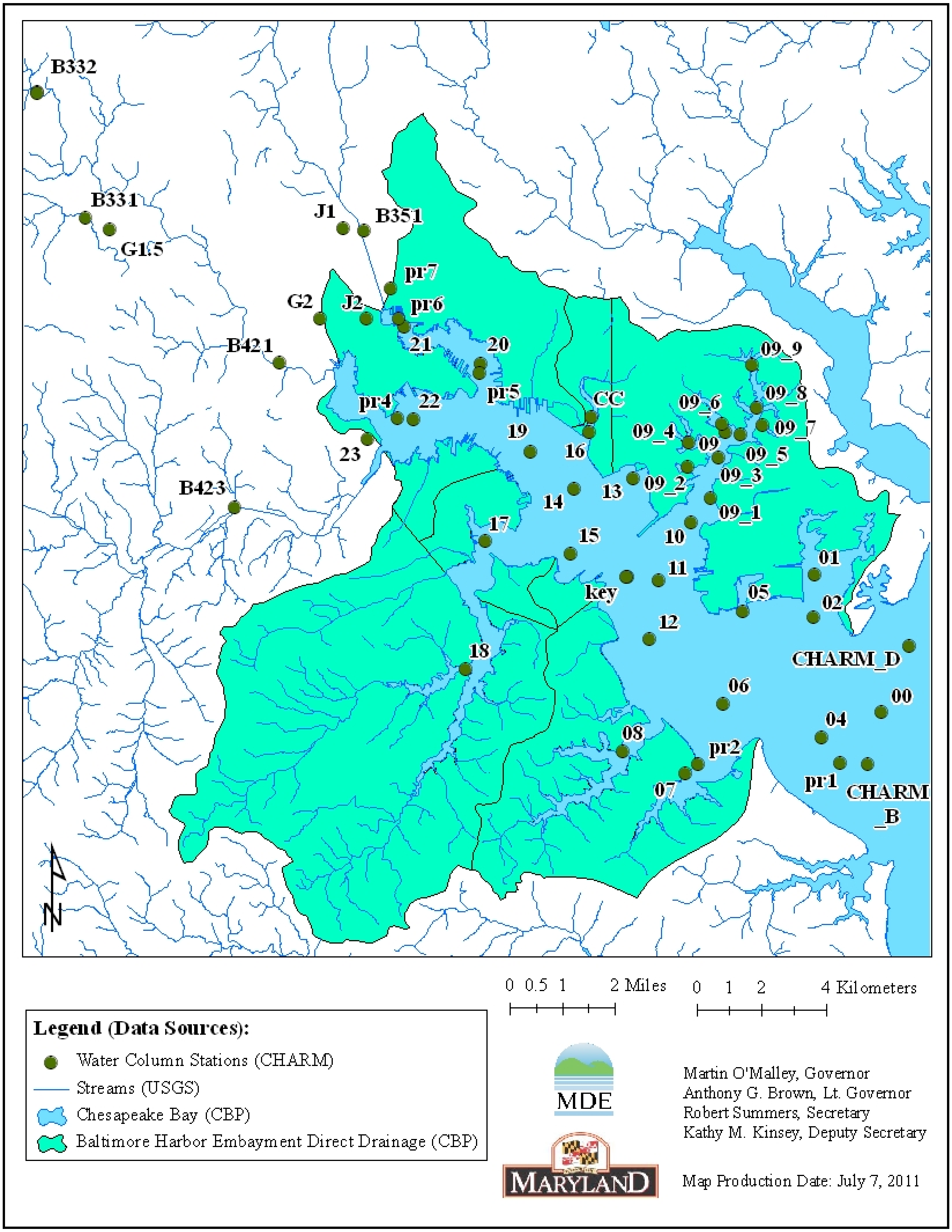


Figure K-2: PCB Water Column Monitoring Stations in the Baltimore Harbor Embayment - CHARM Study

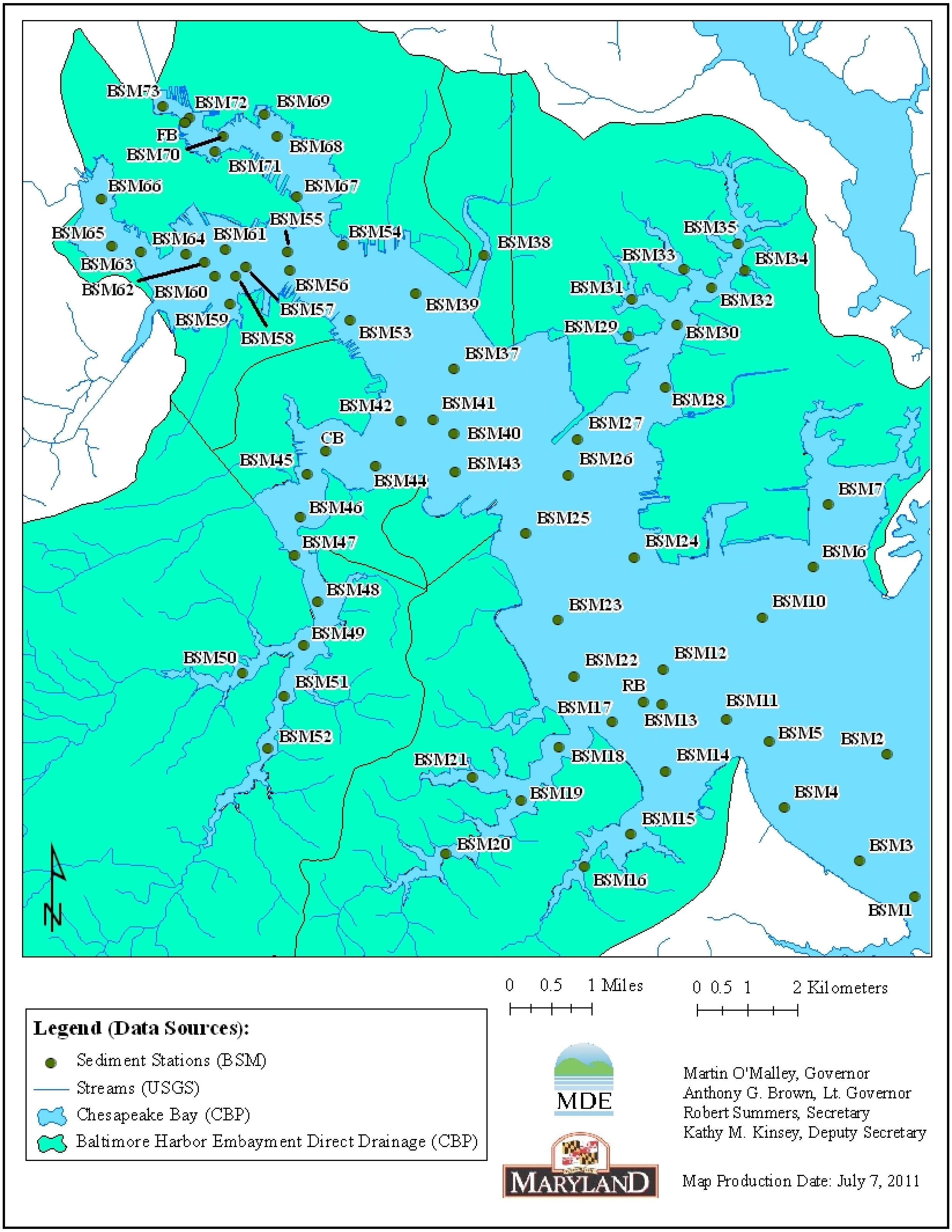
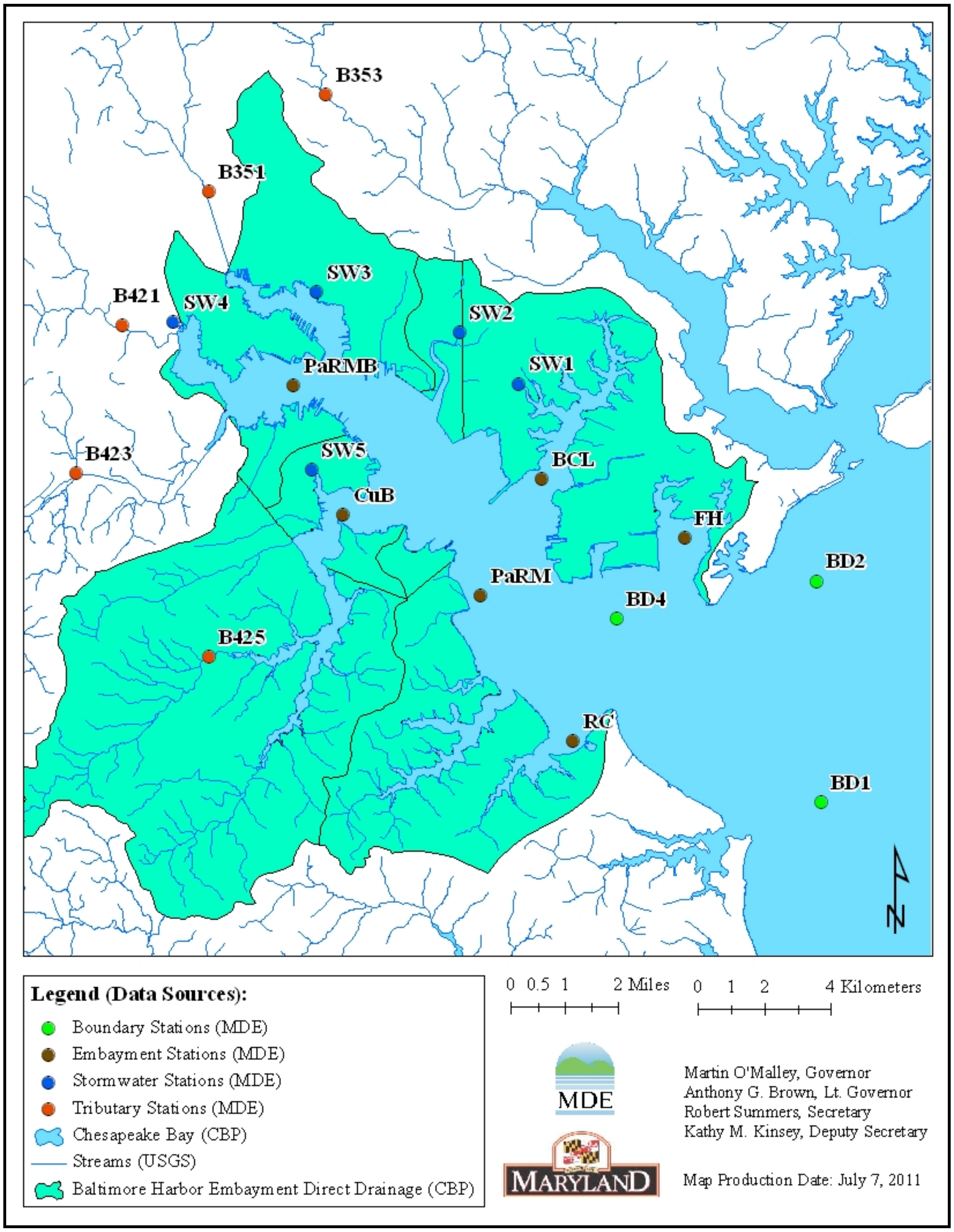


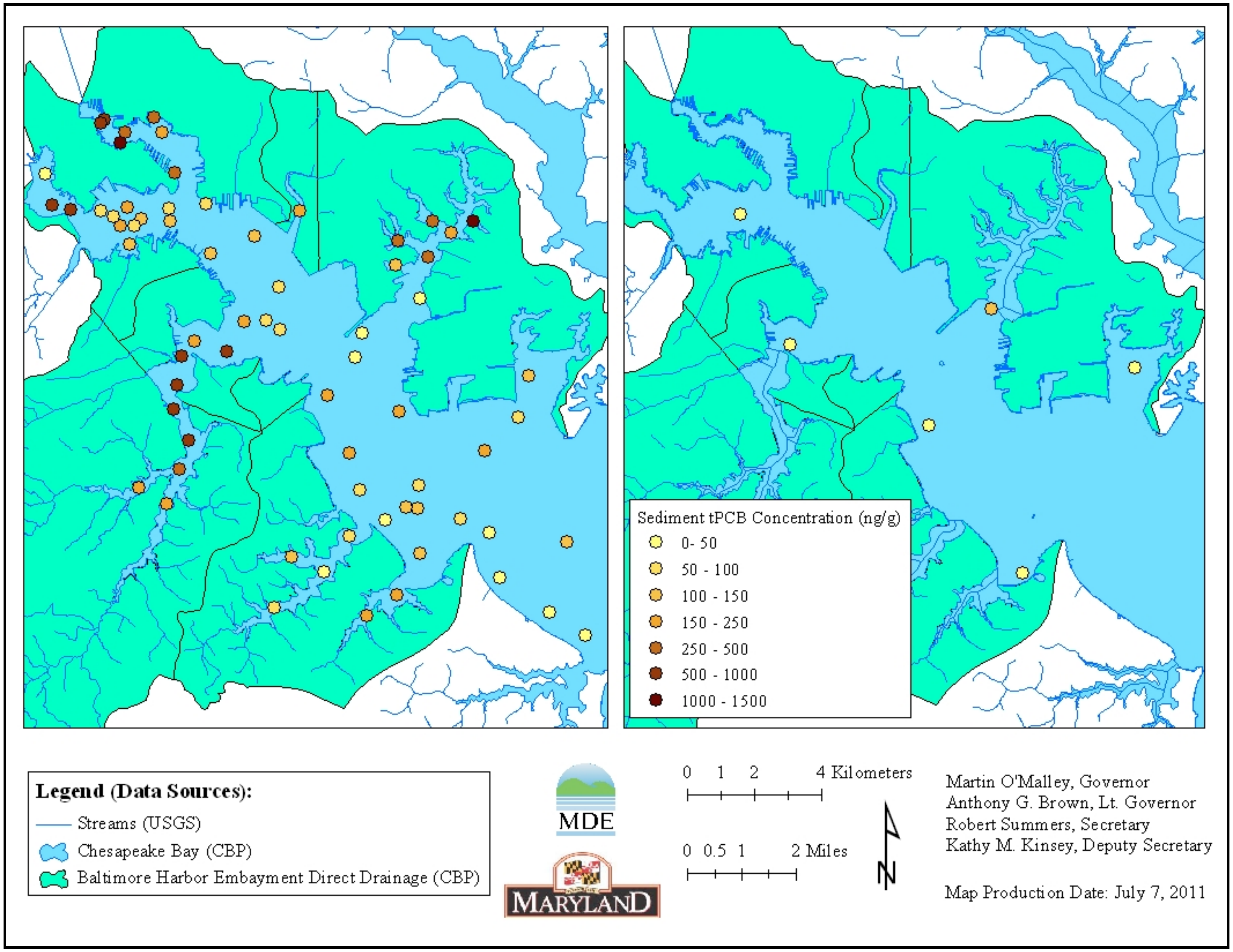
Figure K-3: PCB Sediment Monitoring Stations in the Baltimore Harbor Embayment - Sediment Mapping Study



Note: The embayment stations have water column, sediment, and fish data. other stations have water column data only

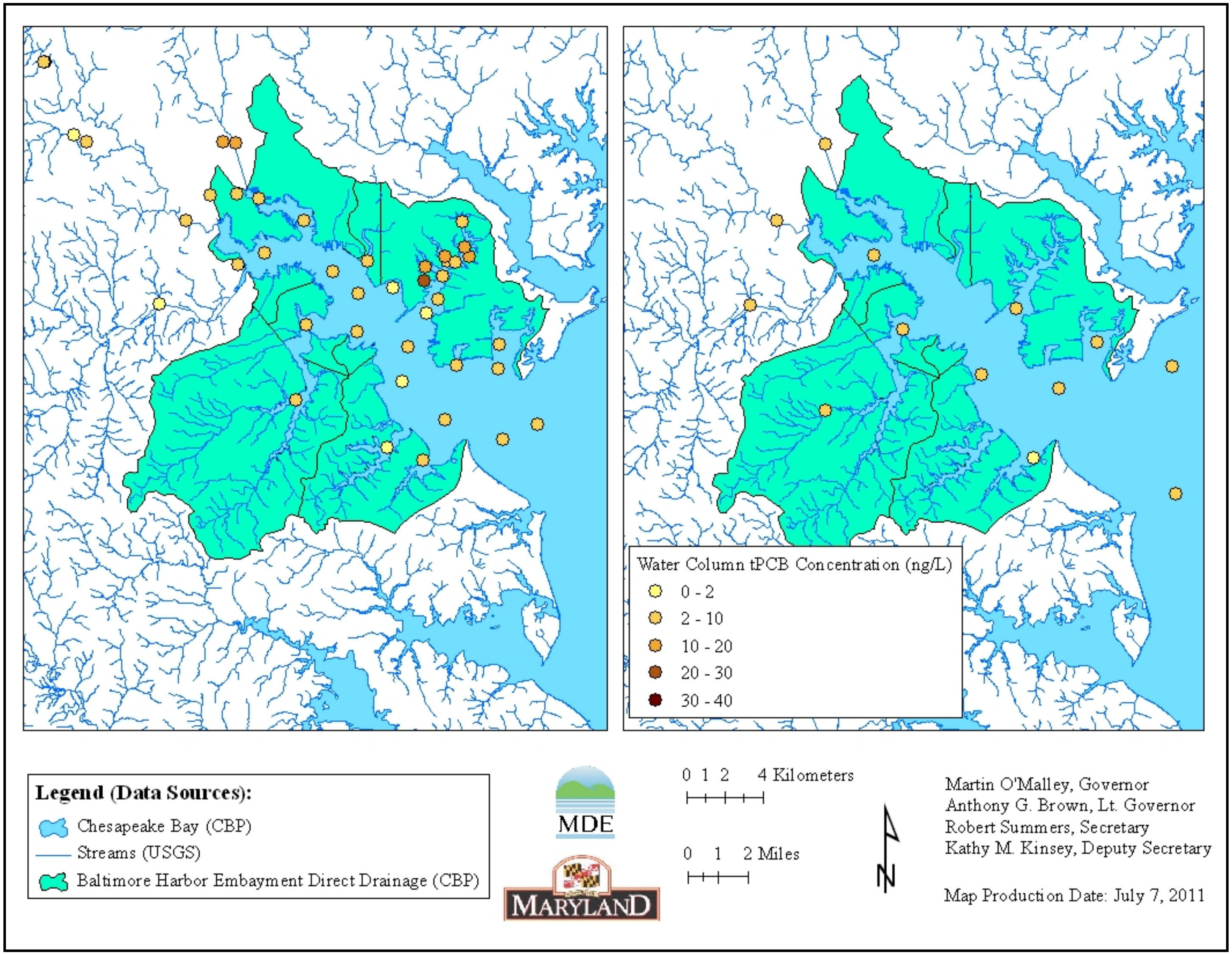
Figure K-4: PCB Monitoring Stations in 2008 and 2009 in the Baltimore Harbor Embayment

The station-averaged tPCB concentrations in the water column and sediment of the Baltimore Harbor embayment in historical and recent studies are shown in Figures K-5 through K-6. Compared with the historical data, the concentrations have decreased significantly in both the water column and sediment. Figure K-7 depicts the locations of the bottom water column monitoring stations adjacent to the navigational channels.



Note: Color scale denotes different concentration levels (Units: ng/g).

Figure K-5: Station-Averaged tPCB Sediment Concentrations - Sediment Mapping Study (Left) and Recent Study (Right) Study



Note: Color scale denotes different concentration levels (Units: ng/L).

Figure K-6: Station-Averaged tPCB Water Column Concentrations - CHARM Study (Left) and Recent Study (Right)

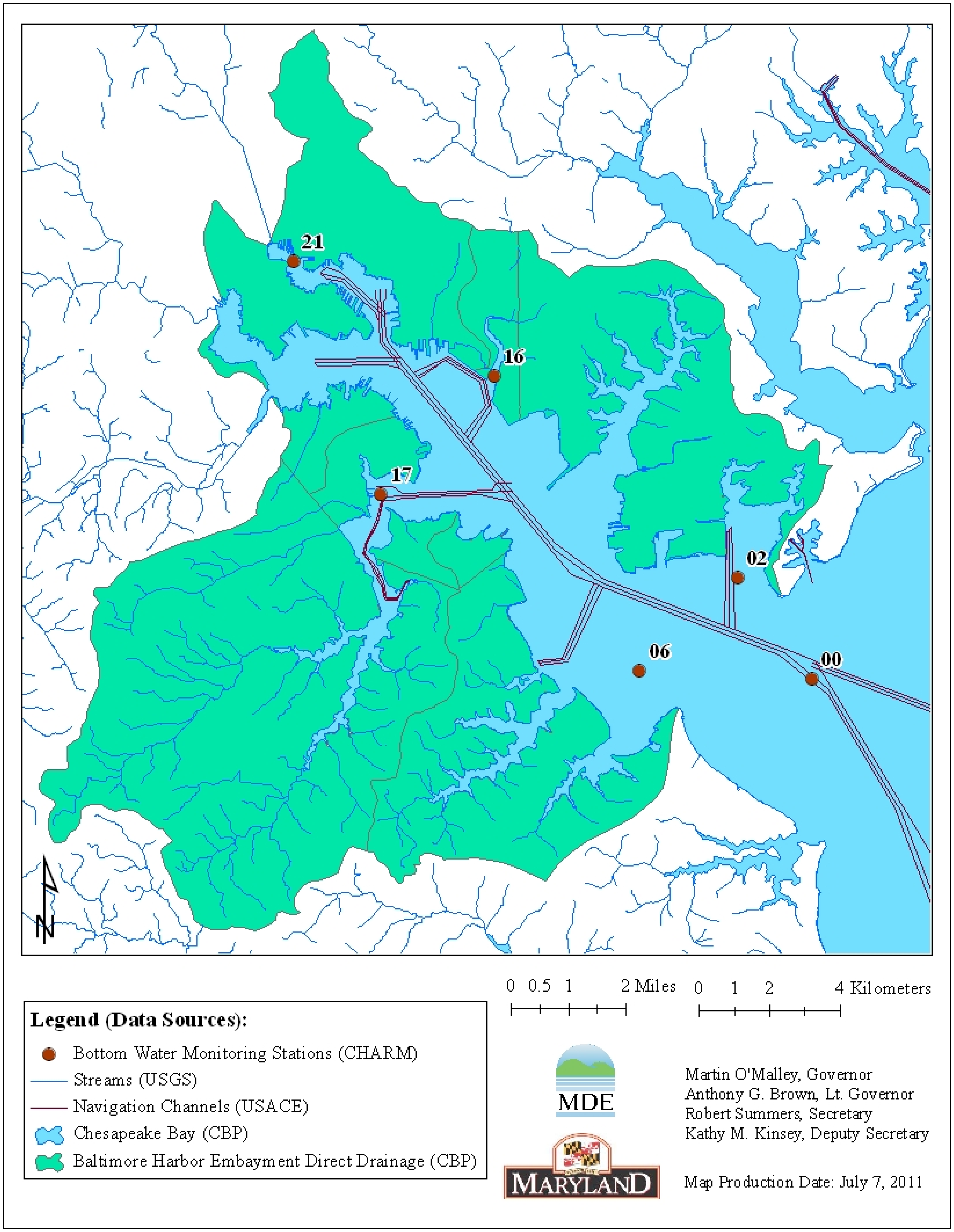


Figure K-7: tPCB Bottom Water Column Monitoring Stations in the Baltimore Harbor Embayment - CHARM Study

Appendix L: Industrial Process Water Facility and DMCF Information

Table L-1 presents the average observed flows and average observed tPCB concentrations for each individual facility used in calculating the aggregate tPCB Baseline Load and WLA for industrial process water facilities and DMCFs.

Table L-1: Summary of Flow Information and tPCB Concentrations for Industrial Process Water Facilities and DMCFs in the Direct Drainage Area of the Baltimore Harbor Embayment's Watershed

Facility Name	NPDES #	Facility Type	Average Flow (MGD)	Average tPCB Concentration (ng/L)	Water Column tPCB TMDL Endpoint (ng/L)
Constellation Power - Fort Smallwood Complex[1]	MD0001503	Industrial	1100.0	0.39	0.27
RG Steel[1,]	MD0001201	Industrial	88.264	1.01	0.27
Constellation - Riverside Generating Plant[1,2]	MD0001481	Industrial	83.0	0.70	0.27
Wheelabrator Baltimore, LP[1,2]	MD0060640	Industrial	62.4	0.70	0.27
Constellation Energy Group - Gould Street Generating Plant[2]	MD0070041	Industrial	2.94	0.70	0.27
Cox Creek DMCF[3]	MDDRG3424	DMCF	9.03	3.11[4]	3.11[4]
Masonville DMCF[3]	MDDRG3650	DMCF	9.03[3]	3.11[4]	3.11[4]

Notes: [1] Monitoring study is currently being conducted to characterize tPCB concentrations in the industrial process water facility's discharge.

[2] Industrial process water facility discharges have not yet been monitored and analyzed for PCBs. Thus, an average of the observed concentrations at the two monitored industrial facilities was used in the baseline load and WLA calculation.

[3] Average Flow value from Cox Creek DMCF will be assigned to the Masonville DMCF as the facility does not currently discharge.

[4] No usable tPCB monitoring data was available for the two DMCFs. Therefore, the average bottom water column tPCB concentration from monitoring stations adjacent to the navigational channels within the embayment was used as a surrogate to calculate the DMCF baseline load. Since any PCBs discharged from these facilities is resultant from tPCB concentrations in the dredged sediments, and is therefore indicative of a pass through condition, the WLA for the DMCFs was set equivalent to their baseline load. Thus, the average bottom water column tPCB concentration is the TMDL endpoint for the DMCFs as well.