U.S. ENVIRONMENTAL PROTECTION AGENCY
REGIONS II AND III

TOTAL MAXIMUM DAILY LOAD FOR POLYCHLORINATED BIPHENYLS (PCBs) FOR ZONE 6 OF THE DELAWARE RIVER

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DELAWARE RIVER BASIN COMMISSION
WEST TRENTON, NJ

December 2006

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Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

DELAWARE RIVER BASIN COMMISSION
WEST TRENTON, NEW JERSEY

December 2006

Authority

This TMDL is established by the U.S. Environmental Protection Agency under the authority of Section 303(d) of the Clean Water Act, 33 U.S.C. § 1251 *et seq.,* and in accordance with EPA's implementing regulations, 40 C.F.R., § 130.

Acknowledgments

This report was prepared by the Delaware River Basin Commission staff: Carol R. Collier, Executive Director. Dr. Namsoo Suk and Dr. Thomas J. Fikslin were the principal authors of the report. Gregory Cavallo and John Yagecic of the Modeling & Monitoring Branch also contributed to this report. Dr. Suk is a Water Resources Engineer/Modeler in the Modeling & Monitoring Branch. Dr. Fikslin is the Head of the Commission's Modeling & Monitoring Branch.

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EXECUTIVE SUMMARY

On behalf of the states of Delaware and New Jersey, and in cooperation with the Delaware River Basin Commission (DRBC), the United States Environmental Protection Agency Regions II and III (EPA) has developed a total maximum daily load (TMDL) for polychlorinated biphenyls (PCBs) from the head of the Delaware Bay at Liston Point to the mouth of the Bay at Cape Henlopen to Cape May. This area is also referred to as Delaware River Basin Commission Water Quality Management Zone 6. EPA establishes this TMDL in order to achieve and maintain the applicable water quality criteria for PCBs designed to protect human health from the carcinogenic effects of eating the contaminated fish now found in the Delaware Estuary and Bay. In accordance with Section 303(d) of the Clean Water Act (CWA) and its implementing regulations, this TMDL provides allocations to point sources (WLAs) discharging PCBs as well as allocations to nonpoint sources (LAs) of PCBs, and an explicit margin of safety to account for uncertainties. This TMDL meets all of the current federal regulatory requirements of a TMDL established under the Clean Water Act.

This TMDL report and its appendices set forth the basis for the TMDL and allocations, and discuss follow up strategies that will be necessary to achieve these substantial reductions of PCBs. EPA will continue to work with the Commission and the States as they develop enhanced Stage 2 PCB TMDLs for the entire Delaware Estuary (also referred to as Delaware River Basin Commission Water Quality Management Zones 2 through 6) based on information to be collected and analyzed over the next several years. While EPA acknowledges that implementation of these TMDLs will be difficult and may take decades to fully achieve, the establishment of these TMDLs sets forth a framework and specific goals to protect human health and restore the Delaware River from the effects of PCB pollution.

Listing under Section 303(d) of the Clean Water Act

The Delaware Department of Natural Resources & Environmental Control (DNREC) first listed Zones 5 and 6 of the Delaware River as impaired for toxics on the state's 1996 Section 303(d) List. In 1998, DNREC again listed Zone 5 of the Delaware River, but specifically listed PCBs as a pollutant contributing to the impairment. In Attachment B to a Memorandum of Agreement (MOA) between the Delaware Department of Natural Resources & Environmental Control and the U.S. Environmental Protection Agency, Region III dated July 25, 1997, DNREC agreed to complete the TMDL for Zone 6 by December 31, 2006 provided that funding and certain other conditions were met. In a Consent Decree between the American Littoral Society, the Sierra Club, and the U.S. Environmental Protection Agency dated July 31, 1997, the U.S. EPA agreed to establish all TMDLs by December 15 of the year following the state's deadline provided that all TMDLs be established by December 15, 2006. In June 2005, New Jersey listed all of Delaware Bay and the tidal portions of tributaries to Delaware Bay (i.e., Zone 6) as impaired by PCBs on their 2004 Integrated List of Waterbodies.

Basis for TMDL

TMDLs must be based upon the water quality criteria and the designated uses for the water body that was listed under Section 303(d). In the Delaware River Basin, applicable water quality criteria and uses have been adopted in regulation by the states bordering the river as well as the Delaware River Basin Commission. The DRBC does not have specific numerical criteria for toxic pollutants including PCBs for Zone 6. Delaware adopted a numerical water quality criterion of 64 pg/l for Total PCBs in 2004. New Jersey currently has a state-wide numerical water quality criterion of 170 pg/l for Total PCBs that was adopted in January 2002. In September 2005, the NJDEP proposed a state-wide numerical water quality criterion of 64 pg/l for Total PCBs. The TMDL presented in this report is based upon a water quality criterion of 64 pg/l for Total PCBs. The TMDL must, however, also ensure that the water quality of adjacent water bodies is met. Numerical water quality criteria to protect designated uses for toxic pollutants including Total PCBs for Zones 2 through 5 of the Delaware River were adopted by the DRBC in October 1996. These criteria do, however, differ from the criterion adopted by Delaware and New Jersey. Human health criteria in Zones 4 and 5 are based solely upon exposure to PCBs through ingestion of fish taken from these estuary zones. The water quality regulations of both Delaware and New Jersey specify that criteria formally adopted by the DRBC are the applicable criteria for that portion of the Delaware River. DRBC criteria for Zones 4 and 5 are more stringent, and must be considered in developing the TMDL.

In January 2006, the Commission's Executive Director requested the concurrence of the U.S. Environmental Protection Agency Regions II and III that the existing human health water quality criteria namely: 64 pg/l in Zone 6, 7.9 pg/l in lower Zone 5 and 44.8 pg/l in upper Zone 5 and all of Zone 4 should be the basis for the Zone 6 TMDL. In a letter received on February 21, 2006, both U.S. EPA regional offices concurred with this approach.

TMDL Approach

The complexity of a TMDL for a class of compounds such as PCBs, the limited time imposed by the MOA and Consent Decree, the limited data available, and the benefits of refining it through time with more data led to a decision to develop the TMDL for PCBs in two stages consistent with EPA TMDL guidance. A staged approach provides for adaptive implementation through execution of load reduction strategies while additional monitoring and modeling efforts proceed in order to refine the wasteload and load allocations. The approach recognizes that additional monitoring data and modeling results will be available following issuance of this Stage 1 TMDL to enable a more refined analysis to form the basis of the Stage 2 TMDL. This staged approach to establishing TMDLs will be utilized for the Zone 6 TMDL as it was for the Stage 1 TMDLs for Zones 2 - 5.

In essence, the Zone 6 TMDL is an extension of the Stage 1 TMDLs developed for Zones 2 - 5. Due to the tidal nature of this portion of the Delaware River, the influence of Zone 6 on the upriver zones had to be considered in the development of the Zones 2 - 5 TMDLs. Similarly in this TMDL, Zones 2 - 5 have a significant influence on the PCB concentrations in Zone 6 and must be considered. The Zone 6 TMDL also needed to be staged due to the lack of any PCB data on point sources as well as tributaries to Delaware Bay, the need to collect additional ambient data in Delaware Bay, and the need for modifications to the penta-PCB water quality model to better describe the processes occurring in the estuarine turbidity maximum (ETM). Other planned enhancements include specification of sediment PCB concentrations based upon additional sediment data and assignment of segment-specific gaseous air concentrations.

Wasteload allocations for individual discharges to Zone 6 were developed using a simplified methodology, which still met all of the current regulatory requirements for establishing a TMDL. A number of key guiding principles were utilized in developing the TMDL and allocations. These principles were based on available scientific data, model simulation results, and policy decisions. The guiding principles are as follows:

1. The Stage 1 TMDL for Zone 6 (Delaware Bay) is built upon TMDLs developed for Zones 2 to 5 in 2003.

2. Pentachlorobiphenyls, the penta-PCB homolog group, are used as a surrogate for Total PCBs. The same ratio used in development of the Zones 2 to 5 TMDLs in 2003, 1:4 for penta to total PCBs, is used in this TMDL.

3. Preliminary model simulations revealed that there are two potential critical locations that control the loading of PCBs to Zone 6. One location is at River Mile 68.75, the location of Delaware Memorial Bridge, where the applicable water quality criteria changes from 44.8 to 7.9 pg/L . The other location is at the boundary of Zone 5 and 6 (River Mile 48.2) where the applicable water quality criteria changes from 7.9 to 64 pg/L in an upstream to downstream direction. Allowable loadings of PCBs to Zone 6 or from the downstream boundary will be determined while focusing on violations at those two locations

4. All WLAs and LAs in Zone 6 are allowed to discharge at the applicable water quality criterion of 64 picograms per liter of total PCBs. Since this Stage 1 TMDL for the Delaware Bay is limited to the mainstem of the Estuary not the individual tributaries, the influence from the WLAs and LAs are relatively minor compared to the influence from the upstream or the downstream boundaries (the Ocean) of Zone 6. .

5. As a policy decision, 5 percent of the TMDL is explicitly reserved for a margin of safety. This is consistent with the margin of safety used in the Zones 2 - 5 TMDLs.

TMDL Procedure

The TMDL for Total PCBs for Zone 6 of the Delaware Estuary is established using a seven step procedure. A brief description of each of the seven steps follows:

1 Using the revised model code and revised input conditions, re-confirm that the TMDLs developed in 2003 are still valid. The governing criterion occurs at two locations, River Mile 68.75 and River Mile 48.2, is 1.975 picograms per liter (pg/L). This value is 25% of 7.9 pg/L, the water quality criterion for Total PCBs at these locations.

2. Determine the usable assimilative capacity for Stage 1 Zone 6 PCB TMDL at the two

critical locations by assigning zero penta-PCBs at the ocean boundary, and for all point and non-point sources to Zone 6. The difference between the simulation results and applicable water quality target is the total assimilative capacity available for Zone 6.

3. Allowable loadings from all point and non-point sources having inflows into Zone 6 are then calculated by multiplying their inflow by the applicable water quality target of 16 pg/L for penta-PCBs. These loadings are distributed in the model proportional to the model segment sizes in Zone 6. The only missing load will then be the influx from the ocean boundary.

4. Determine the allowable ocean boundary by trial and error simulations using the penta-PCB model, the re-confirmed TMDLs for Zones 2 to 5 developed in 2003 plus the Zone 6 loads calculated from the previous step. Compare the results with the applicable water quality target at the two critical locations.

5. Once the allowable ocean boundary is found, calculate and assign equilibrium gaseous atmospheric concentrations in the model. Run the model and go back to Step 4 until the difference between the water quality target and the simulated water column penta PCBs is less than 0.02 pg/L.

6. Convert the ocean boundary concentration to a load and add it to the gross load allocation portion.

7. Reserve 5 percent of the wasteload allocation (WLA) and load allocation (LA) portions for a margin of safety.

Stage 1 TMDL for Zone 6

The Stage 1 TMDL for Total PCBs for Water Quality Management Zone 6 (the Delaware Bay) and its components are listed in the following table:

	TMDL	WLAs	LAs	MOS
Total PCBs	1876.45 mg/day	13.12 mg/day	1769.51 mg/day	93.82 mg/day
Percent of TMDL	-	0.7%	94.3%	5.0%

The wasteload allocation portion of the TMDL represents those source categories that are regulated under the NPDES program (industrial discharges, municipal wastewater treatment plant discharges, combined sewer overflows or CSOs, and municipal separate storm sewer systems or MS4s). Eight (8) industrial and municipal wastewater discharges are assigned wasteload allocations in this TMDL. No CSOs were identified by state permitting authorities. 20 municipal separate storm sewer systems or MS4s were included in the allocation for this point source category. The load allocation portion of the TMDL represents categories including contaminated sites, non-NPDES regulated stormwater discharges, tributaries, air deposition and most importantly input from the Ocean.

Note that the load allocation portion of the TMDL is the largest portion of the TMDL due to the relatively large influence of the ocean on pollutant concentrations in the Bay. Despite this large influence, the allocated loading from the ocean is equivalent to 14.5 picograms per liter (ppq)of Total PCBs rather than the applicable ocean water quality criterion of 64 pg/l. This is primarily attributable to the need to meet the water quality criteria at the two critical locations in Zone 5. With the use of a uniform criterion for the entire estuary for the Stage 2 TMDLs for Zones 2 - 6, this issue should be resolved.

A Stage 2 TMDL, individual WLAs and LAs for Zone 6 will be developed concurrently with those for Zones 2 - 5. They are targeted for development by December 31, 2008. Once the Stage 2 TMDLs are finalized, EPA expects the WLAs developed in Stage 2 to replace the Stage 1 WLAs. EPA expects the Stage 2 WLAs and LAs to be based on all of the monitoring data obtained through the development of the Stage 2 TMDLs, and the additional modeling that will be performed following the establishment of the Stage 1 TMDL. Stage 2 TMDLs will also be based on the summation of those PCB homolog groups accumulated by resident fish and aquatic biota, without the use of extrapolation. It is anticipated that the Stage 2 WLAs will be based upon a more sophisticated allocation methodology than the Stage 1 WLAs, and will likely reflect application of the procedures set forth in the DRBC Water Quality Regulations.

Following establishment of the TMDL for Zone 6, the water quality-based effluent limitations (WQBELs) in NPDES permits that are issued, reissued or modified after the approval date must be consistent with the WLAs. The NPDES permitting authorities (i.e., U.S. EPA, Delaware DNREC and New Jersey DEP) believe that these WQBELs will include non-numeric controls in the form of a best management practices (BMP) approach as the most appropriate way to identify and control discharges of PCBs consistent with the Stage 1 WLAs. Federal regulations (40 CFR Part 122.44(k)(4)) allow the use of non-numeric, BMP-based WQBELs in permits. Appropriate NPDES permitting actions resulting from individual WLAs include 1) the use of Method 1668A for any monitoring of the wastewater influent and effluent at a facility, 2) development of a PCB minimization plan, and 3) implementation of appropriate, cost-effective PCB minimization measures identified through the plan. This approach is identical to the approach used in establishing the TMDLs in Zones 2 - 5.

The identification of point source dischargers that are potentially significant sources of total PCBs is a dynamic process that depends on several factors including the availability and extent of PCB congener data for each discharge, the detection limit of the method used to analyze for PCB congeners, the flows used for each discharge, the procedure used to calculate the loadings, the location of the discharge in the estuary, and the proximity and loading of other sources of PCBs. EPA specifically requests comment on the list of significant point source dischargers contained in Appendix 1 during the public comment period.

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1. INTRODUCTION

1.1 Regulatory Background

Total Maximum Daily Loads or TMDLs are one of the approaches defined in the Clean Water Act (CWA) for addressing water pollution. The first approach of the CWA that was implemented by the U.S. EPA was the technology-based approach to controlling pollutants (Section 301). This approach was implemented in the mid-1970s through the issuance of permits authorized under Section 402 of the Act. The approach specified minimum levels of treatment for sanitary sewage and for various categories of industries. The other water quality-based approach was implemented in the 1980s. This approach includes water quality-based permitting and planning to ensure that standards of water quality established by States are achieved and maintained.

Section 303(d) of the Act establishes TMDLs as one of the tools to address those situations where the technology-based controls are not sufficient to meet applicable water quality standards for a water body (U.S. EPA, 1991). They are defined as the maximum amount of a pollutant that can be assimilated by a water body without causing the applicable water quality criteria to be exceeded. The basis of a TMDL is thus the water quality criteria to protect the designated uses of the waterbody. The designated uses for which criteria may be established include the protection of aquatic life, human health through ingestion of drinking water or resident fish, or wildlife. Under Section 303(d), States are required to identify, establish a priority ranking, and to develop TMDLs for those waters that do not achieve or are not expected to achieve water quality criteria approved by the U.S. EPA. Federal regulations implementing Section 303(d) of the Clean Water Act provide that a TMDL must be expressed as the sum of the individual wasteload allocations for point sources (WLA) plus the load allocation for non-point sources (LA) plus a margin of safety (MOS). This definition may be expressed as the equation:

$$TMDL = WLA + LA + MOS$$

This TMDL meets all of the current federal regulatory requirements of a TMDL established under the Clean Water Act.

1.2 Study Area

Water Quality Management Zone 6 of the Delaware River (Figure 1) has been designated by the Delaware River Basin Commission as that section of the mainstem of the Delaware River including the tidal portions of the tributaries thereto, between the head of Delaware Bay at Liston Point (River Mile 48.2) and the mouth of Delaware Bay between Cape Henlopen and Cape May (River Mile 0.0). Zone 6 is bordered by the States of Delaware and New Jersey.

In 1989, the Delaware River Basin Commission created the Estuary Toxics Management Program to address the impact of toxic pollutants in the tidal Delaware River. By 1993, Commission staff identified several classes of pollutants and specific chemicals that were likely to exceed water quality criteria currently being developed under the program for Zones 2 through 5 of the Delaware River (Figure 1). These included polychlorinated biphenyls (PCBs), volatile organics, metals, chlorinated pesticides, chronic toxicity and acute toxicity. While this program did not specifically address Zone 6, oyster tissue data collected under NOAA's Status and Trends Program indicated that a number of these pollutants, including PCBs, were being transported into Zone 6 from upstream sources (NOAA, 1989).

Beginning in the late 1980's, concern regarding the possible contamination of fish populations that were rebounding as dissolved oxygen levels improved resulted in a number of investigations of contaminant levels in resident and anadromous fish species. The studies subsequently identified PCBs and several chlorinated organics at elevated levels in the tissues of resident fish species in Delaware Bay (Greene and Miller, 1994; Hauge, 1993; U.S. F&WS, 1991). These studies and subsequent data collected by DRBC and the states resulted in fish consumption advisories being issued by both Delaware and New Jersey beginning in 1994. These advisories were principally based upon PCB contamination; and to a lesser degree, chlorinated pesticides such as DDT and its metabolites DDE and DDD, and chlordane.

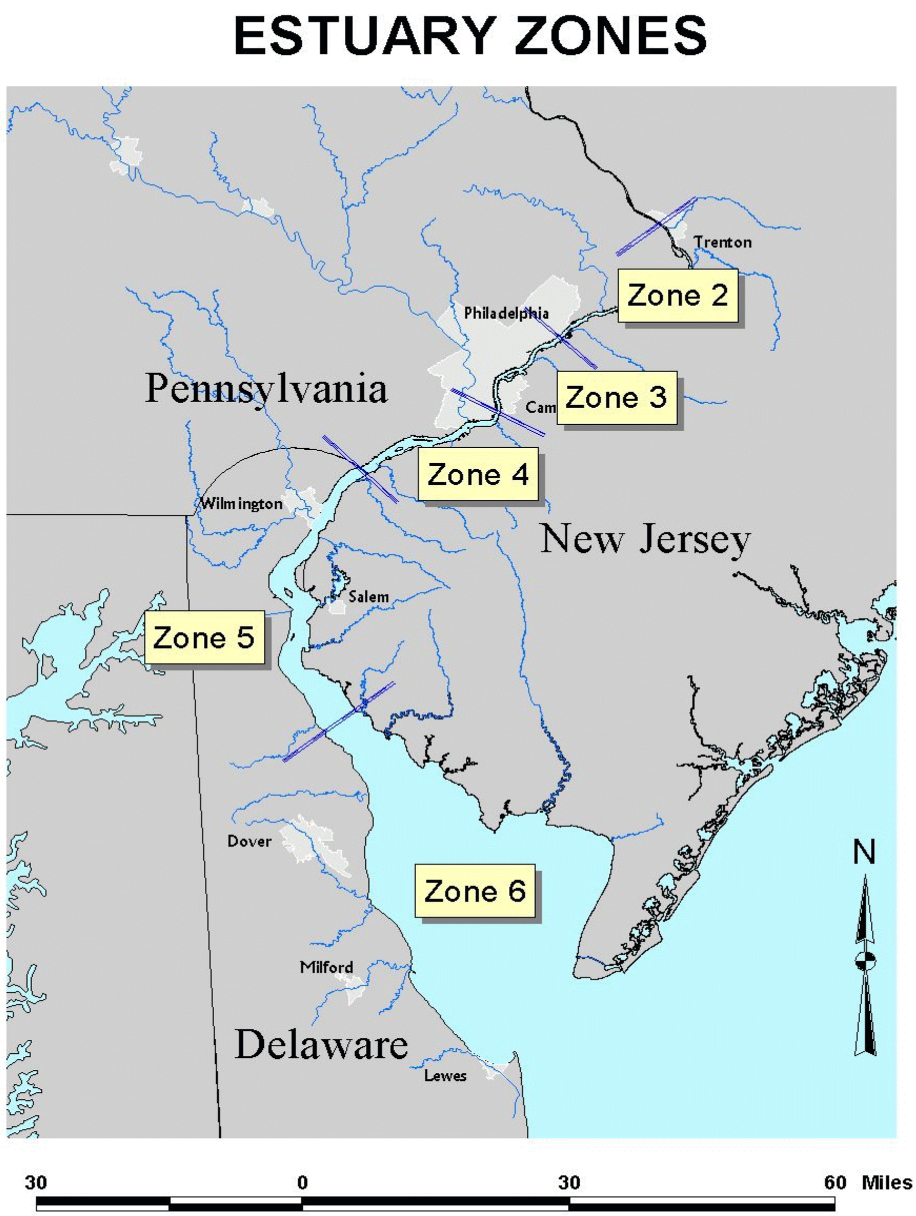
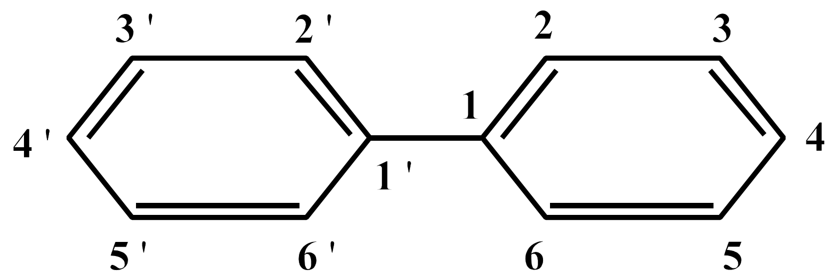


Figure1: Water Quality Management Zones of the Delaware River.

1.3 Polychlorinated biphenyls (PCBs)

Polychlorinated biphenyls (PCBs) are a class of man-made compounds that were manufactured and used extensively in electrical equipment such as transformers and capacitors, paints, printing inks, pesticides, hydraulic fluids and lubricants. Individual PCB compounds called congeners can have up to 10 chlorine atoms on a basic structure consisting of two connected rings of six carbon atoms each. There are 209 possible patterns where chlorine atoms can be substituted on this ring structure resulting in 209 possible PCB compounds. PCB compounds can be grouped by the number of chlorine atoms attached to the carbon rings. These groups are called homologs. For example, one homolog group, the pentachlorobiphenyls or penta-PCBs, consists of all of the congeners that contain five chlorine atoms.



Although their manufacture and use were generally banned by federal regulations in the late 1970s, existing uses in electrical equipment and certain exceptions to the ban were allowed. In addition, PCBs may also be created as a by-product in certain manufacturing processes such as dye and pigment production. PCBs are hydrophobic, sorbing to organic particles such as soils and sediments and concentrating in the tissues of aquatic biota either directly or indirectly through the food chain.

1.4 Applicable Water Quality Criteria and Numerical Target for TMDLs

In the Delaware River Basin, applicable water quality criteria have been adopted in regulation by the states bordering the river as well as the Delaware River Basin Commission. The DRBC does not have specific numerical criteria for toxic pollutants including PCBs for Zone 6. Delaware adopted a numerical water quality criterion of 64 pg/l for Total PCBs in 2004. New Jersey currently has a state-wide numerical water quality criterion of 170 pg/l for Total PCBs that was adopted in January 2002. In September 2005, the NJDEP proposed a state-wide numerical water quality criterion of 64 pg/l for Total PCBs. The basis for the value of 64 pg/l is the use of a revised cancer slope factor of 2.0 mg/kg-day and a fish consumption rate of 17.5 grams per day. This consumption rate is the U.S. EPA recommended default consumption rate (U.S. EPA, 2000), and is also consistent with site-specific consumption data collected by the State of Delaware (DNREC, 1994). Therefore, a value of 64 pg/l was selected as the applicable water quality criterion for Zone 6 of the Delaware River including both the tidal and non-tidal portions of tributaries draining to the zone.

The TMDL must, however, also ensure that the water quality of adjacent water bodies is met. On October 23, 1996, the Commission adopted numerical water quality criteria for toxic pollutants including Total PCBs for Zones 2 through 5 of the Delaware River. These criteria do, however, differ from the criterion adopted by Delaware and New Jersey. In Zone 4 (from River Mile 95.0 to River Mile78.8) and Zone 5 (from River Mile 68.75 to River Mile78.8), use of the water for public water supply is not a designated use, and human health criteria are based solely upon exposure to PCBs through ingestion of fish taken from these estuary zones. Current DRBC criterion in Zone 4 and upper Zone 5 is 44.8 pg/l based upon a consumption rate of

6.5 grams per day. This rate was the U.S. EPA recommended default national value for freshwater fish consumption at the time that the DRBC criteria were adopted. In lower Zone 5, a consumption rate of 37 grams per day was used. This rate was consistent with the rate utilized by the State of Delaware following an evaluation of information available at that time on consumption rates. The current DRBC criterion in lower Zone 5 (below River Mile 68.75) is 7.9 pg/l based upon this consumption rate. The water quality regulations of both Delaware and New Jersey specify that criteria formally adopted by the DRBC are the applicable criteria for that portion of the Delaware River. DRBC criteria for Zones 4 and 5 are more stringent, and must be considered in developing the TMDL.

The TMDL is therefore based upon the most stringent water quality criteria for protecting human health from the carcinogenic effect of PCBs through ingestion of fish taken from these estuary zones. Table 1contains the applicable Delaware, New Jersey and DRBC water quality criteria for this TMDL:

Table 1: Applicable Water Quality Criteria for PCBs for Zones 4 to 6 of the Delaware Estuary

Delaware River Management Zone	**Water Quality Criteria for Total PCBs for the Protection of Human Health from Carcinogenic Effects**		
	Delaware	**New Jersey**	**DRBC**
Zone 4		170 pg/l[1]	44.8 pg/l
Zone 5	64 pg/l	170 pg/l[1]	44.8 pg/l (above RM 68.75) 7.9 pg/l (below RM 68.75)
Zone 6	64 pg/l	170 pg/l[1]	NA

1 - NJDEP proposed a criterion of 64 pg/l in September 2005.

As part of the effort to establish Stage 2 TMDLs for Total PCBs for Zones 2 - 6 and to update adopted water quality standards based upon new information, the Commission's Toxic Advisory Committee developed revised human health criteria for carcinogens for Total PCBs using an updated cancer potency factor (i.e., slope factor), site-specific consumption data for Zones 2 through 6, and a site-specific bioaccumulation factor (BAF) in accordance with revised guidance on developing human health water quality criteria issued by the U.S. EPA in October 2000 (U.S. EPA, 2000). In July 2005, the Toxics Advisory Committee recommended that the Commission proceed with the process of public notice and comment on the adoption of a revised criterion for Total PCBs for Zones 2 - 6. On December 7, 2005, the Commission passed a resolution authorizing public participation of the revised human health criterion for carcinogens of 16 picograms per liter for Zones 2 through 6. Since the basis for the TMDL could be affected by adoption of either new wildlife criteria by the NJDEP or the revised criterion by the DRBC, and the TMDL must be based on the water quality criteria in force when the TMDL is approved, the Commission further directed that the Commission's Executive Director to request the concurrence of the U.S. Environmental Protection Agency Regions II and III that the existing human health water quality criteria namely: 64 pg/l in Zone 6, 7.9 pg/l in lower Zone 5 and 44.8 pg/l in upper Zone 5 and all of Zone 4 should be the basis for the Zone 6 TMDL. In a letter received on February 21, 2006, both U.S. EPA regional offices concurred with this approach.

1.5 Listing under Section 303(d)

Until recently, the attainment of water quality standards for total PCBs could not be measured directly in samples of ambient water so States relied on measurements of contaminants in fish fillet samples collected from the estuary. This is possible since the amount in fish tissue is related to the water concentration by a factor known as the bioaccumulation factor or BAF. This factor accounts for the uptake and concentration of a contaminant in the tissue either directly from the water or through the target species' food chain. Current and historical concentrations of total PCBs in filet samples collected from striped bass, white perch and weakfish collected in Zones 2 through 6 are shown in Figures 2 through 4. While tissue concentrations have declined since the banning in the late 1970s, current levels in these species are approximately 50 to 200 parts per billion (ppb), one to two orders of magnitude above the level expected to occur when estuary waters are at the water quality standards for total PCBs.

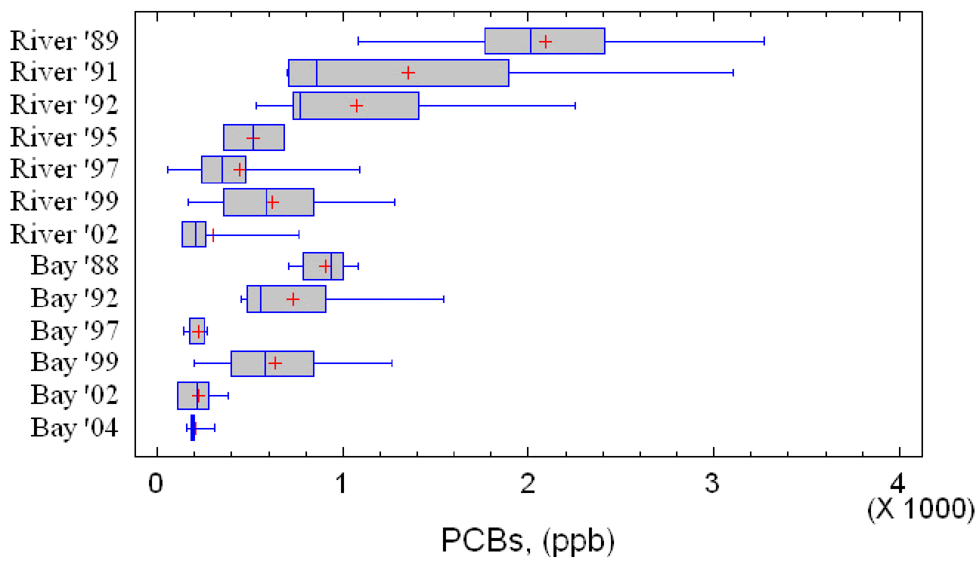


Figure 2: PCB concentrations in fillet samples of striped bass from Zones 5 and 6 of the Delaware Estuary from 1988 to 2004. Units are in parts per billion (ppb) or micrograms per kilogram wet weight of fillet. The range of values (minimum to maximum) is indicated by the full extent of the whiskers which extent from the ends of the boxes. The box encloses the 25^{th} and 75^{th} percentile. The line indicates the median and the red plus sign indicates the mean. Graphs provided by Richard Greene, Delaware DNREC.

After conducting sampling in Zone 5 and 6, Delaware issued an advisory in 1994 recommending limited consumption (no more than five 8-ounce meals per year) of striped bass, channel catfish and white catfish caught between the Chesapeake and Delaware Canal (C&D Canal) and the mouth of Delaware Bay. In 1999, Delaware increased the restrictions to one 8-ounce meal per year and added white perch and eel. By early 2006, bluefish greater than 14 inches had been added to the existing list of species, and consumption of weakfish of all sizes and bluefish less than 14 inches were limited to no more than five 8-ounce meals per month.

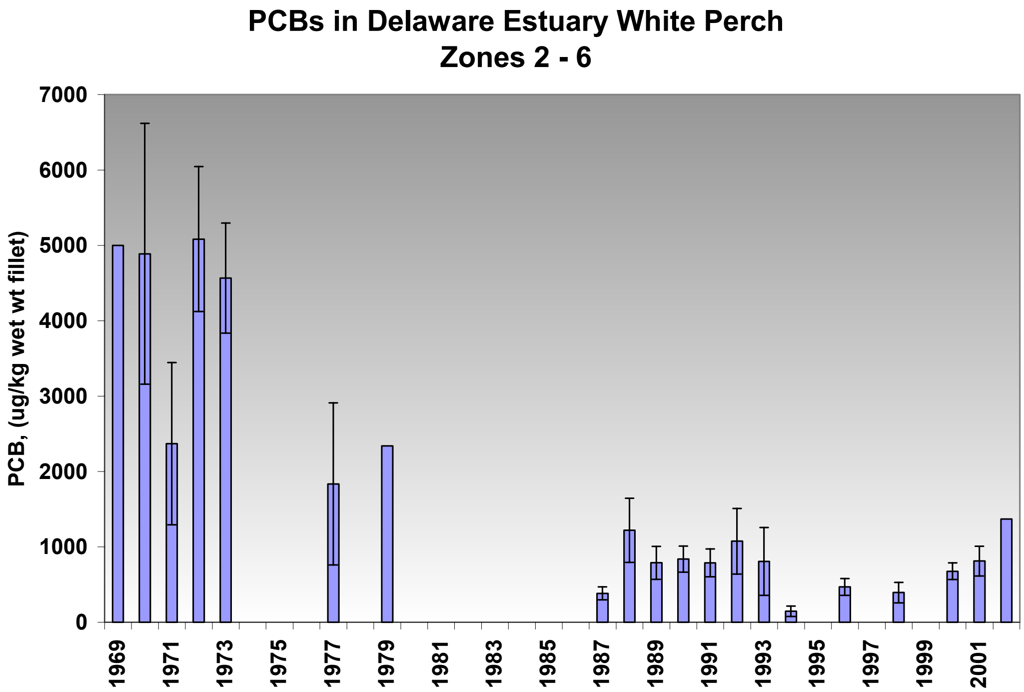


Figure 3: PCB concentrations in fillet samples of white perch from Zones 2 through 6 of the Delaware Estuary from 1969 to 2002. Units are in parts per billion (ppb)or micrograms per kilogram wet weight of fillet. Bars indicate the mean value. Lines represent the standard error of the mean. Graphs provided by Richard Greene, Delaware DNREC.

In March 1995, New Jersey issued updated state-wide and water body-specific advisories due to PCB contamination that included Zone 6. These advisories included advisories issued by Pennsylvania and Delaware covering the Delaware River from Yardley, PA to the mouth of Delaware Bay including the above-cited Delaware advisory. Starting in March 2004, New Jersey and Delaware have issued joint advisories for both Zones 5 and 6 that currently reflect the consumption advice described above.

The Delaware Department of Natural Resources & Environmental Control (DNREC) first listed Zones 5 and 6 of the Delaware River as impaired for toxics on the state's 1996 Section 303(d) List. The Section 303(d) List identifies those waters of a state that are failing to attain the applicable water quality criteria and/or designated use, and for which a TMDL will be needed. In 1998, DNREC again listed Zone 5 of the Delaware River, but specifically listed PCBs as a pollutant contributing to the impairment. In Attachment B to a Memorandum of Agreement between the Delaware Department of Natural Resources & Environmental Control and the U.S. Environmental Protection Agency, Region III dated July 25, 1997, DNREC agreed to complete the TMDL for Zone 6 by December 31, 2006 provided that funding and certain other conditions were met. The MOA also provided that EPA Region III establish the TMDL if DNREC was unable to complete the TMDL by the date set forth in Attachment B. In a Consent Decree between the American Littoral Society, the Sierra Club, and the U.S. Environmental Protection Agency dated July 31, 1997, the U.S. EPA agreed to establish all TMDLs by December 15 of the year following the state's deadline provided that all TMDLs be established by December 15, 2006.

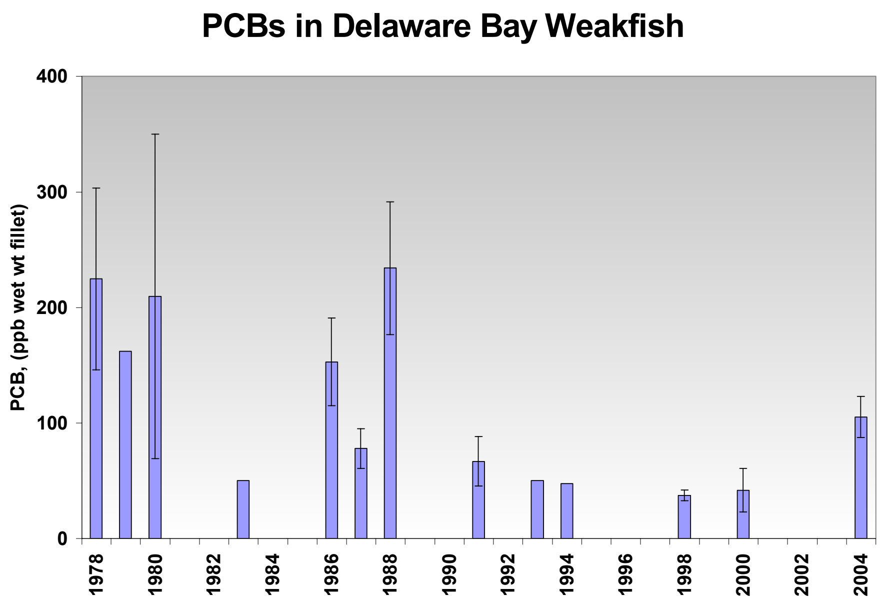


Figure 4: PCB concentrations in fillet samples of weakfish from Zone 6 of the Delaware Estuary from 1978 to 2004. Units are in parts per billion (ppb)or micrograms per kilogram wet weigh of fillet. Graphs provided by Richard Greene, Delaware DNREC.

The New Jersey Department of Environmental Protection included Zones 2 through 5 of the Delaware River for PCBs in a report entitled "1998 Identification and Setting of Priorities for Section 303(d) Water Quality Limited Waters in New Jersey", September 15, 1998, but did not include Zone 6 of the Delaware River in this report. In June 2005, New Jersey listed all of Delaware Bay and the tidal portions of tributaries to Delaware Bay (i.e., Zone 6) as impaired by PCBs on their 2004 Integrated List of Waterbodies.

1.6 Pollutant Sources, Loadings and Ambient Data

The basis for the inclusion of Zone 6 on the Section 303(d) lists of the estuary states was the levels of PCBs observed in fish tissue collected from the estuary. This was necessary since the common analytical method used for ambient water and wastewater up to the mid-1990's had detection limits for total PCBs in the 500 nanogram per liter range. Since the water quality criterion is 1000 times lower than this value, the failure to detect PCBs using this method did not ensure that the criterion was being attained. Development and validation of a new analytical methodology using high resolution gas chromatography/high resolution mass spectrometry (HRGC/HRMS) proceeded from the mid-1990s, culminating in the issuance of Method 1668A by the U.S. Environmental Protection Agency in December 1999 (U.S. EPA, 1999). This method permits the identification and quantitation of all 209 PCB congeners in water, sediment, soil and tissue samples.

Beginning in September 2001, the Commission initiated surveys of the ambient waters of Zones 2 - 6 of the estuary in support of the development of Stage 1 TMDLs for PCBs for Zones 2 - 5 of the estuary. Five of these ambient surveys included sample collection at five locations within the shipping channel of Delaware Bay while three other surveys included sample collection at two of the five locations. Figure 5 presents the results of the surveys conducted in 2002 and 2003. Observed Total PCB concentrations were generally less than 3000 pg/l (parts per quadrillion) during this period with the lowest concentrations occurring near the mouth of Delaware Bay. Concentrations above 3000 pg/l were all observed during a single survey in

November 2003 during high flow conditions (~25,000 cfs at Trenton).

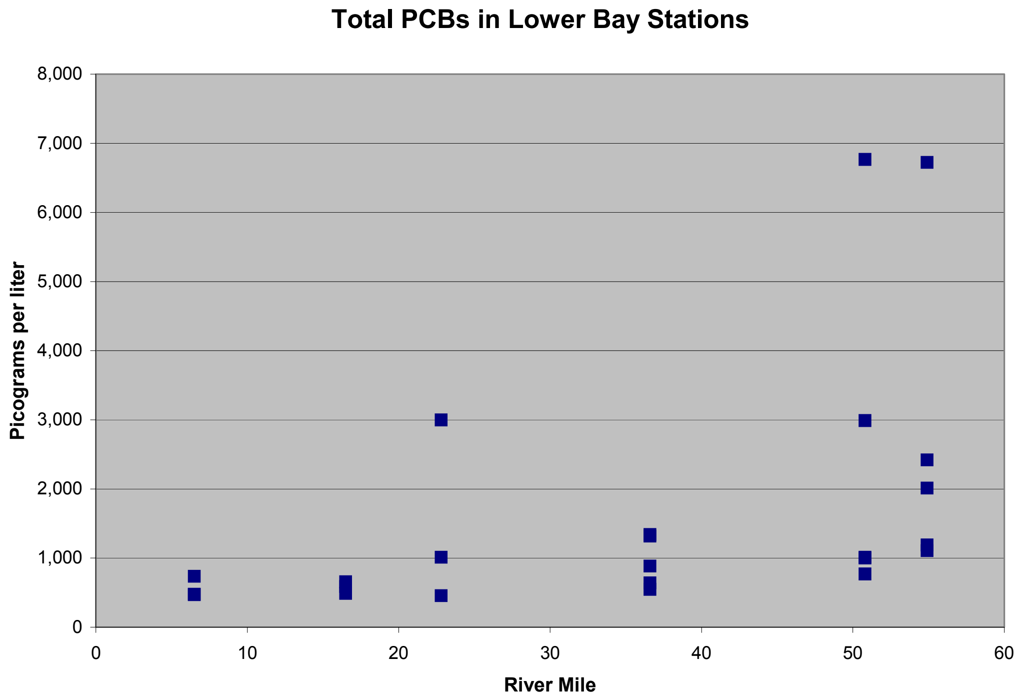


Figure 5: Concentrations of 124 PCB congeners at 5 locations in Zone 6 of the Delaware Estuary during varying flow conditions.

Loadings of PCBs to Zones 2 - 5 the estuary from point sources were first investigated by the Delaware River Basin Commission in 1996 and 1997 (DRBC, 1998). In the spring of 2000, the Commission required 94 NPDES permittees to conduct monitoring of their continuous and stormwater discharges for 81 PCB congeners utilizing analytical methods that could achieve picogram per liter detection limits. The Stage 1 TMDLs established in 2003 indicated that the point source loading category was the third largest source category for PCBs. As part of the Implementation of these TMDLs, the Commission required 96 NPDES permittees to conduct additional monitoring of their continuous and stormwater discharges for all 209 PCB congeners in the fall of 2004 and winter of 2005.

Eight NPDES permittees in Delaware and New Jersey have been identified as possible sources of PCBs to Zone 6. No effluent data is available for these discharges, but the Commission has required the permittees to monitor their continuous and stormwater discharges for 209 PCB congeners. This data will be available along with the additional data from the 96 dischargers to Zones 2 - 5 during the development of the Stage 2 TMDLs for Zones 2 - 6.

1.7 Other Required Elements for Establishing TMDLs

1.7.1 Seasonal variation

TMDL regulations at Section 130.32(b)(9) require the consideration of seasonal variation in environmental factors that affect the relationship between pollutant loadings and water quality impacts. Although seasonal variation is usually not as important for TMDLs based upon human health criteria for carcinogens since the duration for this type of criteria is a 70 year exposure, the Stage 1 TMDL for Zone 6 for Total PCBs do include seasonal variation in several ways. Due to the interaction of PCBs with the sediments of the estuary, long-term model simulations were necessary to both confirm the model parameters established during the short-term calibration, and evaluate the time required for the sediments to reach pseudo steady-state with the overlying water column as loadings of PCBs were reduced.

Model simulations utilize inputs from the period February 1, 2002 until January 31, 2003. This one year period is considered to be representative of long-term hydrological conditions (Section 3.2.3.1, DRBC 2003c). This one year period is also utilized for long-term, decadal scale model simulations by repeating or cycling the same conditions. Use of this one year cycling period, allowed consideration of seasonal variation in model input parameters such as tributary flows, tidal forcing functions, air and water temperature, wind velocity and loadings of penta-PCBs.

1.7.2 Monitoring Plan

The Delaware River Basin Commission has conducted eight surveys of the ambient waters of Zone 6 between August 2002 and June 2006 to provide data for calibrating the water quality model for penta-PCBs. Samples collected during these surveys were analyzed using a more sensitive HRGC/HRMS method (Method 1668A) and larger sample volumes to obtain data at picogram per liter levels. The Commission plans to conduct additional surveys in the Estuary with particular emphasis on Delaware Bay (Zone 6) as part of the effort to calibrate water quality models for the other PCB homologs, and to establish and refine the TMDLs and associated WLAs and LAs for Stage 2 TMDLs for all zones. Contingent on available funding, the Commission plans to continue the ambient water surveys on a yearly basis to track the progress in achieving the load reductions and applicable water quality standards for PCBs.

Twice in the last six years, the Commission has required ~94 NPDES permittees to conduct monitoring of their continuous and stormwater discharges for PCB congeners utilizing analytical methods that could achieve picogram per liter detection limits. The results of this monitoring indicated that loadings to the estuary zones from point sources were significant and of such magnitude to cause the water quality standards to be exceeded. The results showed that significant differences occurred between discharges with 90% of the loadings attributable to 11 discharges. These results have been used to determine the need for and the frequency of additional monitoring in NPDES permits as they have been reissued. These monitoring requirements will provide data in future years to assess the progress in achieving the TMDLs.

Eight NPDES permittees discharging to the tidal portions of tributaries to Zone 6 have been identified as potential sources of PCBs. No direct point source discharges to Zone 6 have been identified. In the summer of 2006, the Commission required these permittees to conduct similar monitoring for 209 PCB congeners. Data from this monitoring requirement will be used to refine the wasteload allocations during the development of the Stage 2 TMDL for Zone 6, and to establish the need for and the frequency of additional monitoring in the NPDES permits for these facilities as their permits are reissued.

The Commission is also continuing to work cooperatively with Rutgers University to continue air monitoring at Lums Pond near the western end of the C&D Canal and at an urban site in Camden, NJ. Contingent on available funding, this program is anticipated to continue for the long-term. Monitoring data at these sites and at a long-term site at Rutgers University will provide data to assess the long-term trends in regional background concentrations of PCBs (Lums Pond) and in regional concentrations in the estuary airshed.

1.7.3 Implementation Plan

Current EPA regulations do not require an implementation plan to be included with TMDLs. EPA NPDES regulations do require that effluent limitations must be consistent with approved WLAs [40 CFR Part 122.44(8)(1)(vii)(B)]. EPA regulations allow the use of non-numeric effluent limits in certain circumstances [40 CFR Part 122.44(K)]. In addition to EPA regulations, the Commission and its signatory parties currently have in place an implementation procedure for utilizing wasteload allocations and other effluent requirements formally issued by the Commission's Executive Director. This procedure has been in use for over 25 years with wasteload allocations for carbonaceous oxygen demand and other pollutants that were developed for discharges to the estuary. Section 4.30.7B.2.c.6). of the Commission regulations requires that WLAs developed by the Commission shall be referred to the appropriate state agency for use, as appropriate, in developing effluent limitations, schedules of compliance and other effluent requirements in NPDES permits. As part of the implementation strategy for this TMDL, the NPDES permitting authorities believe that it is appropriate for 8 NPDES point source discharges to Zone 6 to receive non-numeric WQBELs consistent with the WLAs. It is expected that the non-numeric WQBELs resulting from the Stage 1 WLAs will result in additional monitoring using Method 1668A consistent with state and federal NPDES regulations, and may result in a requirement to submit and implement a pollutant minimization plan (PMP). The New Jersey Department of Environmental Protection has proposed regulations requiring PMPs for discharges to waters impaired by PCBs. In addition, the Commission adopted regulations in May 2005 allowing point and non-point discharges to be required to submit and implement a PMP for PCBs or other designated toxic pollutants. These permit requirements are intended to expedite the reduction in PCB loadings to the Delaware River and Bay while Stage 2 TMDLs and WLAs are being completed.

1.7.4 Reasonable Assurance that the TMDL will be Achieved

Data available to assess whether the TMDL will be achieved include ambient water quality data collected by the Commission during routine surveys of Zones 2 through 6 of the Delaware River. Effluent quality data and PMPs required by the Commission or through NPDES permits issued by state permitting authorities will provide the basis for assessments regarding consistency with the WLAs developed or issued in Stage 1 and Stage 2. Commission regulations also require that the WLAs be reviewed and, if required, revised every five years, or as directed by the Commission. This will ensure that additional discharges of the pollutant or increased non-point source loadings in the future will be considered.

Achieving the reductions in the load allocations for tributaries to Zones 2 through 6 will require the listing of the tributary on future Section 303(d) lists submitted by the estuary states for those tributaries that are not currently listed for impairment by PCBs, and completion and implementation of TMDLs for PCBs for those tributaries that are already listed as impaired by PCBs. Achieving the load reductions required for contaminated sites will require close coordination with the federal CERCLA programs and state programs overseeing the assessment and cleanup of these sites. Actions by federal and state authorities to reduce air emissions from point and non-point air sources will also be necessary before achievement of the applicable water quality criteria is achieved.

The Commission also has broad powers under Article 5 of the Delaware River Basin Compact (Public Law 87-328) to control future pollution and abate existing pollution in the waters of the basin including Section 2.3.5B of the Commission's Rules of Practice and Procedure (DRBC, 2002).

2. TWO STAGE APPROACH TO ESTABLISHING AND ALLOCATING THE TMDL FOR PCBs

2.1 Background

Developing TMDLs for a complex pollutant in a complex estuarine ecosystem with numerous point and non-point sources is an enormous task requiring substantial levels of effort, funding and time. As discussed above, the deadlines contained in the Section 303(d) lists prepared by the States and approved by the U.S. EPA, Memoranda of Understanding, and Consent Decrees discussed above imposed limited time for developing the TMDLs for Zones 2 through 6. A coordinated effort to develop the TMDLs (with emphasis on the initial deadline for Zones 2 - 5) was initiated in 2000 when Carol R. Collier, Executive Director of the Delaware River Basin Commission in a letter dated May 25, 2000 requested that U.S. EPA Regions II and III endorse the Commission as the lead agency in developing the TMDLs for PCBs in the Delaware Estuary. In a letter dated August 7, 2000, Region II endorsed the Commission's role as the lead agency to develop the TMDLs. An August 11, 2000 letter from Region III also acknowledge the important role of the Commission while identifying the legal constraints on the date for establishing the TMDLs for Zones 2 - 5. On July 26, 2000, the Commission passed Resolution 2000-13 stating that the Commission would continue its ongoing program to control the discharge of toxic substances, including PCBs, to the Delaware Estuary, and would work cooperatively with the signatory parties to the Delaware River Basin Compact and their agencies and affected parties in this effort.

2.2 Staged Approach

As noted in Section 1 of this document, this TMDL meets all of the federal regulatory requirements of a TMDL. However, the states and DRBC are working on a Stage 2 TMDL that would be submitted to EPA for review and approval consideration. The states and DRBC are undertaking this effort because of the complexity of a TMDL for a class of compounds such as PCBs, the limited time and data available, and the benefits of refining it through time with more data led to a decision to develop the TMDLs for PCBs in two stages consistent with EPA TMDL guidance concerning phased TMDL development and staged implementation. A staged approach provides for adaptive implementation through execution of load reduction strategies while additional monitoring and modeling efforts proceed in order to refine the wasteload and load allocations. The approach recognizes that additional monitoring data and modeling results will be available following issuance of the Stage 1 TMDLs to enable a more refined analysis to form the basis of the Stage 2 TMDLs. This staged approach to establishing TMDLs would be utilized for the Zone 6 TMDL as it was for the Stage 1 TMDLs for Zones 2 - 5.

In essence, the Zone 6 TMDL is an extension of the Stage 1 TMDLs developed for Zones 2 - 5. Due to the tidal nature of this portion of the Delaware River, the influence of Zone 6 on the upriver zones had to be considered in the development of the Zones 2 - 5 TMDLs. Similarly in this TMDL, Zones 2 - 5 have a significant influence on the PCB concentrations in Zone 6 and must be considered. The States and DRBC are committed to development of a Stage 2 TMDL due to the lack of any PCB data on point sources, the need to incorporate the results of on going data collection surveys in tributaries to Delaware Bay, the need to collect additional ambient data in Delaware Bay and nearshore coastal waters, and the need to make modifications to the penta-PCB water quality model to better describe the processes occurring in the estuarine turbidity maximum (ETM). Other planned enhancement include specification of sediment PCB concentrations based upon additional sediment data and assignment of segment-specific gaseous air concentrations.

Like the Zones 2 - 5 TMDLs, the Stage 2 TMDL for Zone 6 will be based upon an improved water quality model. While Total PCBs are extrapolated from penta-PCBs in Stage 1, the Stage 2 TMDL will be based upon the sum of the PCB homologs that occur in the tissue of resident fish and biota. Data collected to date indicate that this will be the sum of the tetra, penta, hexa and hepta homologs that constitute 90% of the PCB tissue burden in resident fish.

Wasteload allocations for individual discharges to Zone 6 were developed using a simplified methodology, which still met all of the current regulatory requirements for establishing a TMDL. Consistent with the recommendations of an expert panel of scientists experienced with PCB modeling, this TMDL was extrapolated from penta homolog data using the observed ratio in the ambient waters of the Delaware Estuary of the penta homolog to total PCBs (see Section 3.2.3 and 3.2.4).

A Stage 2 TMDL, individual WLAs and LAs for Zone 6 is being developed by the DRBC concurrently with those for Zones 2 - 5. Once the Stage 2 TMDLs are completed, EPA expects WLAs developed in Stage 2 to replace Stage 1 WLAs. EPA expects the Stage 2 WLAs and LAs to be based on all of the monitoring data obtained through the development of the Stage 2 TMDLs, and the additional modeling that will be performed following the establishment of the Stage 1 TMDL. Stage 2 TMDLs will also be based on the summation of those PCB homolog groups accumulated by resident fish and aquatic biota, without the use of extrapolation. It is anticipated that the Stage 2 WLAs will be based upon a more sophisticated allocation methodology than the Stage 1 WLAs, and will likely reflect application of the procedures set forth in the DRBC Water Quality Regulations.

Following establishment of the TMDL for Zone 6, the water quality-based effluent limitations (WQBELs) in NPDES permits that are issued, reissued or modified after the approval date must be consistent with the WLAs. The NPDES permitting authorities (i.e., U.S. EPA, Delaware DNREC and New Jersey DEP) believe that these WQBELs will include non-numeric controls in the form of a best management practices (BMP) approach as the most appropriate way to identify and control discharges of PCBs consistent with the Stage 1 WLAs. Federal regulations (40 CFR Part 122.44(k)(4)) allow the use of non-numeric, BMP-based WQBELs in permits. Appropriate NPDES permitting actions resulting from individual WLAs include 1) the use of Method 1668A for any monitoring of the wastewater influent and effluent at a facility, 2) development of a PCB minimization plan, and 3) implementation of appropriate, cost-effective PCB minimization measures identified through the plan. This approach is identical to the approach used in establishing the TMDLs in Zones 2 - 5.

The identification of point source dischargers that are potentially significant sources of total PCBs is a dynamic process that depends on several factors including the availability and extent of PCB congener data for each discharge, the detection limit of the method used to analyze for PCB congeners, the flows used for each discharge, the procedure used to calculate the loadings, the location of the discharge in the estuary, and the proximity and loading of other sources of PCBs. EPA specifically requests comment on the list of significant point source dischargers during the public comment period (see Appendix 1).

An important component of the staged approach is the assessment and evaluation of options to control non-point sources of PCBs. These sources include contaminated sites (sites covered under CERCLA or RCRA), non-NPDES regulated stormwater discharges, tributaries to the estuary, air deposition, and contaminated sediments.

3. STAGE 1 APPROACH TO ESTABLISHING THE TMDL

3.1 Background

A TMDL for total PCBs is an estimate of the loading of the sum of all the PCB homologs that can enter the estuary and still meet the current water quality criteria. TMDLs are, by nature, abstract. They are the *projected*, not the current, loadings from all sources that should result in the achievement of water quality standards at all points in the estuary.

In order to meet standards at all points in the estuary, some parts of the estuary will have to be less than the standard for that portion of the estuary. This is particularly true for this TMDL for Delaware Bay as it was for the Stage 1 TMDLs for Zones 2 - 5 that were established in 2003. Similar to those TMDLs, the water quality standards vary between the zones, and the controlling standard in lower Zone 5 (7.9 pg/l) below the Delaware Memorial Bridges is approximately 8 times lower than the controlling standard of 64 pg/l in Zone 6 (see Section 1.4).

Even though the task is to develop a Zone 6 TMDL, it is necessary to consider all upstream zones. Any loadings or exchanges of PCBs within or through interfaces of the entire Delaware Estuary has to be included in this Zone 6 TMDL development because Zone 6 is the most downstream of the water quality management zones and is heavily influenced by the ocean through tidal exchanges.

As emphasized in the TMDL document for Zones 2 - 5 (DRBC, 2003c), theoretically, there will be no net exchange between air and water column when the water column reaches the water quality criterion. This can be implemented in the water quality model by assigning the atmospheric gaseous PCBs at a concentration that will be in equilibrium with the truly dissolved PCBs in water column under the continuous input of total maximum daily loadings. This is very important concept to bear in mind throughout any TMDL development case. It is important to distinguish TMDL conditions from the existing conditions. Even though it may take decades to reach ambient concentrations that are equal to the water quality criterion, the TMDL numeric number has to be calculated under this equilibrium condition. At present time, atmospheric gaseous PCBs alone may be sufficient to cause the impairment of the Delaware Estuary, however, TMDLs have to be calculated assuming no effect from atmosphere.

The same principle applies to the sediments of the estuary. PCBs are exchanged between the water column and the underlying sediments through resuspension/settling of particles and diffusion of pore water. When the water quality criterion is achieved, the sediments will also be in equilibrium with the overlying water column. In order to shorten the computation time for model simulations, PCB concentrations can be assigned that will be in equilibrium with the overlying water column under the input of continuous TMDL loadings. These PCB concentrations in the sediment layer can also be far lower than the existing conditions.

While simplistic approaches can be used to estimate TMDLs, significant effort has been devoted to developing and calibrating a hydrodynamic and water quality model for the Delaware Estuary to be used in establishing PCB TMDLs for this water body (DRBC, 2003a; DRBC, 2003b; DRBC, 2006). There are several reasons why a more sophisticated approach is appropriate. These reasons include:

1. The Delaware River and Bay are significantly influenced by tidal forces producing a 6 foot tidal range at Trenton, NJ and tidal excursions of up to 12 miles. The model incorporates this tidal movement in the hydrodynamic model (DRBC, 2003a).
2. PCBs are hydrophobic, sorb to dissolved, colloidal and particulate carbon, and are transported with carbon molecules and particulates associated with carbon. The model incorporates these characteristics, partitions PCBs to each of these phases, and simulates the concentrations of the 3 phases in the estuary (DRBC, 2003b).
3. PCBs are a class of chemicals; each having different physical-chemical properties such as volatilization rate and partitioning rate. The model can incorporate these properties for each of the ten homolog groups (DRBC, 2003b).
4. There are many sources of PCBs that enter the estuary at different locations in different amounts and at different times. The model can simulate the spatial and temporal nature of these sources (DRBC,

2006).

5. A model can simulate the additional assimilative capacity provided by the burial of PCBs into the deeper layers of the estuary sediments, and the exchange of PCBs in the gas phase in the estuary airshed with the dissolved phase of PCBs in the ambient waters of the estuary (DRBC, 2003b).

A modified version of the U.S. EPA's TOXI5/DYNHYD5 numerical models which were used in the Zone 2 to 5 TMDL development in the year of 2003 were also used in the development of this TMDL. The Delaware Estuary PCB Model has been updated and detailed revisions are described in DRBC (2006). One key update in this newer version of the model, compared to the version used in 2003, is correction of minor errors in wind velocity calculation which affects to the gaseous PCB exchanges between water column and atmosphere. The impact on Stage 1 TMDLs developed for Zones 2 to 5 by use of this revised version of the model is evaluated and discussed in Section 3.3.2. The physical model domain remains the same as that used for the Stage 1 TMDLs for Zones 2 - 5. The hydrodynamic and water quality models incorporate all influxes and effluxes within and through interfaces of the entire Estuary and calculate instream concentrations.

3.2 Conceptual Approach

3.2.1 Guiding Principles

TMDLs require that each source of PCBs meet the water quality criterion by itself and in conjunction with all other sources. A number of key guiding principles were developed based on available scientific data, model simulation results, and policy decisions for the development of the Zone 6 TMDL. The guiding principles are as follows:

1. Stage 1 TMDL for Zone 6 (Delaware Bay) is built upon TMDLs developed for Zones 2 to 5 in 2003. The revised version of Delaware Estuary PCB model is used in this TMDL development. Total Maximum Daily Loads developed for Zones 2 to 5 will not be changed either by the use of the revised version of the model or by this Stage-1 Zone 6 TMDL development. In addition, the assigned equilibrium PCB concentrations for the atmosphere will be remain the same as that used for Zones 2 to 5.

2. Pentachlorobiphenyls, the penta-PCB homolog group, are used as a surrogate for Total PCBs. The same ratio used in development of the Zones 2 to 5 TMDLs in 2003, 1:4 for penta to total PCBs, is used in this TMDL. A comparison of penta to total PCB concentrations in ambient water samples for the entire estuary are depicted in Figure 6. Simulating a single homolog group rather than total PCBs allows the model to simulate kinetic transfers accurately. Therefore, all the model simulations and applicable water quality target (i.e., criteria) for the development of the TMDL for the Delaware Bay is based on penta-PCBs. The TMDL for total PCBs is calculated by multiplying the penta-PCB TMDL and their components by four to obtain the Total PCB TMDL.

3. Preliminary model simulations revealed that there are two potential critical locations that control the loading of PCBs to Zone 6. These locations occur at transitions between different water quality criteria as described in Section 1.4. One location is at River Mile 68.75, the location of Delaware Memorial Bridge, where the applicable water quality criteria changes from 44.8 to 7.9 pg/L as the water quality changes from freshwater to marine conditions. Another potential location is at the boundary of Zone 5 and 6 (River Mile 48.2) where the applicable water quality criteria changes from 7.9 to 64 pg/L in an upstream to downstream direction. If any exceedance occurs during model simulations, it will occur either of these two locations as shown in example scenario results shown in Figure 7. Therefore, allowable loadings to Zone 6 or from the downstream boundary will be determined while focusing on violations at those two locations.

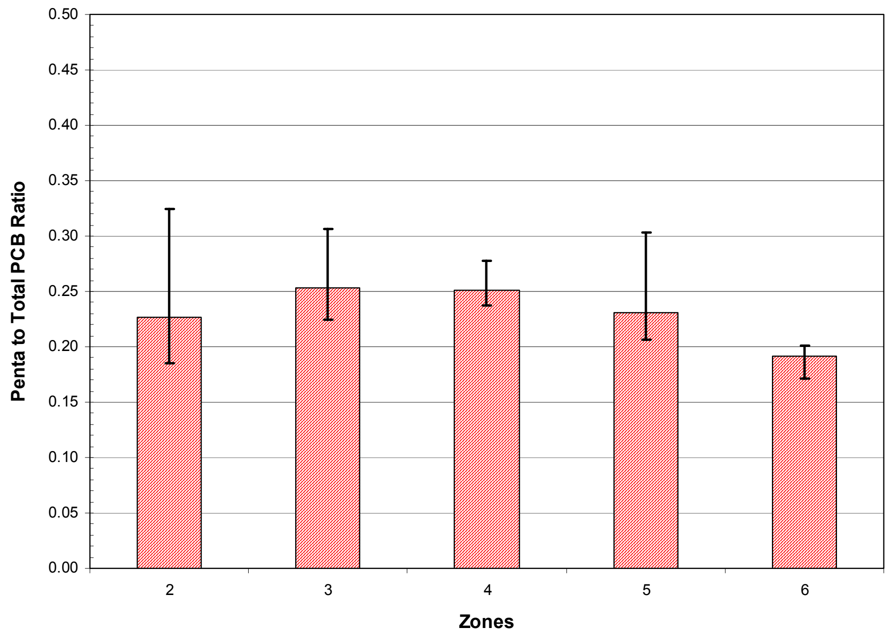


Figure 6: Ratio of Penta-PCBs to Total PCBs in ambient water samples collected from 15 sites in Zone 2-5 and 6 sites in Zone 6 between September 2001 and November 2003. Error bars indicate the minimum and maximum ratios observed at any sampling site during all surveys.

4. All WLAs and LAs in Zone 6 are allowed to discharge at the applicable water quality criterion of 64 picograms per liter of total PCBs. Based on the hydrodynamic model outputs, the averaged tidal cycle inflow during flooding tide near the mouth of the Bay is about 110,000 cubic meters per second. The annual median advective net inflow from the Zone 5 to Zone 6 is about 450 cubic meters per second. While, the annual median inflow from point and non-point sources into the Zone 6 is about 17.84 cubic meters per second. Since this Stage 1 TMDL for the Delaware Bay is limited to the mainstem of the Estuary not the individual tributaries, the influence from the WLAs and LAs are relatively minor compared to the influence from the upstream or the downstream boundaries of Zone 6. Note that because of tidal forcing, the Delaware Bay is heavily influenced by the water quality of the Ocean.

5. As a policy decision, 5 percent of the TMDL is explicitly reserved for a margin of safety. This is consistent with the margin of safety used in the Zones 2 - 5 TMDLs.

3.2.2 Modeling Approach

3.2.2.1 Justification for the Use of One-dimensional Model for Delaware Bay

In many cases, two or three dimensional numerical models are applied for an estuarine system with a large bay like the Delaware Bay. A one-dimensional model is used, however, to develop Stage 1 TMDL for Zone 6. The reasons for this include the following:

1. Limited data, and resources and extended computational time prohibit a use of multi-dimensional model in this TMDL development. Since this TMDL is based upon a human health criterion for protection from carcinogenic effects, long-term simulations are necessary due to the 70 year

exposure time for this type of criterion.

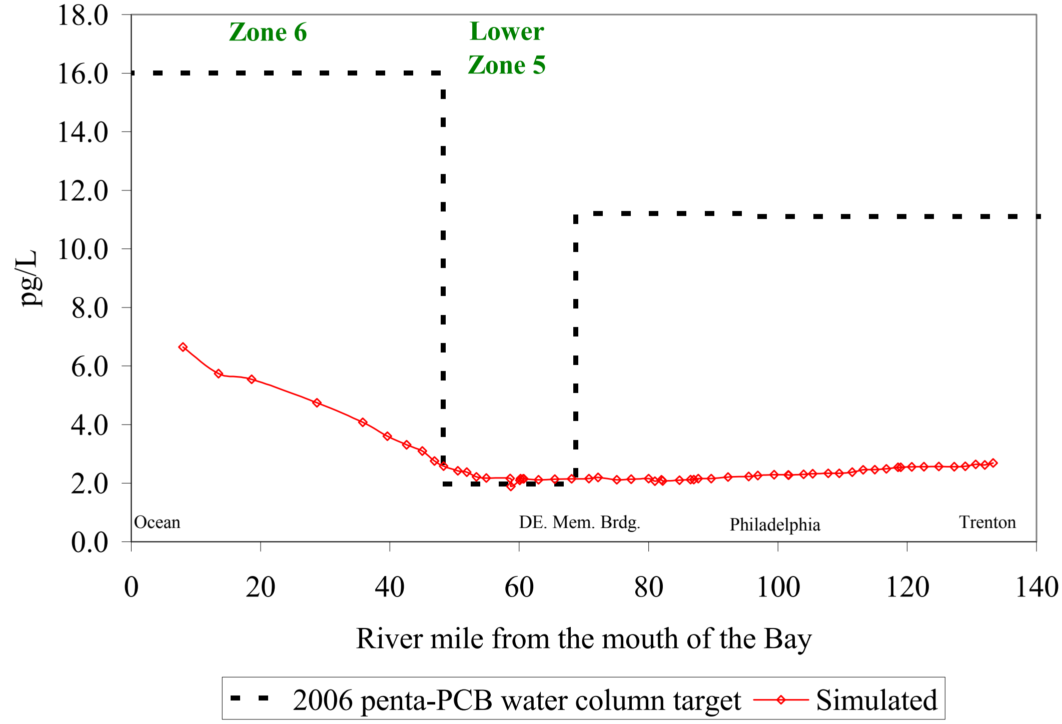


Figure 7: Exemplary simulation showing two potential critical locations at River mile 48 and 68 because of sharp transition of the applicable water quality criteria in Zone 6 TMDL Development.

2. The purpose of modeling work is not to track any sudden spike or changes in water column or any localized (lateral or vertical) variations. Rather, the TMDL is developed under the long-term, steady state loading conditions, even though the hydrologic conditions are cycled from a single year to consider any seasonal impacts. It is important that the model projects the average conditions after reaching to the equilibrium condition.

3. Because the model is run under steady state conditions for the TMDL calculation, the proximity of a downstream boundary to the area of interest is not an issue. In addition, lack of information regarding the sediment dynamics and flow patterns in the nearshore areas of the Bay and in the nearby coastal areas would amplify the model uncertainty if the downstream boundary is extended to the outside of the Bay.

4. Lastly, the existing one dimensional model has proven its capability of reproducing conservative substance profiles throughout the estuary (DRBC, 2003a) and was successfully used to develop Stage-1 TMDLs for Zones 2 to 5 in 2003 (DRBC, 2003c).

3.2.2.2 Hydrodynamic Model

A representative one year hydrologic condition is used for this Zone 6 TMDL development. This same condition was used in the development of the Zones 2 to 5 TMDLs in 2003. The hydrological conditions and the logic in selecting this condition is described in the Stage 1 Zones 2 - 5 TMDLs document in Section 3.2.4.1 (DRBC, 2003d). The description of the hydrodynamic model and calibration results are documented in DRBC (2003a). The representative hydrologic condition is then input into the hydrodynamic model and the output of this hydrodynamic model is fed to the water quality model. Decadal or centennial PCB model simulations are conducted by using this one year hydrologic condition year after year to develop the PCB TMDL.

Using the gaged daily flow data and drainage area, flow rate per unit area is calculated for the gaged tributaries. This information are then utilized to obtain flow rates for the nearby ungaged tributaries and direct runoff into Zone 6 of the Delaware Estuary. Median daily inflow value for the sum of point and non-point source inflows from Zone 6 during the cycling year is calculated at 17.84 m^3/sec.

3.2.3 TMDL Approach

Although the water quality standards are expressed as Total PCBs and the TMDL must be expressed as Total PCBs, the current water quality model only addresses penta-PCBs. As discussed in Section 2.2, the TMDL for Total PCBs is extrapolated from the TMDL for penta-PCBs using the observed ratio in the Delaware River/Estuary of the penta homolog to Total PCBs. Therefore, a water quality target for penta-PCBs must be established for use in the TMDL procedures. This target is determined by assuming that the ratio of penta-PCBs to Total PCBs is approximately 0.25. Figure 6 presents the ratio of penta-PCBs to Total PCBs in ambient water samples collected in Zones 2 through 6. While difference between zones are evident, 0.25 is a reasonable value for the ratio, and makes the Stage 1 Zone 6 TMDL consistent with the Stage 1 TMDLs for Zones 2 - 5.

The TMDL for Total PCBs for Zone 6 of the Delaware Estuary is established using a seven step procedure. A flow chart of these steps is presented in Figure 8. The TMDL is calculated over a one year period (annual median) to be consistent with both the model simulations and the 70 year exposure used for human health criteria.

The wasteload allocation portion of the TMDL represents those source categories that are regulated under the NPDES program (industrial discharges, municipal wastewater treatment plant discharges, combined sewer overflows or CSOs, and municipal separate storm sewer systems or MS4s). Eight (8) industrial and municipal wastewater discharges are assigned wasteload allocations in this TMDL. No CSOs were identified by state permitting authorities. Twenty (20) municipal separate storm sewer systems or MS4s were included in the allocation for this point source category. The load allocation portion of the TMDL represents categories including contaminated sites, non-NPDES regulated stormwater discharges, tributaries, air deposition and most importantly input from the Ocean.

In accordance with the TMDL regulations, a portion of TMDL must be allocated to a margin of safety. The margin of safety (MOS) is intended to account for any lack of knowledge concerning the relationships between pollutant loadings and receiving water quality. Commission regulations also require that a portion of the TMDL be set aside as a margin of safety, with the proportion reflecting the degree of uncertainty in the data and resulting water quality-based controls. The MOS can be incorporated into the TMDL either implicitly in the design conditions under which the TMDL is calculated or explicitly by assigning a fixed proportion of the TMDL. Since the conditions under which the TMDL is determined like tributary flows are related to the long-term conditions and not to design conditions associated with human health water quality standard for carcinogens (such as the harmonic mean flow of tributaries), expression of the MOS as an explicit percentage of each zone TMDL was considered the more appropriate approach. An explicit percentage of 5% was then utilized in the apportionment of the Zone 6 TMDL, which is in accordance with MOS used in Zones 2 to 5 TMDLs in 2003.

3.3 Procedure for Establishing The TMDL

3.3.1 Summary

The TMDL for total PCBs for Zone 6 of the Delaware Estuary is established using a multi-step procedure that incorporated the guiding principles discussed in Section 3.2.1. As discussed in Section 1.4, the existing human health water quality criterion for PCBs adopted by the State of Delaware of 64 pg/l, and the existing DRBC criteria are used as the basis for the Stage 1 TMDL. The lower DRBC criterion of 7.9 pg/L from the Delaware Memorial Bridge to the head of the Bay result in two critical locations. The resultant PCB loadings are thus limited to meet the criterion in this section of the estuary.

The DRBC Water Quality Management Zone 6 is located at the downstream end of the Delaware River. Inflows from upstream, tributaries, direct runoff, point sources, and exchanges with Atlantic Ocean through the mouth of the Bay are all contributors to the water quality of Delaware Bay. Because of this geophysical location, entire tidal Delaware River and Atlantic Ocean (or conditions at the mouth of the bay), has to be considered in the development of TMDL for Delaware Bay. In addition, because of the lower water quality criterion in lower Zone 5 which form critical locations, it is crucial to evaluate the conditions upstream of Zone 6.

Stage-1 PCB TMDLs for the entire tidal Delaware River, or Zones 2 to 5, were established in 2003. In the 2003 TMDLs, zero loadings were assigned for both point and non-point sources with exception of the ocean boundary condition which was set at one-fourth of the applicable water quality criterion of 7.9 pg/L (1.975 pg/L of penta-PCBs). The applicable water quality criterion has changed to 64 pg/L of Total PCBs; a water quality target of 16 pg/L of penta-PCBs for this Zone 6 TMDL development. While maintaining the Zones 2 to 5 TMDLs developed in 2003, the Zone 6 TMDL is calculated by multiplying inflows and water quality target for point and non-point sources. The ocean boundary condition, which has a substantial influence on water quality in Zone 6, was determined by trial and error methods through model simulations so as not to cause exceedances of the applicable water quality targets throughout the estuary. The gas phase concentrations for the lower Bay that would be in equilibrium with the penta-PCB water concentrations are then updated in the water quality model. The model is then run to confirm that the water quality targets are still being met.

The Zone 6 TMDL is calculated in a seven step procedure. A brief description of seven steps is as follows:

1. Using the revised model code and revised input conditions, re-confirm that the TMDLs developed in 2003 are still valid. The governing value occurs at two locations, River Mile 68.75 and River Mile 48.2, is 1.975 pg/L. This value is 25% of 7.9 pg/L, the applicable water quality criterion for Total PCBs at these locations.
2. Determine the usable assimilative capacity for Stage 1 Zone 6 PCB TMDL at the two critical locations by assigning zero penta-PCBs at the ocean boundary. The difference between the simulation results and the governing value is the total assimilative capacity available for Zone 6.
3. Allowable loadings from all point and non-point sources having inflows into Zone 6 are then calculated by multiplying their inflow by 16 pg/L for penta-PCB. These loadings are distributed in the model proportional to the model segment sizes in Zone 6. The only missing load will then be the influx from the ocean boundary.
4. Determine allowable ocean boundary by trial and error simulations using the penta-PCB model,

re-confirmed TMDLs for Zones 2 to 5 developed in 2003, and the Zone 6 load calculated from the previous step. Compare the results with the applicable water quality target at the two critical locations.

5. Once the allowable ocean boundary is found, calculate and assign equilibrium gaseous atmospheric concentrations in the model. Run the model and go back to Step 4 until the difference between the water quality target of 16pg/Land the simulated water column penta PCBs is less than 0.02 pg/L.
6. Convert the ocean boundary concentration to a load and add it to the gross load allocation portion.
7. In steps 1 through 6, the load of penta-PCBs that is required to meet applicable water quality target for penta-PCBs was determined. In step 7, five (5) percent of wasteload allocation (WLA) and load allocation (LA) are allocated to margin of safety (MOS).

Stage 1 PCB TMDL Development Procedure for Delaware Bay (Zone 6)

Step 1: Use the revised model codes and revised input conditions to re-confirm that the TMDLs developed in 2003 are still valid. Governing value for both locations (at River Mile 68.75 and RM 48.2) is 1.975 pg/L (25% of 7.9 pg/L, water quality criterion for Total PCBs)

Step 2: Determine usable assimilative capacity for Stage 1 Zone 6 PCB TMDL at the critical locations, RM 48 and/or 68 by assigning zero penta-PCBs at the ocean boundary from the input conditions of the previous Step. The difference between the simulation result and applicable water quality criteria is the total assimilative capacity for Zone 6.

Step 3: Calculate allowable loadings from all point and non-point sources having inflows into Zone 6: Inflow times applicable water quality target of 16 pg/L for penta-PCB (Zone 6). These loadings are distributed in the model proportional to the model segment sizes in Zone 6. The only missing load will be the influx from the ocean boundary.

Step 4: Determine the allowable ocean boundary by trial and error simulations using the penta-PCB model, the re-confirmed TMDLs for Zones 2 to 5 developed in 2003 plus Zone 6 loads calculated from the previous step. Compared the results with the applicable water quality target at critical locations.

Step 5: Calculate and assign equilibrium gaseous PCB concentrations in the model under the TMDL conditions developed in Steps 3 and 4. If the usable assimilative capacity is larger than 0.02 pg/L at the critical locations, go back to Step 4.

Step 6: Convert the ocean boundary concentration to a load and add it to the gross load allocation portion to finalize individual WLAs and the gross LAs.

Step 7: Allocate 5% of Margin of Safety by removing 5% of Ocean Boundary and 5% of WLA/LA loading.

Figure 8: Seven Step Procedure for Establishing TMDL for Zone 6.

3.3.2 Step 1: Confirmation of the 2003 TMDLs for Zones 2 - 5 using the revised model code

A concern was raised after revisions to the model code and input file parameters to correctly simulate the volatilization that these revisions may have affected the Zone 2 - 5 TMDLs. Because the Zone 6 TMDL is built upon the TMDLs for Zones 2 to 5, it was necessary to confirm the validity of 2003 TMDL results using the revised model code as a first step.

The 100 year simulations with the revised DELPCB model were conducted with the input conditions for the TMDLs developed in 2003 for Zones 2 to 5. Long-term, or 100 year in this case, simulations are required to assure that the model reaches steady state. The simulated results using the new code are compared with the simulation results generated with the model code in 2003 as shown in TMDL report (DRBC, 2003c). Figure 9 and 10 are the same comparison plots with different y-axes to visually compare the two simulation results. Simulation results were summarized to generate spatial plots with annual median values in the 99th and 100th years of the simulation. Slight differences are apparent between the simulation results in Figure 10. The relative differences between two models are from -3.2 to 2.7 percent. Simulation results from the revised code tend to show slightly lower water column PCBs concentrations compared to concentrations from the 2003 modeling results in the lower Zone 5 and Zone 6. This implies that Zone 6 will get additional assimilative capacity because of the use of the improved version of the model. It is also important to note that no exceedances are observed in both simulation results confirming that the TMDLs established for the Delaware Estuary Zones 2 to 5 are valid under the revised model coded and input conditions. All the simulation results presented in the rest of the report are generated by the revised model code.

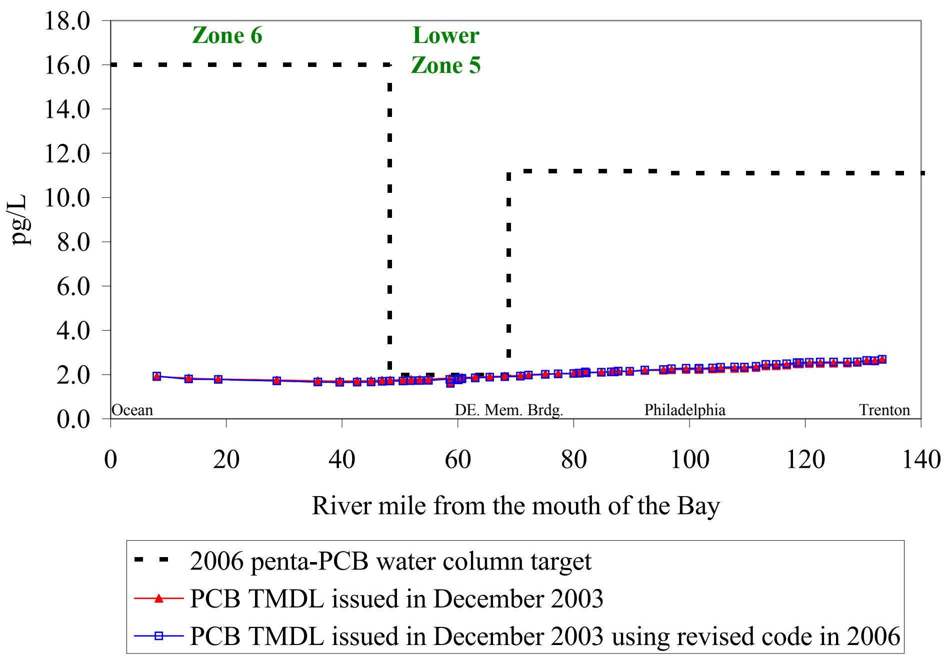


Figure 9: Comparison and validation of Zones 2 to 5 TMDLs established in 2003 using the revised DELPCB model code and input conditions (full Y-axis scale). Blue and red solid lines show median water column Penta-PCBs concentrations from the 99th and 100th year of the simulation using the old and revised code.

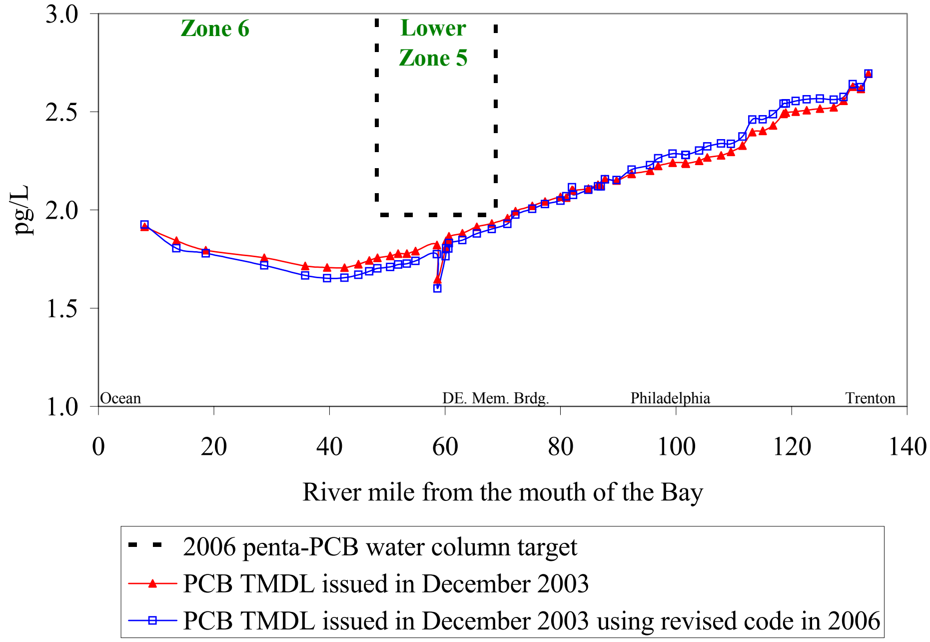


Figure 10: Comparison and validation of Zones 2 to 5 TMDLs established in 2003 using the revised DELPCB model code and input conditions (smaller range in Y-axis scale). Blue and red solid lines show median water column Penta-PCBs concentrations from 99th and 100th year of the simulation using the old and revised code.

3.3.3 Step 2: Determination of usable assimilative capacity for Zone 6

No external loadings were assigned for Zone 6 during the development of the Zones 2 to 5 PCB TMDLs in 2003 with exception of the assignment of the ocean boundary at 1.975 pg/L of penta PCBs (25% of the applicable water quality criterion for the State of Delaware). As discussed in Section 3.2.1 of the Guiding Principles, the Stage 1 TMDL for Zone 6 of the Delaware Estuary, is built upon TMDLs developed for Zones 2 to 5 in 2003. Total Maximum Daily Loads developed for Zones 2 to 5 will not be changed either by the use of revised version of the model or by this Stage-1 Zone 6 TMDL development.

In this Step, the ocean boundary is assigned a zero concentration of penta-PCBs, so that the assimilative capacity can be obtained for Zone 6. Assimilative capacities at the two potential critical locations of interest are shown in Figure 11. The assimilative capacity at upstream critical point (at River Mile 68.75) is about 0.095 pg/L. The assimilative capacity at the head of the Bay (at River Mile 48.3) is about 0.527. Influences from ocean boundary to these two critical locations are different. A much higher influence of the ocean to the critical location at the head of the Bay are expected because of its proximity.

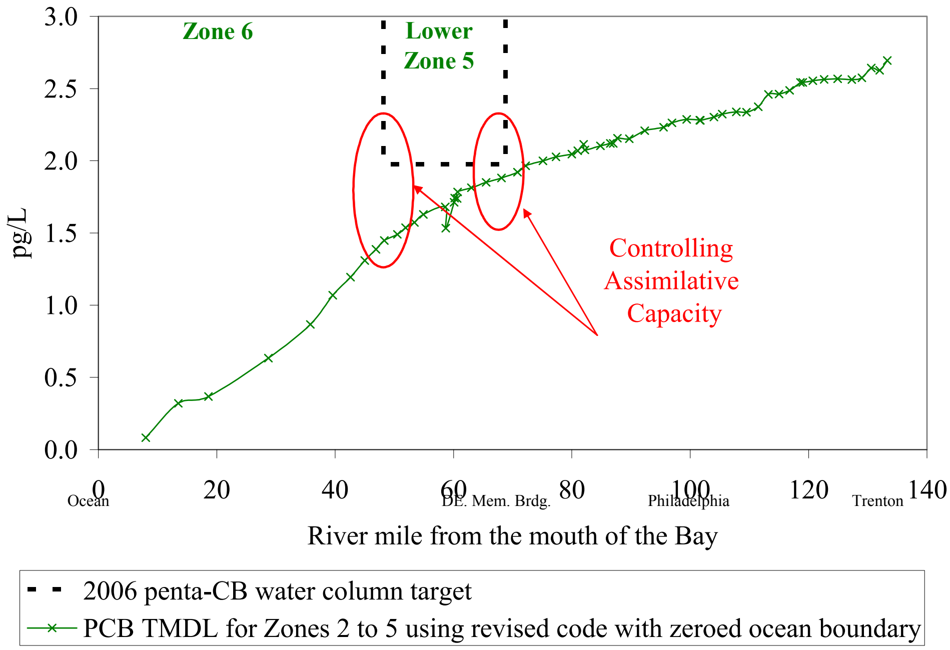


Figure 11: 100 year simulation results under the Zones 2 to 5 TMDLs with zero penta-PCB concentration for the ocean boundary. The solid green line represents median values for 99th and 100th year.

3.3.4 Step 3: Calculation of allowable loadings from WLAs and LAs without the ocean influence

As discussed in the Section 3.2.1 of the Guiding Principles, all point and non-point source discharges are allowed to discharge at the applicable water quality criterion of 64 pg/L of Total PCBs or 16 pg/L of penta PCB in this calculation. This approach is justified because the influences from sum of WLAs and LAs compared to the Ocean boundary were found to be very minimal. All the inflows into the Zone 6 are estimated from available USGS tributary gaging data. The median daily flow for the representative cycling year is 17.84 cubic meters per second, which includes point source, non-point source, and tributary inflows into Zone 6.

Model simulations, without considering the influence of the ocean boundary, suggest that even with all the sources are discharging at 16 pg/L of penta PCBs, the influences of point and non-point sources are 0.0003 pg/L at River Mile 68 and 0.001pg/L at River Mile 48, respectively. Individual allocations may have to be lowered to meet a TMDL for a local tributary, and are subject to change when the Stage-2 PCB TMDLs are developed for the entire Delaware Estuary (Zones 2 to 6).

3.3.4.1 Calculation of Individual allowable loadings for point sources

The wasteload allocation portion of the TMDL represents those source categories that are regulated under the NPDES program. There are two types of WLAs to be considered for the Zone 6 TMDL. One category consists of municipal and industrial NPDES point sources and the other type is municipal separate storm sewer systems or MS4s. There are no combined sewer overflow (CSOs) systems in Zone 6.

Eight NPDES point source dischargers have been identified for individual wasteload allocations. The wasteload allocations for those eight permittees consisting of 12 discharges are calculated based on their permitted flow multiplied by the applicable penta-water quality target of 16 pg/L. Calculation results for the individual allowable penta-PCB loadings before allocating margin of safety are listed in Appendix 1. The total inflow from the eight NPDES dischargers is 1.306 m^3/sec. The sum of the allowable loadings assigned to these 12 discharges is about 1.81 mg/day of penta-PCBs.

Twenty (20) Municipal Separate Storm Sewer Systems (MS4s) are also considered and they are listed in Appendix 2. 7.2 percent of the remainder of the inflows (16.534 m^3/sec) are assigned to the flows from the MS4s for Zone 6. This flow is 1.190 m^3/sec. Therefore, the allowable loadings for MS4s in Zone 6 is calculated by multiplying the MS4 flow rate of 1.190 m^3/sec times the 16 pg/L water quality target for penta-PCBs. After unit conversions, the gross, allowable loadings for penta-PCBs before considering margin of safety for municipal separate storm sewer systems are 1.65 mg/day.

The gross WLA for Zone 6 is therefore 3.451 mg/day for penta-PCBs before the margin of safety is set aside (see Appendix Table 1.1).

3.3.4.2 Calculation of allowable loadings for non-point sources without the ocean influence

The load allocation portion of the TMDL represents the remaining source categories including contaminated sites, non-NPDES regulated stormwater discharges, tributaries, and air deposition. Subtracting 2.497 m^3/sec of point source inflow rate from the total inflow of 17.84 m^3/sec, 15.343 m^3/sec of inflows are assigned to these other non-point sources. Therefore, the gross load allocation (LA), excluding the influence from the ocean, is obtained by multiplying this flow rate of 15.343 m^3/sec by the 16 pg/L water quality target for penta-PCBs. After unit conversions, the gross LA is 21.21 mg/day.

About 14 percent of the total allowable loadings of penta-PCBs are allocated to point source discharges in Zone 6 before considering the influence from the ocean boundary (Figure 12).

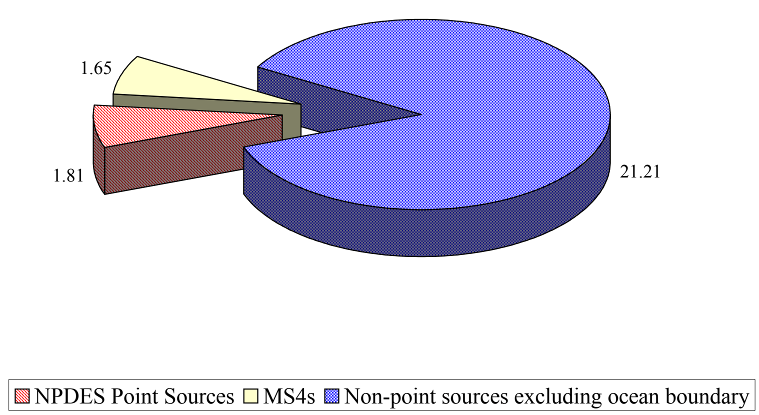


Figure 12: Allowable loadings for point and non-point sources in mg/day for the Delaware Bay excluding influences from the ocean without 5 percent of MOS reservation.

3.3.5 Step 4: Determination of ocean boundary concentration

The mouth of Delaware Bay is one of the downstream boundaries in the DELPCB model. The other downstream boundary is the western end of the C&D Canal which is located in Zone 5. In establishing the Stage-1 PCB TMDLs for Zones 2 through 5, these downstream boundaries were set at the water quality criteria of 7.9 pg/L of Total PCBs. In the Zone 6 TMDL development, the ocean boundary is the only downstream boundary of concern. A fixed concentration can be assigned at the downstream boundary since the TMDL is established under the steady state, or equilibrium conditions. As the applicable water quality criterion in Zone 6 is now 64 pg/L, the ocean boundary was set at a value of 16 pg/L. However, because of the reversing tidal flows and massive volume of ocean water entering the Bay during the flooding tide, exceedances can occur at the critical locations by the influence of the ocean boundary (Figure 13). Section 4.20.4B.1 of the Commission's Water Quality Regulations specify that in establishing WLAs, the concentrations at the boundaries of the area of interest shall be set at the lower of actual data or the applicable water quality criteria (DRBC, 1996). Even though the exceedances are not occurring within Zone 6, the ocean boundary condition has to be reduced below this criteria so as not to cause any violations in Zone 5.

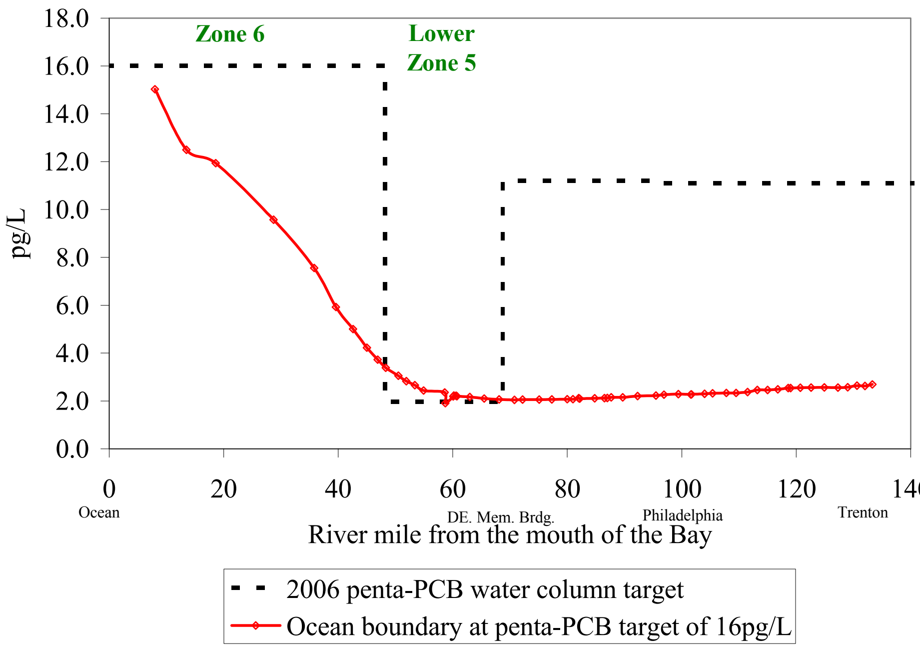


Figure 13: Simulation results under the loading conditions developed up to Step 3 and assigned ocean boundary at the penta-PCB water quality target of 16pg/L.

A series of simulations were performed while lowering the ocean downstream boundary concentration from 16 pg/L until no violations was observed at the critical locations. In these simulations, daily loadings established for Zones 2 to 5 are maintained and th Zone 6 WLAs and LAs, which are calculated in the previous Step 3, are input to the model as distributed loadings based on sizes of model segments. The ocean boundary concentration that did not cause any violations at critical locations was determined to 3.62 pg/L of penta-PCBs. Even though the applicable water quality target for penta-PCBs in Delaware Bay is 16 pg/L, the ocean boundary has to be limited to 3.62 pg/L. These critical locations exist because of changes in the water quality criteria in Zones 2 - 6.

3.3.6 Step 5: Determination of the equilibrium air concentration of penta-PCBs

Step 5 in developing TMDL for penta-PCBs for Zone 6 of the Delaware Estuary is to include the exchange of penta-PCBs between the gas phase in the atmosphere and truly dissolved penta-PCBs in the water. In the current model framework, the gas phase air concentrations are assigned, and are not dynamically simulated by the model. However, when the TMDL is achieved there should be close to zero net exchange between the water and air. It was therefore necessary to estimate the gas phase concentration that would be in equilibrium with the water quality targets and then confirm that the water quality targets are still being met.

Equilibrium, atmospheric gas phase concentration for penta-PCBs with truly dissolved water column under the TMDL conditions can be calculated using the following relationship (see Section 3.3.5; DRBC, 2003c)

$$C_W \times H/RT_K = C_A$$

where: C_W = truly dissolved fraction of the chemical in water, mg/L
C_A = atmospheric gas phase concentration, mg/L
H = Henry's Law Constant, atm-m^3/day
R = universal gas constant
T_K = water temperature in degrees Kelvin

The truly dissolved fraction of the penta-PCBs in Zone 6 is extracted from the model simulation results determined under the loading conditions from Step 4. The equilibrium atmospheric gas phase concentration for penta-PCBs are then calculated. The results are presented in Figure 14 for the one-year cycling period. Step 4 and 5 are iteratively repeated until the difference between the simulation results and water quality target is less than 0.02 pg/L at the most restrictive of the two critical locations.

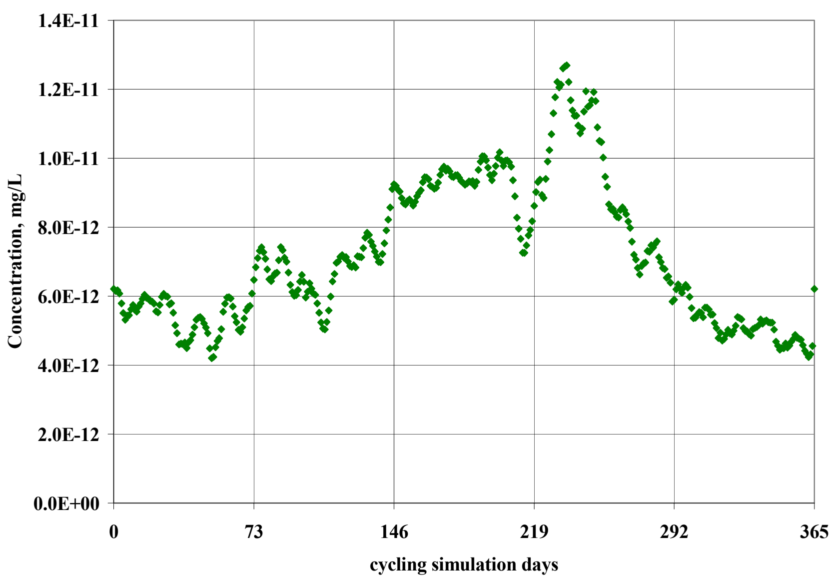


Figure 14: Yearly, back calculated, equilibrium, gas phase penta-PCB concentration for Delaware Bay.

The penta-PCB water quality model is then run for 200 years with the conditions obtained from Step 3, 4, and 5 including the loadings from the model boundaries (3.62 pg/L for the ocean boundary) and to each estuary zone, initial penta-PCB concentrations in the sediment, and with the calculated, median, equilibrium gas phase penta-PCB concentrations during the one year model cycling period. The purpose of this simulation is to confirm that the penta-PCB concentrations in the sediments (Figure 15) and the penta-PCB gas phase air concentrations are in equilibrium with the estuary concentrations that will meet the water quality target of 1.975 pg/L at the critical location when all fate processes are enabled in the model (Figure 16). The ocean boundary is limited to 3.62 pg/L by the critical location at River mile 48.2 where the interface between the Zone 5 and 6 is located. This simulation result confirms that under the assigned daily loadings from Zones 2 to 6, inputs from boundary interfaces, exchanges with sediment and atmosphere, the water column penta-PCB concentrations meet the penta-PCB water quality target.

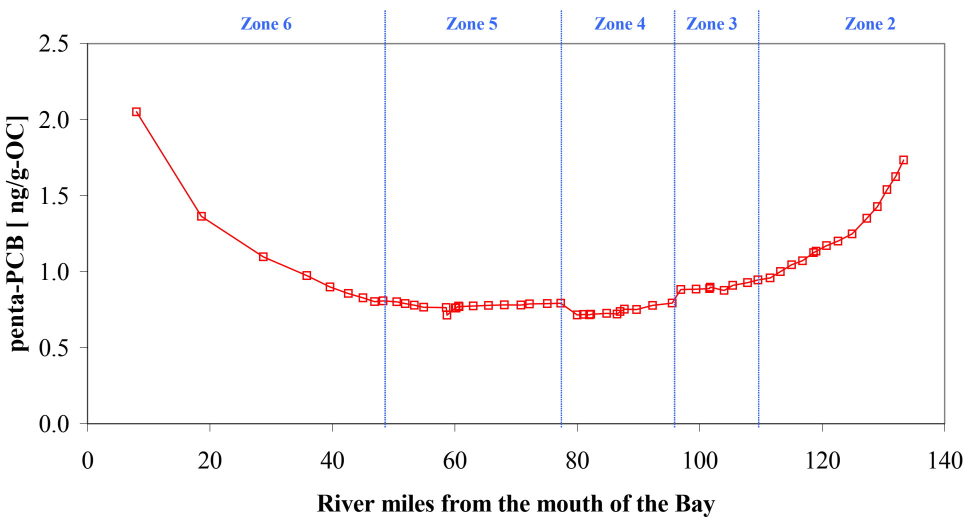


Figure 15: Equilibrium, carbon normalized sediment penta-PCB concentrations after 200year simulation.

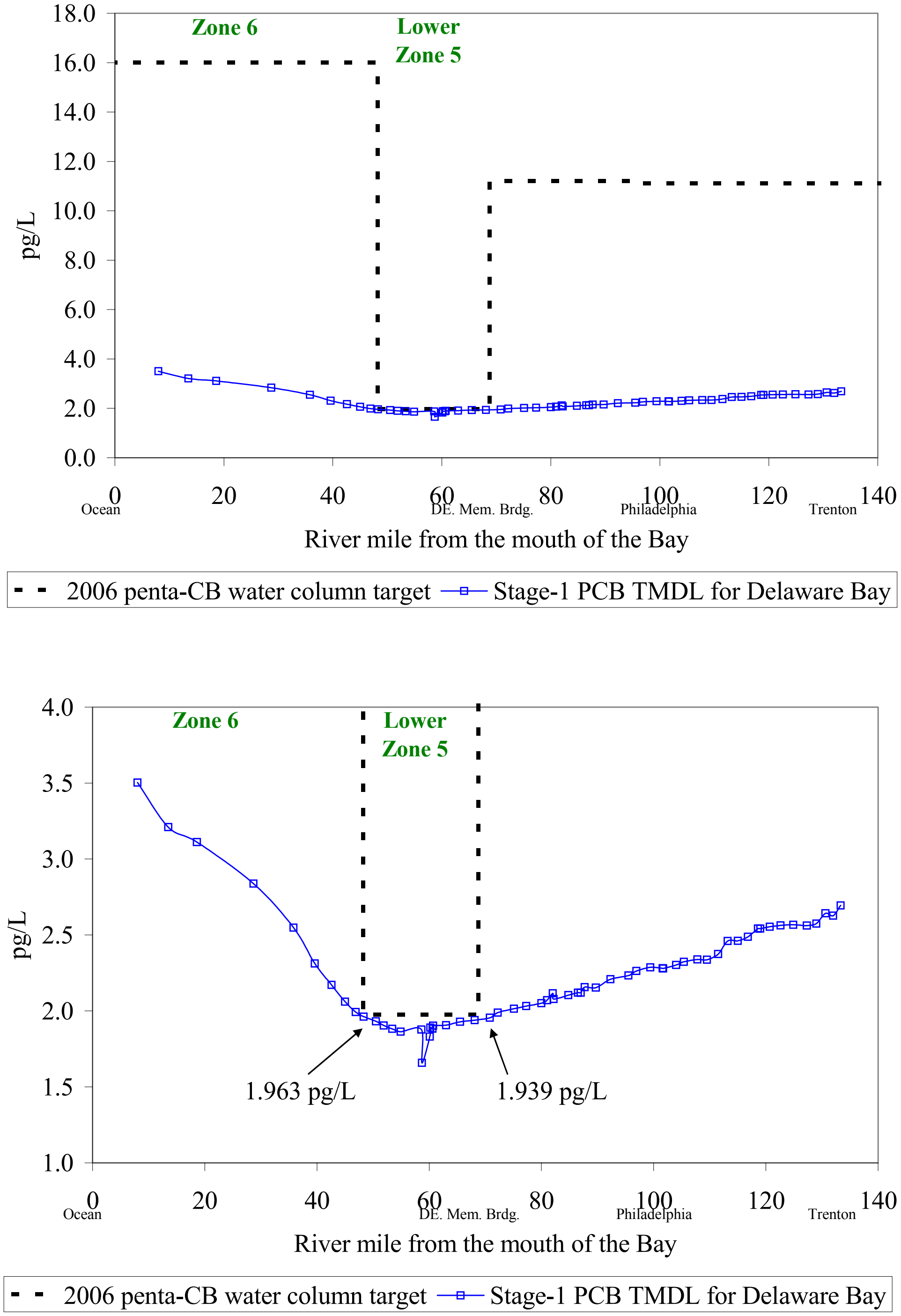


Figure 16: Simulation results after the Step 5 of the TMDL development process. The lower figure is an expansion of the upper figure with a finer scale for the penta-PCB concentration.

3.3.7 Step 6: Determination of ocean boundary as a load

TMDL development is a process of determining allowable loadings of a pollutant of concern that does not result in exceedances of water quality standards. A TMDL is expressed as a unit of daily loading. As described in Step 4 of this TMDL calculation (Section 3.3.5), the ocean boundary is determined as a unit of concentration under the existing modeling framework. The amount and direction of loading flux at this boundary is internally calculated within the model as influenced by tidal conditions and concentration gradients. The updated version of DELPCB model used in Zone 6 TMDL development, has been revised to track mass exchanges of PCBs between segments throughout the simulation. This update allowed the quantitation of the influence of the ocean into Delaware Bay as a unit of daily loading. The ocean boundary is limited to a concentration of 3.62 pg/L to achieve the applicable penta-PCB water quality target at the critical location at the head of the Bay. The influence from the ocean boundary is extracted from the 100 year model simulation results under the conditions obtained up to previous Step 5. The average daily loadings from the ocean boundary is calculated to be 444.45 mg/day of penta- PCBs under the TMDL condition. This amount is added to LA portion calculated in Step 3 of 21.21 mg/day to complete the gross load allocation for non-point sources. The gross allocation to the non-point sources in Zone 6 is 465.66 mg/day before the margin of safety is set aside.

3.3.8 Step 7: Reservation of a Margin of Safety

The TMDL and allocations to WLAs and LAs is calculated through Step 6. As a final step, a portion of the TMDL must be allocated to a margin of safety. The Commission's Toxics Advisory Committee made several recommendations on the policies and procedures to be used to establish allocations for Zones 2 to 5 in 2003. Federal regulations at 40 CFR Part 130.7(c)(1) require a margin of safety or MOS to be included in a TMDL to account for any lack of knowledge concerning the relationships between pollutant loadings and receiving water quality. Commission regulations (Section 4.30.7B.2.b.) also require that a portion of the TMDL be set aside as a margin of safety, with the proportion reflecting the degree of uncertainty in the data and resulting water quality-based controls.

The margin of safety can be incorporated either implicitly in the design conditions used in establishing the TMDL or explicitly by assigning a proportion of each TMDL. Both of these approaches were considered by the Toxics Advisory Committee in the development of the Stage 1 TMDLs for Zones 2 - 5. This committee recommended that an explicit margin of safety of 5% be assigned in allocating the zone-specific TMDLs at that time. This recommendation was based upon the use of a one year cycling period for the hydrodynamic and water quality model that mimics the period of record for the two major tributaries to the estuary rather than design tributary flows; and the use of tide data, precipitation data and the actual effluent flows that occurred during the one year cycling period. Since the TMDL for Zone 6 is developed using similar design conditions, this recommendation is also implemented in the development and allocation of the Zone 6 TMDL.

From Section 3.3.4.1 (Step 3), the gross WLA is 3.45 mg/day, and from Section 3.3.7 (Step 6), the gross LA is 465.66 mg/day before reserving a margin of safety. A total maximum daily loading or TMDL for Zone 6 is therefore 469.11 mg/day of penta PCBs. The TMDL and its allocation to WLAs, LAs and a MOS is summarized in Table 2.

Table 2: TMDL for penta-PCBs for Zone 6 (Delaware Bay) in milligrams per day.

TMDL	WLAs	LAs	MOS
469.11 mg/day	3.28 mg/day	442.38 mg/day	23.46 mg/day

4. TMDL, WLAs AND LAs FOR TOTAL PCBs

As discussed in Section 3.2.1, the TMDL for Total PCBs will be extrapolated from the penta homolog results using the observed ratio in the Delaware Estuary of the penta homolog to total PCBs. This approach was recommended by the expert panel established by the Commission due to time limitations and the technical difficulty in developing and calibrating a PCB model for each of the ten PCB homologs. Figure 6 presents the ratio of penta-PCBs to Total PCBs for each zone based upon currently available data. EPA finds this extrapolation to be reasonable and supported by the best available data.

For Stage 1 TMDL, a fixed value of 0.25 was used to scale up the TMDL, WLAs, LAs and MOSs for Total PCBs. Table 3 summarizes the TMDL for Zone 6 of Delaware Estuary for Total PCBs as well as the allocations to WLAs, LAs and the MOSs. As indicated in Table 3, 94.3% of the TMDL is allocated to the load allocation portion of the TMDL. Individual WLAs for the NPDES discharges are listed in Table 4.

Table 3: Apportionment of the TMDL for penta-PCBs and Total PCBs for Zone 6 in milligrams per day.

	TMDL	WLAs	LAs	MOS
penta-PCB	469.11 mg/day	3.28 mg/day	442.38 mg/day	23.46 mg/day
Total PCBs	1876.45 mg/day	13.12 mg/day	1769.51 mg/day	93.82 mg/day
Percent of TMDL	-	0.7%	94.3%	5.0%

Table 4: Calculation of individual wasteload allocations (WLAs) for Total PCBs for point sources with 5 percent reserved for a MOS.

Facility	NPDES No.	DSN	Permitted Flow (MGD)	Permitted Flow (m^3/sec)	WLA (mg/day)	MOS (mg/day)
City of Dover, McKee Run	DE0050466	001	1.250	0.0548	0.2877	0.0151
		004	0.006	0.0003	0.0014	0.0001
		005	0.001	0.0000	0.0002	0.0000
Harrington STP	DE0020036	001	0.750	0.0329	0.1726	0.0091
Kent County STP	DE0020338	001	15.000	0.6572	3.4523	0.1817
Reichhold Chemicals	DE0000591	001	0.150	0.0066	0.0345	0.0018
		002*	0.005	0.0002	0.0011	0.0001
		003*	0.032	0.0014	0.0074	0.0004
Millville City	NJ0029467	001A	5.000	0.2191	1.1508	0.0606
Cumberland County UA (CCUA)	NJ0024651	001A	7.000	0.3067	1.6111	0.0848
Glass Tubing Americas – Millville Tubing	NJ0004171	005A	0.514	0.0225	0.1183	0.0062
Lower Alloways Creek – Canton Village	NJ0062201	001A	0.050	0.0022	0.0115	0.0006
MS4s	-	-	27.171	1.1904	6.2535	0.3291
Total			56.929	2.49	13.10	0.69

* Flow is estimated based on their drainage area, assumed runoff coefficient, and 45 inch of annual rainfall.

5. STAGE 1 TMDLS FOR THE DELAWARE ESTUARY

5.1 Stage 1 TMDLs, WLAs and LAs for Total PCBs for the entire Delaware Estuary

Stage 1 TMDLs for Total PCBs for Zones 2 - 5 the tidal Delaware River were established by the U.S. EPA in 2003. This report presents the Stage 1 TMDL for Total PCBs for water quality management Zone 6 (the Delaware Bay). As discussed in Section 3.2.1, a guiding principle was to maintain the TMDLs that were established for Zones 2 to 5 while developing the TMDL for Zone 6. Thus, TMDLs representing Stage 1 PCB TMDLs for the entire Delaware Estuary have now been completed. Table 5 summaries zone-specific TMDLs, WLAs and LAs for Total PCBs for the entire Delaware Estuary. Figure 16 shows the relative percentage apportionment of the TMDLs and their components among the zones of the Delaware Estuary.

Table 5: TMDLs, WLAs, LAs and MOS for Total PCBs for the entire Delaware Estuary

Estuary Zone	TMDL	WLA	LA	MOS
	mg/day	mg/day	mg/day	mg/day
Zone 2	257.36	11.03	233.46	12.87
Zone 3	17.82	5.67	11.26	0.89
Zone 4	56.71	6.54	47.34	2.84
Zone 5	48.06	15.63	30.04	2.40
Zone 6	1876.45	13.12	1769.51	93.82
Entire Estuary	2256.40	51.99	2091.61	112.82

Relatively larger portions of TMDLs are allocated to Zones 2 and 6 because of the large influence from the upstream and downstream boundaries, the Delaware River at Trenton and Ocean, respectively.

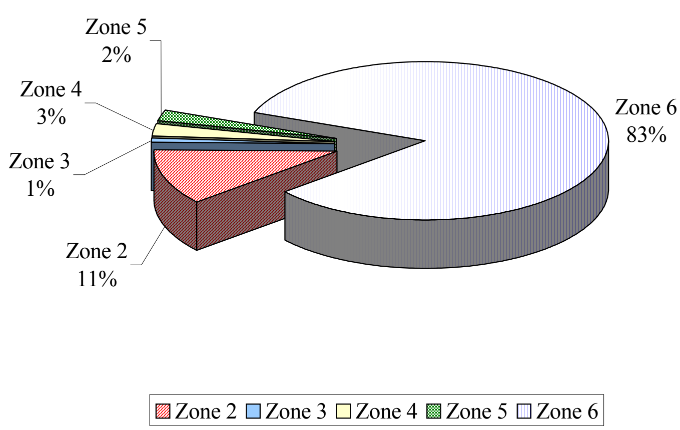


Figure 17: Stage 1 TMDL for Total PCBs for the entire Delaware Estuary

In 2003, the ocean boundary was set at 1.975 pg/L in Stage 1 TMDLs for Zones 2 to 5 because the applicable water quality target for penta-PCBs in Zone 6 was 1.975 pg/L. This applicable water quality target in Zone 6 has changed to 16 pg/L. However, the ocean boundary has to be limited to 3.62 pg/L in this Zone 6 TMDL development because an exceedance occurs at the critical location at the head of the bay. Still, the change in the applicable water quality target in Zone 6 allows the ocean boundary to be set at a higher concentration while still meeting the water quality target. Figure 17 demonstrates that the simulation results based on the Stage 1 TMDLs for Zones 2 to 6 condition utilize more of the assimilative capacity in lower Zone 5 and Zone 6 compared to the Stage 1 Zone 2 - 5 TMDLs developed in 2003.

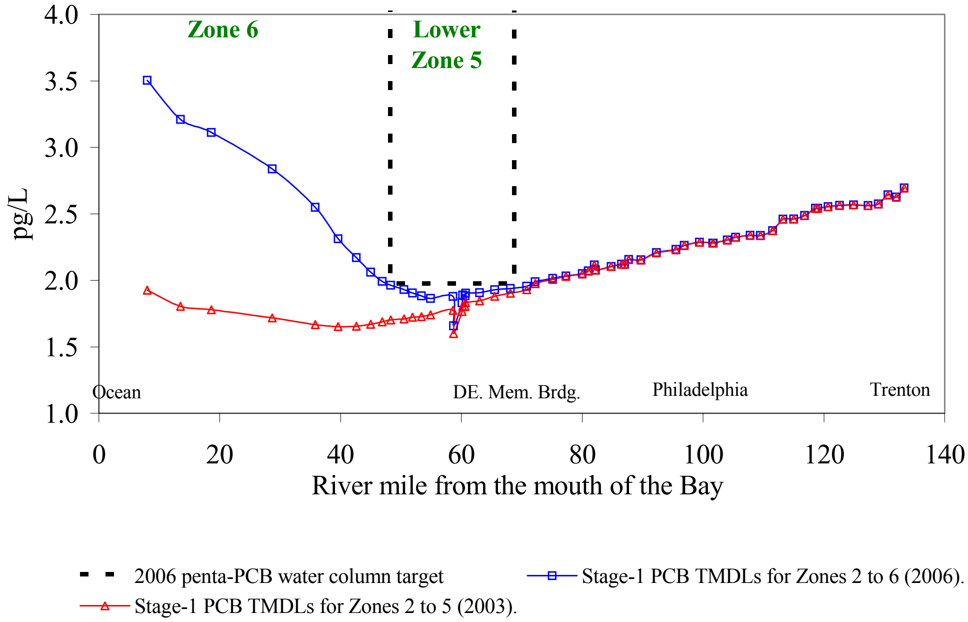


Figure 18: Comparison of 100 year simulation results under Stage - 1 PCB TMDLs developed in 2003 and 2006.

5.2 Mass Fluxes under the TMDL conditions

PCB mass loadings and net fluxes of penta-PCBs calculated internally by the model are summarized in Appendix 3. Appendix Table 3.1 contains the results for penta-PCBs and Appendix Table 3.2 contains the results for Total PCBs in a tabular format. Various types of mass flux inputs and exchanges are included. A positive sign indicates flux of PCBs into the Estuary while a negative sign indicates a flux out of the Estuary. The categories of fluxes summarized by individual Zone include: external loads, boundary loads, exchanges between zones, gas phase exchanges between air-water interfaces, net sediment-water diffusion, and net settling and resuspension of particulate PCBs. All are expressed in the unit of milligrams/day. External loadings are sum of WLAs and LAs excluding influences from boundaries. These loadings are calculated as allowable loadings per zone, and match the results presented in Table 4 of the TMDL Report (DRBC, 2003c) for penta PCBs, for example.

Two upstream and two downstream boundary exchanges are summarized and all four boundaries act as a source of PCBs into the Delaware Estuary. The largest input into the estuary is from the ocean boundary. Net advective movement between zones is also summarized. Net downstream transport occurred in all of interfaces with exception of the downstream boundary interface. The direction of net advective transport at the downstream boundary, or at the mouth of the Bay is upstream under the TMDL condition.

As described in Section 3.1 and Section 3.3.6, the TMDL has to be calculated under the equilibrium condition. Thus, there will be no net exchanges between the truly dissolved PCBs in the water column and gas phase PCBs in the atmosphere. As indicated in the mass flux tables, the net exchange of penta-PCBs is close to, but does not achieve no net exchange. Two explanations are possible for not having net zero exchanges between the water column and atmosphere under the TMDL condition. Gas phase exchanges between water column and atmosphere for Zones 2, 3, and 6 are positive for PCBs (Appendix Table 3.2). About 840 mg/day of total

PCBs are volatilized from Zone 6 under the TMDL condition. This magnitude of volatilization flux is about 100 times more than that of Zone 2, and more than 1000 times higher than in Zone 5. The reason for the large net gaseous flux exchanges in Zone 6 are the larger surface area in Zone 6 compared to other water quality management zones. The surface area normalized gas phase exchange flux are in same order of magnitude as the flux in Zones 2, 4, and 6. The reason for any existence of net gaseous exchanges under the TMDL condition is because gaseous PCB concentrations for the atmosphere are calculated and assigned for spatially average (median) condition for the entire lower bay rather than model segment by segment. In Stage 2 TMDLs development, the model will be refined so that segment-specific gaseous PCB concentrations can be assigned to achieve true equilibrium conditions.

Pore water diffusion provides a source of PCBs to water column by squeezing the sediment layer when the burial of solids (carbon) and PCBs occurs in the model. Because the model was calibrated to have a net burial of solids at any point of the Estuary in the Stage 1 TMDL development, based on limited core data, the sediment layers act as a net sink for PCBs. Net settling of solids (carbon) causes the net sink for the PCBs under the TMDL condition. This net settling to the sediment layer provides approximately 25 percent of the total assimilative capacity at the critical location in Stage 1 TMDLs for Zones 2 to 5. Solids, or carbon dynamics in the model are expected to be refined in Stage 2 TMDLs development utilizing more recent survey results.

The mass flux exchange table provides valuable insight of the direction and the magnitude of flux exchanges between media when the TMDL condition is met. Under the Stage-1 TMDLs for the Delaware Estuary for Zone 2 through Zone 6, PCB loadings are allocated for point and non-point sources including boundaries. These loadings into the Estuary are dissipated to the atmosphere by volatilization and to the sediment layer by net burial to maintain the applicable water quality criteria.

6. REFERENCES

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Appendix 1

Point source discharges included in the WLAs
for penta-PCBs for the Zone 6 TMDL

Table 1.1: Calculation of wasteload allocations for penta-PCBs for NPDES discharges without reserving margin of safety.

Facility	NPDES No.	DSN	Permitted Flow - MGD	Flow (m^3/sec)	WQ Target (pg/L)	Load (mg/day)
City of Dover, McKee Run	DE0050466	001	1.250	0.0548	16	0.0757
		004	0.006	0.0003	16	0.0004
		005	0.001	0.0000	16	0.0001
Harrington STP	DE0020036	001	0.750	0.0329	16	0.0454
Kent County STP	DE0020338	001	15.000	0.6572	16	0.9085
Reichhold Chemicals	DE0000591	001	0.150	0.0066	16	0.0091
		002*	0.005	0.0002	16	0.0003
		003*	0.032	0.0014	16	0.0019
Millville City	NJ0029467	004	5.000	0.2191	16	0.3028
Cumberland County UA (CCUA)	NJ0024651	004	7.000	0.3067	16	0.4240
Glass Tubing Americas – Millville Tubing	NJ0004171	008	0.514	0.0225	16	0.0311
Lower Alloways Creek – Canton Village	NJ0062201	004	0.050	0.0022	16	0.0030
MS4s	-	-	27.171	1.1904	16	1.6457
Total			56.929	2.49		3.45

* Flow is estimated based on the drainage area contributing to the outfall, an assumed runoff coefficient, and 45 inches of annual rainfall.

Appendix 2

Wasteload Allocation Estimates for Municipal Separate Storm Sewer Systems (MS4s) in Watersheds in Delaware and New Jersey that Drain to Zone 6

A November 22, 2002 EPA Memorandum entitled, "Establishing Total Maximum Daily Load (TMDL) Wasteload Allocations (WLAs) for Stormwater Source and NPDES Permit Requirements Based on Those WLAs" clarified existing regulatory requirements for municipal separate storm sewer systems (MS4s) connected with TMDLs, i.e. that where a TMDL has been developed, the MS4 community must receive a WLA rather than a LA (U.S. EPA, 2002). In this document, EPA identified two options for assigning MS4 WLAs. This Appendix outlines the method used to assign Zone 6 with a single categorical WLA for multiple point source discharges of storm water.

Appendix Table 2-1 identifies the municipalities in New Jersey and Delaware that drain to tributaries of Delaware Bay (Zone 6).

In order to estimate the portion of the Load Allocation (LA) that corresponds to separate storm sewer systems (MS4) so that these MS4 allocations could be converted to Wasteload Allocations (WLAs) we only considered MS4's likely to discharge to the mainstem Delaware or tidal portions of tributaries. We used GIS land use coverages to estimate MS4 service area. The total, potential runoff area for Zone 6 is about 1370 mi^2 and urban area for the listed municipalities is about 94 mi^2. Since delineated MS4 service areas have not been identified for many communities, we estimated MS4 service area is about 74 percent of urban area, or 69 mi^2. Therefore, MS4 coverage area is about 5 % of total, potential runoff area. Since the MS4 area tends to have more impermeable surfaces compared to the natural land coverage area, forest for example, it is expected to have higher runoff rates in MS4 coverage area. Based on runoff estimations performed for allocations for MS4s in Zones 2 to 5 (DRBC, 2003, Appendix 6), MS4 areas generate an average about 135 % more runoff compared to the other types of land coverage. This relationship was applied to this Zone 6 MS4 flow estimation. Therefore, 7.2 percent of the potential runoff will be captured and discharged through MS4s. 7.2 percent of the remainder of the inflows (a total inflows minus traditional NPDES inflows: 16.534 m^3/sec) is equivalent to a flow of 1.190 m^3/sec.

Appendix Table 2.1 - Municipalities in Delaware and New Jersey designated as Phase II Separate Stormwater Sewer Systems (MS4s) that drain to Zone 6

STATE	MUNICIPALITY	COUNTY	NJPDES #
DE	DELAWARE DEPT. OF TRANSPORTATION	KENT	DE0051144
DE	DOVER CITY	KENT	DE0051161
DE	DOVER AIR FORCE BASE	KENT	DE0051187
NJ	BUENA BORO	ATLANTIC	NJG0149314
NJ	BUENA VISTA TWP	ATLANTIC	NJG0154989
NJ	CAPE MAY POINT BORO	CAPE MAY	NJG0150401
NJ	DENNIS TWP	CAPE MAY	NJG0150291
NJ	LOWER TWP	CAPE MAY	NJG0151092
NJ	MIDDLE TWP	CAPE MAY	NJG0149250
NJ	WEST CAPE MAY BORO	CAPE MAY	NJG0151866
NJ	BRIDGETON CITY	CUMBERLAND	NJG0147826
NJ	MILLVILLE CITY	CUMBERLAND	NJG0149063
NJ	VINELAND CITY	CUMBERLAND	NJG0152765
NJ	CLAYTON BORO	GLOUCESTER	NJG0150754
NJ	FRANKLIN TWP	GLOUCESTER	NJG0151025
NJ	GLASSBORO BORO	GLOUCESTER	NJG0148270
NJ	MONROE TWP	GLOUCESTER	NJG0148946
NJ	NEWFIELD BORO	GLOUCESTER	NJG0149187
NJ	WASHINGTON TWP	GLOUCESTER	NJG0153664
NJ	PITTSGROVE TWP	SALEM	NJG0154512

Appendix Table 2.2: Summary of the Zone 6 TMDLs for penta-PCBs and Total PCBs including the allocation to MS4s.

	TMDL mg/day	**MOS** mg/day	**Load Allocation** mg/day	**Wasteload allocation minus MS4s** mg/day	**Allocations to MS4s** mg/day
Penta-PCBs	469.11	23.46	442.38	1.72	1.56
Total PCBs	1876.45	93.82	1769.51	6.86	6.25

Appendix 3

Summary of mass flux exchanges for penta-PCBs and Total PCBs for Zones 2 to 6 under the TMDL conditions

Table 3.1: Summary of mass flux exchanges for the Stage 1 penta-PCB TMDL for Zones 2 to 6

Mass Flux Type (penta-PCB)	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	All Zones
External Loads, mg/day	6.61	4.46	4.57	12.01	24.66	52.31
Boundary*, mg/day	71.04		14.58	2.94	444.45	533.01
Downstream interface Advection, mg/day	-66.53	-68.03	-78.70	-77.38	445.45	
Air-Water Exchange, mg/day	-2.55	-0.44	1.03	0.19	-209.42	-211.19
Net Sediment-Water Diffusion, mg/day	1.54	0.96	1.22	7.12	152.47	163.32
Net of Settling and Resuspension, mg/day	-8.45	-3.35	-8.84	-21.39	-481.71	-523.74
Net Sediment-Water Exchange, mg/day	-6.91	-2.39	-7.62	-14.27	-329.24	-360.42
Surface Area, km^2	21.96	20.98	32.04	146.53	1690.23	1911.74
Air-Water Exchange per unit area, mg/day-km^2	-0.116	-0.021	0.032	0.001	-0.124	-0.110
Net Sediment-Water Diffusion per unit area, mg/day-km^2	0.070	0.046	0.038	0.049	0.090	0.085
Net of Settling and Resuspension per unit area, mg/day-km^2	-0.385	-0.160	-0.276	-0.146	-0.285	-0.274
Net Sediment-Water Exchange per unit area, mg/day-km^2	-0.315	-0.114	-0.238	-0.097	-0.195	-0.189

*Four major boundaries are considered in the model

Zone 2 - Upstream boundary of Delaware River at Trenton
Zone 4 - Upstream boundary of Schuylkill River at Philadelphia
Zone 5 - Downstream boundary of C&D Canal at Chesapeake City
Zone 6 - Downstream boundary at the mouth of the Bay (Ocean)
All Zones - Net fluxes into the entire estuary from four boundaries

Table 3.2: Summary of mass flux exchanges for the Stage 1 Total PCB TMDL for Zones 2 to 6

Mass Flux Type (total-PCBs)	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	All Zones
External Loads, mg/day	26.45	17.82	18.27	48.06	98.65	209.25
Boundary*, mg/day	284.15		58.33	11.76	1777.79	2132.03
Downstream interface Advection, mg/day	-266.12	-272.12	-314.79	-309.52	1777.79	
Air-Water Exchange, mg/day	-10.20	-1.77	4.16	0.75	-837.68	-844.77
Net Sediment-Water Diffusion, mg/day	6.14	3.86	4.89	28.49	609.90	653.28
Net of Settling and Resuspension, mg/day	-33.81	-13.39	-35.37	-85.56	-1926.82	-2094.94
Net Sediment-Water Exchange, mg/day	-27.67	-9.53	-30.48	-57.07	-1316.92	-1441.67
Surface Area, km^2	21.96	20.98	32.04	146.53	1690.23	1911.74
Air-Water Exchange per unit area, mg/day-km^2	-0.464	-0.084	0.130	0.005	-0.496	-0.442
Net Sediment-Water Diffusion per unit area, mg/day-km^2	0.280	0.184	0.153	0.194	0.361	0.342
Net of Settling and Resuspension per unit area, mg/day-km^2	-1.540	-0.638	-1.104	-0.584	-1.140	-1.096
Net Sediment-Water Exchange per unit area, mg/day-km^2	-1.260	-0.454	-0.951	-0.389	-0.779	-0.754

* Four major boundaries are considered in the model:

Zone 2 - Upstream boundary of Delaware River at Trenton
Zone 4 - Upstream boundary of Schuylkill River at Philadelphia
Zone 5 - Downstream boundary of C&D Canal at Chesapeake City
Zone 6 - Downstream boundary at the mouth of the Bay (Ocean)
All Zones - Net fluxes into the entire estuary from four boundaries