# Total Maximum Daily Loads of Nitrogen and Phosphorus for the Baltimore Harbor in Anne Arundel, Baltimore, Carroll and Howard Counties and Baltimore City, Maryland

## FINAL

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DEPARTMENT OF THE ENVIRONMENT

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## List of Abbreviations

| | |
|---|---|
| BHEM | Baltimore Harbor Eutrophication Model |
| BMPs | Best Management Practices |
| BNR | Biological Nutrient Removal |
| CBP | Chesapeake Bay Program |
| CE-QUAL-ICM | Corps of Engineers Water Quality Integrated Compartment Model |
| CEWES | Corps of Engineers Waterways Experiment Stations |
| CFD | Cumulative Frequency Distribution |
| CH3D-WES | Curvilinear Hydrodynamics in Three Dimensions – Waterways Experiment Stations |
| Chl *a* | Active Chlorophyll *a* |
| COMAR | Code of Maryland Regulations |
| CTIC | Conservation Technology Information Center |
| CWA | Clean Water Act |
| DMCF | Dredged Material Containment Facility |
| DO | Dissolved Oxygen |
| ENR | Enhanced Nutrient Removal |
| EPA | Environmental Protection Agency |
| HSPF | Hydrological Simulation Program Fortran |
| FSA | Farm Service Agency |
| ISG | International Steel Group |
| LA | Load Allocation |
| lbs/yr | Pounds per Year |
| MD | Maryland |
| MDA | Maryland Department of Agriculture |
| MDE | Maryland Department of the Environment |
| MDP | Maryland Department of Planning |
| mg/l / µg/l | Milligrams per Liter / Micrograms per Liter |
| mgd | Million Gallons per Day |
| MOS | Margin of Safety |
| MS4 | Municipal Separate Stormwater Sewer System |
| NOAA | National Oceanic and Atmospheric Administration |
| NPDES | National Pollutant Discharge Elimination System |
| NPS | Nonpoint Source |
| PATMH | Patapsco River Mesohaline Stream Segment |
| PCBs | Polychlorinated Biphenyls |
| TMDL | Total Maximum Daily Load |
| TN | Total Nitrogen |
| TP | Total Phosphorus |
| WLA | Wasteload Allocation |
| WQIA | Water Quality Improvement Act |
| WQLS | Water Quality Limited Segment |
| WWTP | Waste Water Treatment Plant |

## EXECUTIVE SUMMARY

Upon approval by the U.S. Environmental Protection Agency (EPA) this document will establish Total Maximum Daily Loads for nitrogen and phosphorus in the Patapsco River Mesohaline Stream Segment – PATMH (not including Bodkin Creek). Hereafter this stream segment will be referred to as the Baltimore Harbor or the Harbor (basin number 02130903). The Baltimore Harbor drains into the Chesapeake Bay and is part of the Patapsco/Back River Tributary Strategy Basin.

Baltimore Harbor (basin number 02130903) was identified on the State's 1996 list of water quality limited segments (WQLSs) submitted to the U.S. EPA by the Maryland Department of the Environment (MDE) as impaired by nutrients. The Baltimore Harbor has also been identified on the 303(d) list as impaired by bacteria (fecal coliform) (1998), toxics (polychlorinated biphenyls, or PCBs) (1998), metals (chromium, zinc and lead) (1998), suspended sediments (1996), and impacts to biological communities (2004). These other impairments will be addressed separately. The TMDLs described within this document were developed to address the water quality impairments associated with excess nutrient loadings.

The TMDLs for the nutrients nitrogen and phosphorus were determined using a time-variable, three-dimensional water quality eutrophication model package, which includes a watershed model (Hydrological Simulation Program Fortran (HSPF)), a hydrodynamic model (Curvilinear Hydrodynamic in Three Dimensions (CH3D)), a water quality model (Corps of Engineers-Water Quality-Integrated Compartment Model (CE-QUAL-ICM)), and a sediment flux model. Loading caps for total nitrogen and total phosphorus entering the Baltimore Harbor are established for growing season conditions and for average annual flow conditions.

To assure that critical conditions are addressed, the growing season TMDL for nitrogen is 2,145,750 lbs/growing season, and the growing season TMDL for phosphorus is 149,152 lbs/growing season. These TMDLs apply from May 1 through October 31. The allowable loads have been allocated between point and nonpoint sources. The nonpoint sources are allocated 459,912 lbs/growing season of total nitrogen, and 12,776 lbs/growing season of total phosphorus. The National Pollutant Discharge Elimination System (NPDES) point sources, including municipal wastewater treatment plant (WWTP) loads, NPDES industrial discharge loads and NPDES regulated urban stormwater loads, are allocated 1,642,014 lbs/growing season of nitrogen, and 113,212 lbs/growing season of phosphorus. A future allocation (FA) load to account for future growth and an explicit margin of safety comprises the remainder of the nitrogen and phosphorus allocations.

The average annual TMDL for nitrogen is 5,323,963 lbs/year, and the average annual TMDL for phosphorus is 324,309 lbs/year. The allowable loads have been allocated between point and nonpoint sources. The nonpoint source loads are allocated 1,246,036 lbs/year of total nitrogen and 34,654 lbs/year of total phosphorus. The point sources, including NPDES WWTP loads, NPDES industrial discharge loads and NPDES urban stormwater loads, are allocated 3,976,215 lbs/year of total nitrogen and 243,127 lbs/year of total phosphorus. A future allocation (FA) load to account for future growth and an explicit margin of safety comprises the remainder of the nitrogen and phosphorus allocations.

Several legislative and policy-derived programs will be utilized to implement these TMDLs. First, NPDES permits will reflect TMDL loadings as they are renewed. Additionally, the Chesapeake Bay Restoration Fund will be used to finance Enhanced Nutrient Removal (ENR) upgrades to WWTPs discharging into the Baltimore Harbor. Second, Maryland has several well-established programs to draw upon, including Maryland's Tributary Strategies for Nutrient Reductions, developed in accordance with the Chesapeake Bay 2000 Agreement. Third, Maryland's Water Quality Improvement Act (WQIA) of 1998 requires that nutrient management plans be implemented for all agricultural lands throughout Maryland. Finally, Maryland has adopted a watershed cycling strategy, which will ensure that future monitoring and water quality evaluations are conducted.

The water quality goal of these TMDLs is to reduce excessive algal blooms that result in high chlorophyll *a* concentrations, and maintain the dissolved oxygen concentrations at levels above the water quality criteria for the specific designated uses of the Baltimore Harbor. MDE has described the legislative and policy-derived programs that will result in significant nutrient reductions and the achievement of water quality standards for all designated uses in the Baltimore Harbor except the Deep Channel.

Based on information generated in the TMDL analysis, MDE is unable to ensure that the Deep Channel Refuge designated use water quality criterion for dissolved oxygen can be met at all times that it is applicable. The regions to which the Deep Channel Refuge designated use applies represent approximately 10% of the area of the Harbor. These regions include the main navigation channel of the Harbor, the channels into Curtis Bay, Middle Branch, and Northwest Branch and associated anchorages (COMAR 26.08.02.08). The region subject to potential non-attainment is in the main shipping channel, from the mouth of the Harbor to Fort McHenry, and represents < 5% of the area of the Harbor. The volume of water that does not meet the dissolved oxygen criteria represents approximately 3% of the total volume of the Harbor.

The reason that the designated use cannot be fully attained is due to the deepening of the natural river channel into a navigation channel that began in 1836 and continues today. In the past 170 years the dredging effort has incrementally deepened and expanded the size of the channels and their associated turning basins and anchorages. As a result, the channels and the water that flows within them, has been hydrologically modified. In a portion of the main navigation channel, from the mouth of the Harbor to Fort McHenry, it has been observed that water from the upper portion of the water column does not mix with the lower portion of the water column. This observed stratification of the water column, and the lack of mixing associated with it, occurs every spring/summer/fall. As a result, there is a limited region within the navigation channel that does not meet the dissolved oxygen criteria during the observed spring/summer/fall stratification period. Additionally, a computer model simulation was conducted that removed all anthropogenic sources of nutrients to the system and returned the watershed to a forest. Even under these conditions, the results indicated that the designated use could not be attained.

## 1.0 INTRODUCTION

Section 303(d)(1)(C) of the federal Clean Water Act (CWA) and the U.S. Environmental Protection Agency's (EPA) implementing regulations direct each state to develop a Total Maximum Daily Load (TMDL) for each impaired water quality limited segment (WQLS) on the Section 303(d) list, taking into account seasonal variations and a protective margin of safety (MOS) to account for uncertainty. A TMDL reflects the total pollutant loading of the impairing substance a waterbody can receive and still meet water quality standards.

TMDLs are established to achieve and maintain water quality standards. A water quality standard is the combination of a designated use for a particular body of water and the water quality criteria designed to protect that use. Designated uses for the Patapsco River Mesohaline Stream Segment – PATMH (hereafter referred to as the Baltimore Harbor or the Harbor) are: (1) Migratory Fish Spawning and Nursery, (2) Seasonal Shallow Water Submerged Aquatic Vegetation, (3) Open Water Fish and Shellfish Habitat, (4) Deep Water Seasonal Fish and Shellfish Habitat, and (5) Deep Channel. Water quality criteria consist of narrative statements and numeric values designed to protect the designated uses. Criteria differ among waters with different designated uses.

The Baltimore Harbor (basin number 02130903) was first identified on the 1996 303(d) list submitted to EPA by the Maryland Department of the Environment (MDE). It was listed as impaired by nutrients due to signs of eutrophication, expressed as high levels of chlorophyll *a* (Chl *a*) and low concentrations of dissolved oxygen (DO). Eutrophication is the over-enrichment of aquatic systems by excessive inputs of nutrients (nitrogen and/or phosphorus). The nutrients act as a fertilizer leading to excessive growth of algae. The algae die and are eventually consumed by bacteria. During the consumption process the bacteria utilize the available DO, which results in decreased DO concentrations in the water column particularly when stratification or layering prevents oxygen in the surface layers from mixing with deeper layers. Therefore, MDE uses measures of DO and Chl *a* to understand the impact of the nitrogen and phosphorus on the ecosystem. For these reasons, this document, upon EPA approval, establishes TMDLs for the nutrients nitrogen and phosphorus in the Baltimore Harbor.

The Baltimore Harbor has also been identified on the 303(d) list as impaired by bacteria (fecal coliform) (1998), toxics (polychlorinated biphenyls (PCBs) (1998), metals (chromium (Cr), zinc (Zn), and lead (Pb)) (1998), suspended sediments (1996), and impacts to biological communities (2004). To date, Cr and Zn impairments in Bear Creek and the Inner Harbor/Northwest Branch and Pb in the Inner Harbor/Northwest Branch have been addressed with water quality analyses. The remaining impairments will be addressed separately.

# 2.0 SETTING AND WATER QUALITY DESCRIPTION

## 2.1 General Setting and Source Assessment

### 2.1.1 Watershed Description

The watershed draining into the Baltimore Harbor estuary is the Patapsco River Watershed. The Patapsco River Watershed is located in the western shore region of Maryland (Figure 1), and includes the mainstem Patapsco and the tributaries of Jones Falls, Gwynns Falls, Colgate Creek, Bear Creek, Curtis Creek, Stony Creek, and Rock Creek. The Patapsco River Mesohaline (PATMH) segment, or Baltimore Harbor estuary, is located on the west side of the upper Chesapeake Bay about 160 miles from the Virginia Capes at the entrance to the Bay. The Harbor estuary is the 15-mile tidal region of the lower Patapsco River. It is the end of the Patapsco River where it joins the Chesapeake Bay. The PATMH segment includes the Baltimore Harbor estuary and the tidal segments of the Colgate Creek, Bear Creek, Curtis Creek, Stony Creek, Rock Creek and Bodkin Creek tributaries. Bodkin Creek is identified in the 303(d) list as a separate waterbody and will be addressed in the future.

Natural water depths in the Harbor are generally less than 20 feet except for the main navigation channel maintained by the U.S. Army Corps of Engineers, which is maintained at a depth of 50 feet. The tidal range in the Harbor is approximately one foot. Other than the Patapsco River, the only sizable tributaries entering the Harbor directly are Jones Falls and Gwynns Falls.

The Jones Falls, Gwynns Falls and Patapsco River discharge into the Baltimore Harbor. The South Branch and mainstem of the Patapsco River flows about 85 miles (134 km) from Parr's Spring in Carroll County to the Middle Branch. The North Branch, formed at the confluence of the East Branch and West Branch, flows into Liberty Reservoir where it is retained for drinking water purposes. A small segment of the North Branch exists below the dam and joins the South Branch near the Town of Sykesville. After flowing through Baltimore Harbor, the Patapsco River discharges into the Chesapeake Bay.

The subwatersheds draining into the Harbor are located within Baltimore City and Baltimore, Anne Arundel, Carroll, and Howard Counties. The total area of these subwatersheds is 268,671 acres (1,087 square kilometers), excluding the land area above Liberty Reservoir. Water from the subwatershed draining into Liberty Reservoir typically does not drain to the Baltimore Harbor because it is used for drinking water.

Table 1 shows the area in acres that the Patapsco River watershed (not including Liberty Reservoir watershed) occupies in each of the above counties. Table 2 shows the area in acres for each of the four major subwatersheds draining into the Baltimore Harbor estuary.

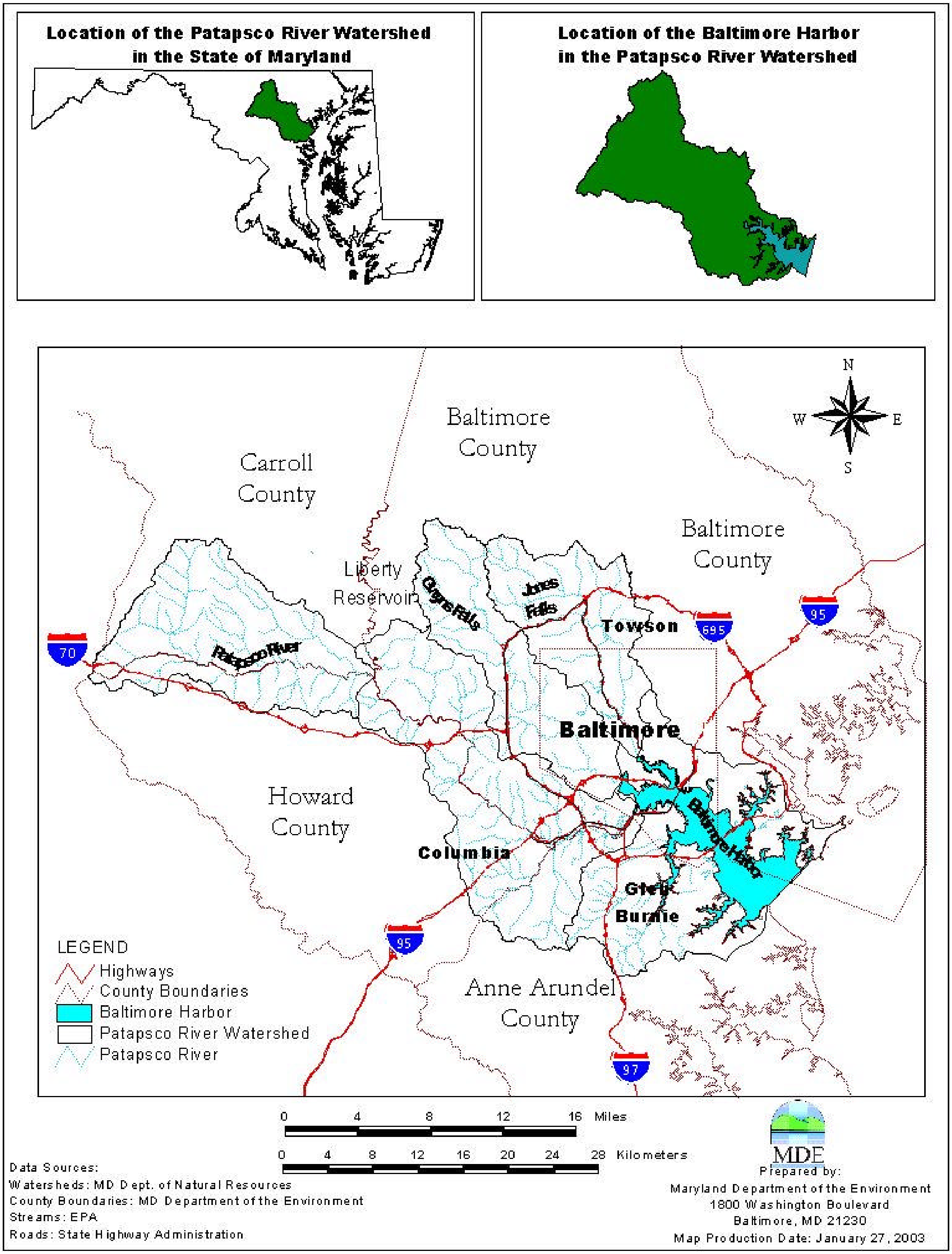



**Figure 1: Location Map of Baltimore Harbor Drainage Basin**

**Table 1: Baltimore Harbor Subwatershed Areas Within Maryland Jurisdictions**

| Jurisdictions | Area (acres) |
|---|---|
| Anne Arundel County | 46,223 |
| Baltimore City | 40,476 |
| Baltimore County | 100,600 |
| Carroll County | 40,182 |
| Howard County | 41,190 |
| Total | 268,671 |

**Table 2: Baltimore Harbor Subwatershed Areas**

| Subwatersheds | Area (acres) |
|---|---|
| Gwynns Falls | 41,701 |
| Jones Falls | 37,273 |
| Patapsco River | 130,662 |
| Baltimore Harbor | 59,035 |
| Total | 268,671 |

### 2.1.2 Land Use

The land use in the Baltimore Harbor watershed is diverse. The land cover consists of urban, suburban, rural, industrial, forest, and agricultural land uses. One of the largest forested areas in the watershed is the Patapsco Valley State Park.

The watershed draining into the Baltimore Harbor (not including the watershed draining into the Liberty Reservoir) has an area of approximately 268,671 acres (1,087.3 square kilometers). The land uses in the watershed consist of forest and other herbaceous growth (77,077 acres or 29%), mixed agriculture (41,848 acres or 15%), water (1,806 acres or 1%), and urban (147,940 acres or 55%). Land use information was derived from the 1997 Maryland Department of Planning (MDP) land cover database, the Farm Service Agency (FSA), the 1997 Agricultural Census, and information from the 1996 Conservation Technology Information Center (CTIC). See Figure 2 for the predominant land uses in the Baltimore Harbor watersheds. Figure 3 shows the relative amounts of different land uses in the watersheds draining into the Baltimore Harbor.

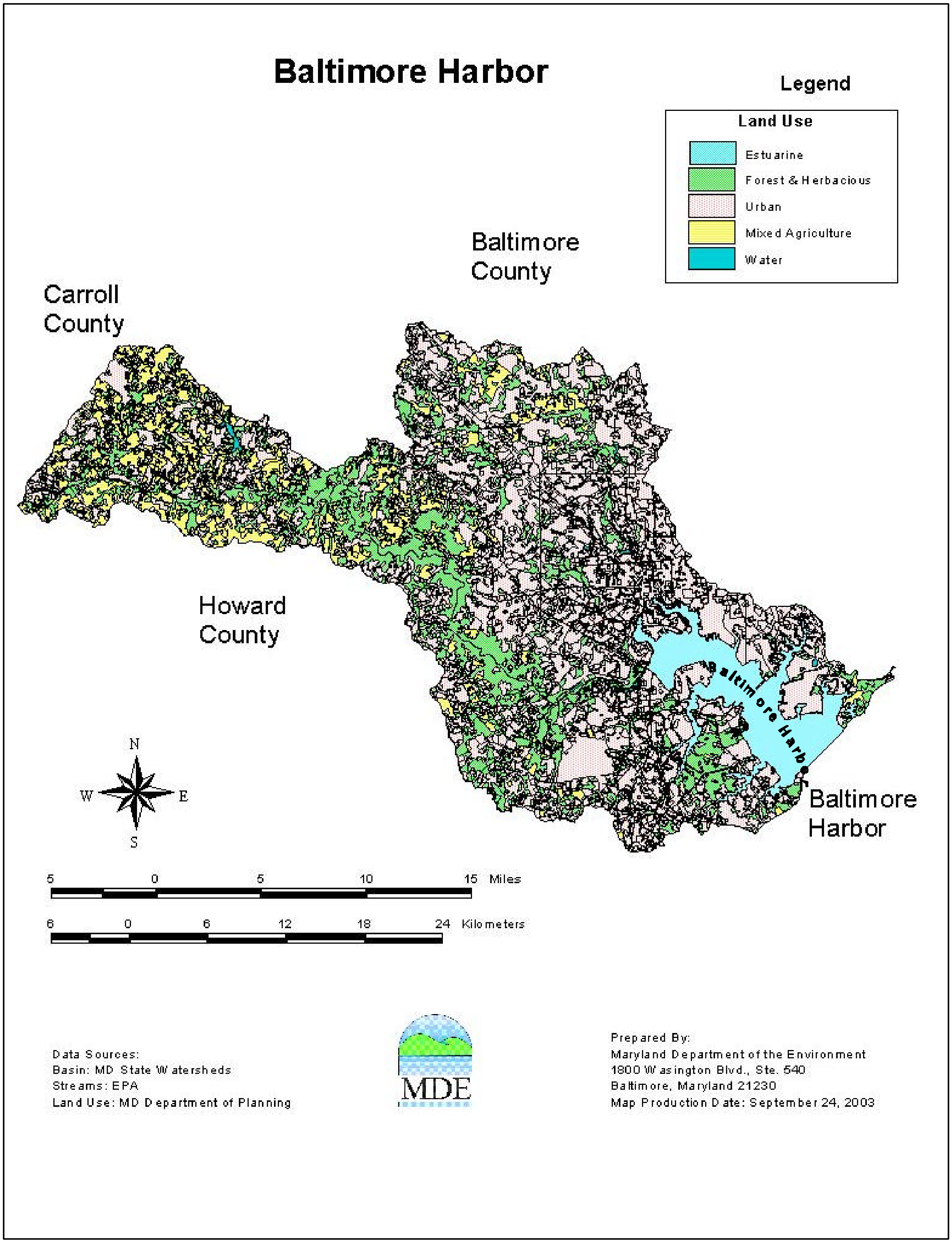



**Figure 2: Predominant Land Uses in the Watershed Draining into Baltimore Harbor**

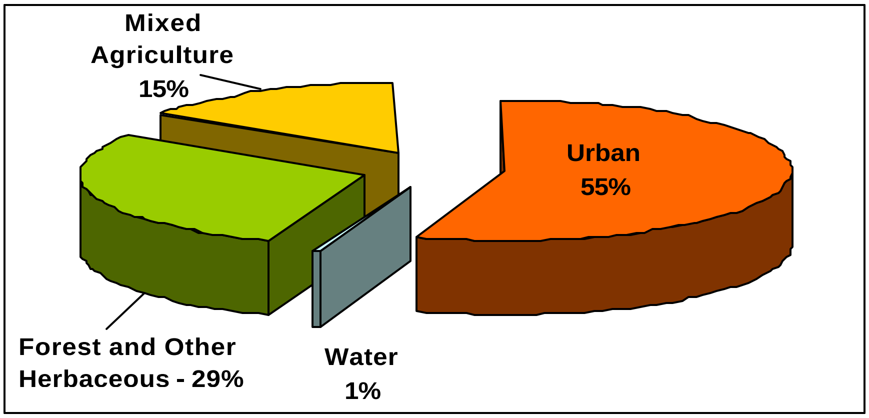



**Figure 3: Proportions of Land Use in the Basins Draining into Baltimore Harbor**

### 2.1.3 Geology

The watersheds draining into the Baltimore Harbor lie primarily within the Piedmont and, to a lesser extent, the Coastal Plain provinces of Central Maryland. The surficial geology is characterized by crystalline rocks of volcanic and sedimentary origin, consisting primarily of schist and gneiss. These formations are resistant to short-term erosion, and often determine the limits of stream bank and streambed. Crystalline formations decrease in elevation from northwest to southeast, eventually extending beneath the younger sediments of the Coastal Plain. The fall line represents the transition between the Atlantic Coastal Plain Province and the Piedmont Province. The Atlantic Coastal Plain surficial geology is characterized by thick, unconsolidated marine sediments deposited over the crystalline rock formations of the Piedmont Province (Coastal Environmental Services, 1995).

### 2.1.4 Nutrients Source Assessment

#### 2.1.4.1 Point Sources: Municipal and Industrial Wastewater Treatment Plant Loads

The Patapsco Wastewater Treatment Plant (WWTP) and Cox Creek WWTP are municipal point sources that discharge directly into Baltimore Harbor. International Steel Group (ISG), Grace Davison, Erachem-Comilog, US Gypsum, and Millenium Specialty are the five industrial point sources that discharge directly into the Harbor. The combined estimated average annual loads from municipal WWTPs for 1992-1997 (the model calibration period) are 3,455,063 lbs/yr for total nitrogen (TN) and 216,099 lbs/yr for total phosphorus (TP). The combined estimated average annual loads from industrial WWTPs for 1992-1997 are 3,001,015 lbs/yr for TN and 89,376 lbs/yr for TP. Thus, the total average annual loads from all WWTPS are 6,456,078 lbs/yr for TN and 305,475 lbs/yr for TP. This information was obtained from discharge monitoring reports stored in MDE's point source database. The municipal average annual point source loads for 1992-1997 are presented in Table 3. The industrial average annual point source loads for 1992-1997 are shown in Table 4. Table 5 lists the average daily flows for all permitted point sources discharging into Baltimore Harbor during 1992-1997 in millions of gallons per day (mgd).

**Table 3: Average Municipal WWTP Loads, 1992-1997**

| Year | TN | TP |
|---|---|---|
| | lbs/yr | lbs/yr |
| 1992 | 2,762,146 | 207,976 |
| 1993 | 3,814,825 | 235,890 |
| 1994 | 5,132,577 | 220,309 |
| 1995 | 3,049,908 | 243,216 |
| 1996 | 3,059,893 | 221,403 |
| 1997 | 2,911,024 | 167,800 |
| Average | 3,455,063 | 216,099 |

**Table 4: Average Industrial WWTP Loads, 1992-1997**

| Year | TN | TP |
|---|---|---|
| | lbs/yr | lbs/yr |
| 1992 | 3,506,205 | 93,862 |
| 1993 | 2,846,814 | 88,115 |
| 1994 | 2,636,706 | 84,041 |
| 1995 | 2,697,273 | 85,333 |
| 1996 | 3,127,613 | 90,767 |
| 1997 | 3,191,478 | 94,140 |
| Average | 3,001,015 | 89,376 |

**Table 5: Average Daily Flows for Permitted Point Sources Discharging into Baltimore Harbor during the 1992-1997 Model Calibration Period**

| Facility | Type | Average Flow (mgd) |
|---|---|---|
| Patapsco WWTP | Municipal | 47.96 |
| Cox Creek WWTP | Municipal | 11.18 |
| Erachem-Comilog | Industrial | 0.089 |
| Grace Davison | Industrial | 2.38 |
| US Gypsum-1 | Industrial | 0.001 |
| US Gypsum-2 | Industrial | 0.000 |
| ISG-1 | Industrial | 37.34 |
| ISG-2 | Industrial | 5.66 |
| ISG-3 | Industrial | 55.42 |
| ISG-4 | Industrial | 3.60 |
| ISG-5 | Industrial | 0.064 |
| ISG-6 | Industrial | 3.94 |
| ISG-7 | Industrial | 1.51 |
| Millennium 001 | Industrial | 0.067 |
| Millennium 002 | Industrial | 0.589 |

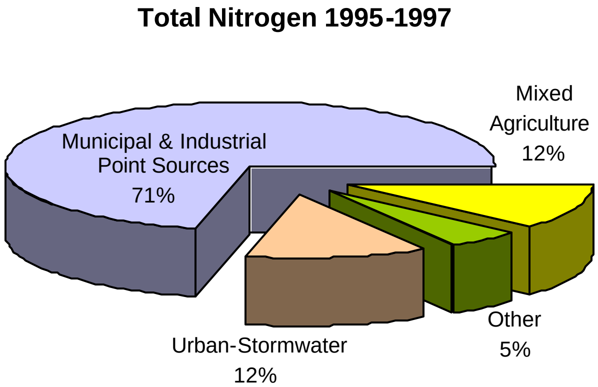
These flow and point source load estimates represent actual discharge into the Baltimore Harbor from municipal WWTPs and industrial plants from 1992-1997. It is important to note that these plants were not all discharging at their maximum flow capacities and/or nutrient permit limits during this period. For example, the Patapsco River and Cox Creek municipal WWTPs discharged an average of 3.5 million lbs/yr of TN and 0.22 million lbs/yr of TP during the 1992-1997 study period. If these plants discharged consistently at their maximum capacity flow, their loads could increase to 3.9 million lbs/yr of TN and 0.46 million lbs/yr of TP, assuming the TN concentration was the same as the actual 1992-1997 concentrations and the TP concentration equal to the current permit limit of TP = 2.0 mg/l for both plants. Similarly, industrial facilities loads could increase significantly if they discharged at maximum capacity for long periods of time.

#### 2.1.4.2 Nonpoint Source Loads and Urban Stormwater Loads

Nonpoint source loads and urban stormwater loads entering the Baltimore Harbor were estimated using the Hydrologic Simulation Program-Fortran (HSPF). The HSPF model is used to estimate flows, suspended solids and nutrient loads from the watershed's sub-basins. Nonpoint source and urban stormwater loads are linked to a three-dimensional, time-variable hydrodynamic model and a water quality model coupled with a sediment process model designed specifically for Baltimore Harbor. The water quality model is used to determine the maximum load of nutrients that can enter the Harbor while maintaining the water quality criteria associated with its designated uses. The water quality modeling framework is shown in Section 4.2.

The Baltimore Harbor HSPF watershed model used the following assumptions: (1) variability in patterns of precipitation were estimated from existing National Oceanic and Atmospheric Administration (NOAA) meteorological stations; (2) hydrologic response of land areas were estimated for a simplified set of land uses in the basin; and (3) agricultural information, like crop types and tilling practices, were estimated from MDP land use data, the 1997 Agricultural Census Data, and the Farm Service Agency (FSA) data. The HSPF simulates nonpoint source and urban stormwater loads and integrates all natural and human-induced sources, including direct atmospheric deposition and loads from septic tanks, which are associated with river base flow during growing season conditions. Details of the HSPF watershed model developed to estimate these urban and non-urban loads are found in the "Patapsco/Back River Watershed HSPF Model Report" (MDE, 2001).

Figure 4 presents the relative average annual amounts of nitrogen and phosphorus from nonpoint source, municipal and industrial point source, and urban stormwater delivered loadings to the Baltimore Harbor during the 1995-1997 period.



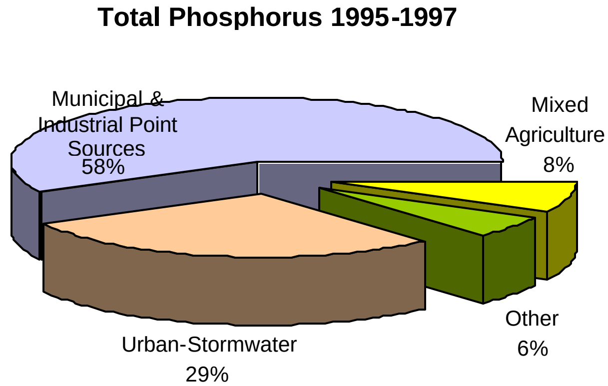




**Figure 4: Percentages of Average Annual Nitrogen and Phosphorus Loads from Municipal and Industrial Point Sources, Urban Stormwater and NPS in Baltimore Harbor, 1995-1997**

The calibration of the model was conducted for the 1992-1997 period. The TMDL analysis was conducted using the 1995-1997 period as a baseline, which includes dry, wet and average years. For these reasons, the delivered loads percentages in the figures represent an average for the 1995-1997 period.

In the Baltimore Harbor watershed, the estimated 1995-1997 average annual TN delivered load from nonpoint sources (NPS) is 1,364,400 lbs/yr, and the NPS TP delivered load is 37,465 lbs/yr. The estimated 1995-1997 average annual TN load for point sources, including regulated urban stormwater TN load, is 7,053,689 lbs/yr and the estimated 1995-1997 average annual point source TP load is 317,423 lbs/yr.

### 2.2 Water Quality Characterization

Eutrophication is the over-enrichment of aquatic systems by excessive inputs of nutrients (nitrogen and/or phosphorus). The nutrients act as a fertilizer leading to excessive growth of algae. The algae grow rapidly, die and are subsequently consumed by bacteria. The bacterial consumption of the algae results in the use of available dissolved oxygen in the water column, which produces hypoxic (low oxygen) or anoxic (no oxygen) conditions. Eutrophication has probably been more extensively studied in the Chesapeake Bay and its tributaries than in any other coastal ecosystem. Scientists have uncovered the relationships of how nutrients stimulate biological productivity in the Bay, and how eutrophication results in oxygen depletion, increased turbidity, loss of submersed vegetation, and alteration of food webs (Boesch *et al.*, 2001).

Portions of the Chesapeake Bay and its tributaries often show signs of eutrophication. The Baltimore Harbor has shown clear indications of eutrophication for several decades (Robertson, 1977; Magnien *et al.*, 1993; Boynton *et al.*, 1998). For example, extensive and persistent anoxic or hypoxic conditions were observed regularly in the bottom waters of the Baltimore Harbor.

The Chesapeake Bay Water Quality Monitoring Program has recorded measurements in the Baltimore Harbor indicating anoxic and hypoxic events occur as early as April and extend until October every year. Also, increased algal blooms have been found to occur yearly during the warm season (Wang *et al.*, 2004). Anoxic conditions occur at the bottom of the navigation channel as well as in most tributaries, such as the Inner Harbor and the Middle Branch. Anoxic water exists in the mainstem of the Chesapeake Bay each summer. However, Wang *et al* (2004) and Liu (2002) hypothesize that the origin of low DO in the Harbor is not from the intrusion of anoxic Bay water, but rather is an internal process of the Harbor.

Wang *et al*,. (2004) indicate that the water circulation and exchange within the Baltimore Harbor region are generally regulated by local wind forces, which overwhelm the weak currents driven by river and tidal forces. Pritchard and Carpenter (1960) inferred the existence of a three-layered circulation in Baltimore Harbor based on salinity and dye distributions. This was confirmed by Boicourt and Olson (1982) with direct measurements. This unique hydrodynamic feature has to be taken into consideration because it can affect the dynamics of water quality parameters.

Data for the 1992-1997 period have been selected for the development of the eutrophication model and the subsequent nutrient TMDL analyses. There are 24 water quality stations located in the Baltimore Harbor that MDE and the Chesapeake Bay Program (CBP) surveyed during the model calibration period. The reader is referred to Figure 5 for the locations of the water quality sampling stations.

The CBP has sponsored a long-term water quality sampling station (WT5.1) in the Baltimore Harbor since 1984 to monitor its physical, chemical, and biological parameters. MDE also monitored the Baltimore Harbor intensively at the other 23 stations during the period March 1994 to May 1995 for parameters similar to those monitored by the CBP. A detailed list of all parameters measured in these surveys can be found in the report "The Development of a Water Quality Model for Baltimore Harbor, Back River and the Adjacent Upper Chesapeake Bay" (Wang *et al.*, 2004).

The time series data for dissolved oxygen (DO) and chlorophyll *a* (Chl *a*) at stations WT5.1 and M16 are presented in this report to provide a trend analysis of the two parameters associated with Maryland water quality standards. Additional time series and longitudinal data profiles from the MDE and CBP stations for various nutrient parameters are available upon request and through the MDE TMDL website as supporting documentation. The time series data files are too large to incorporate as appendices to this report.

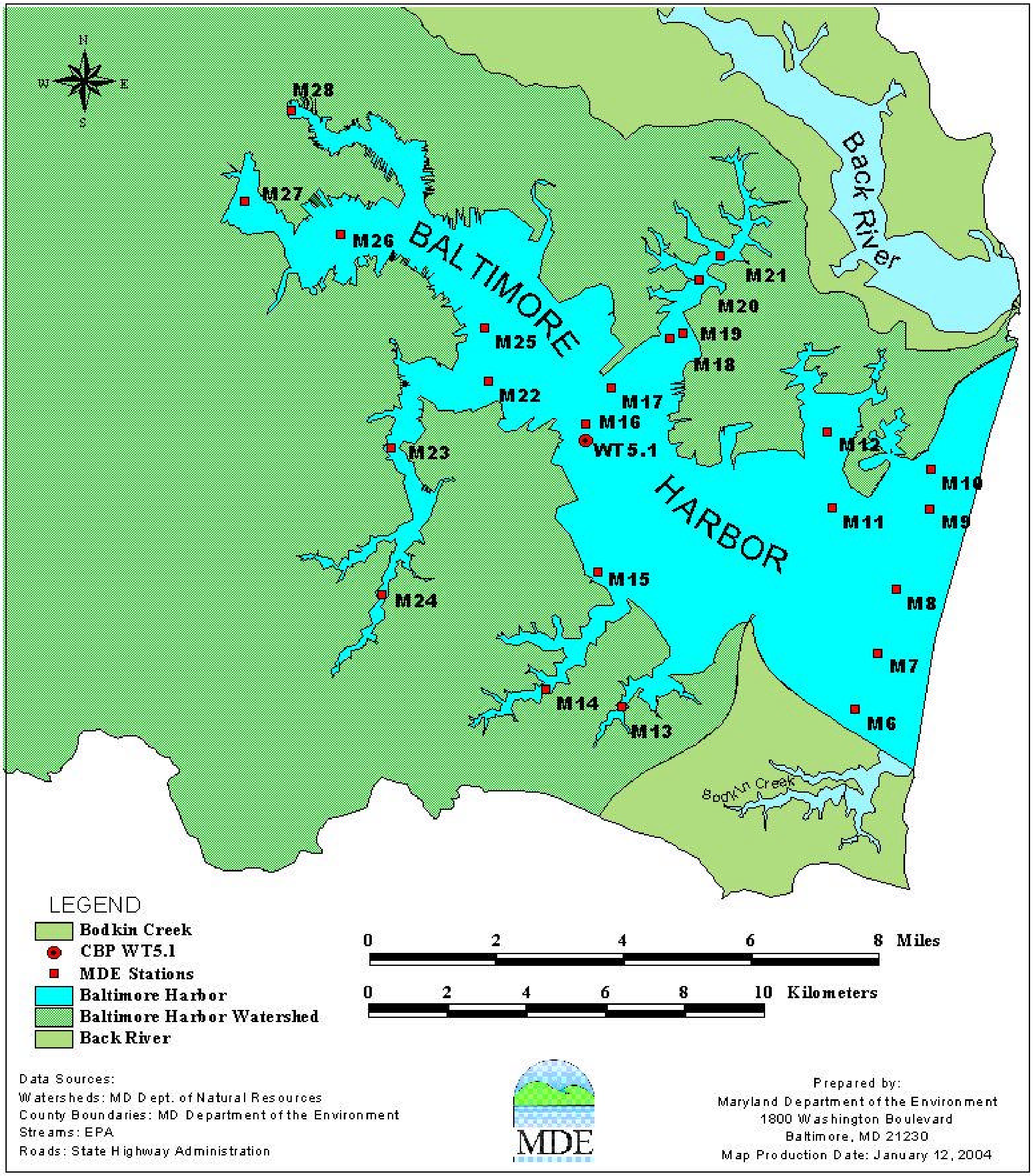
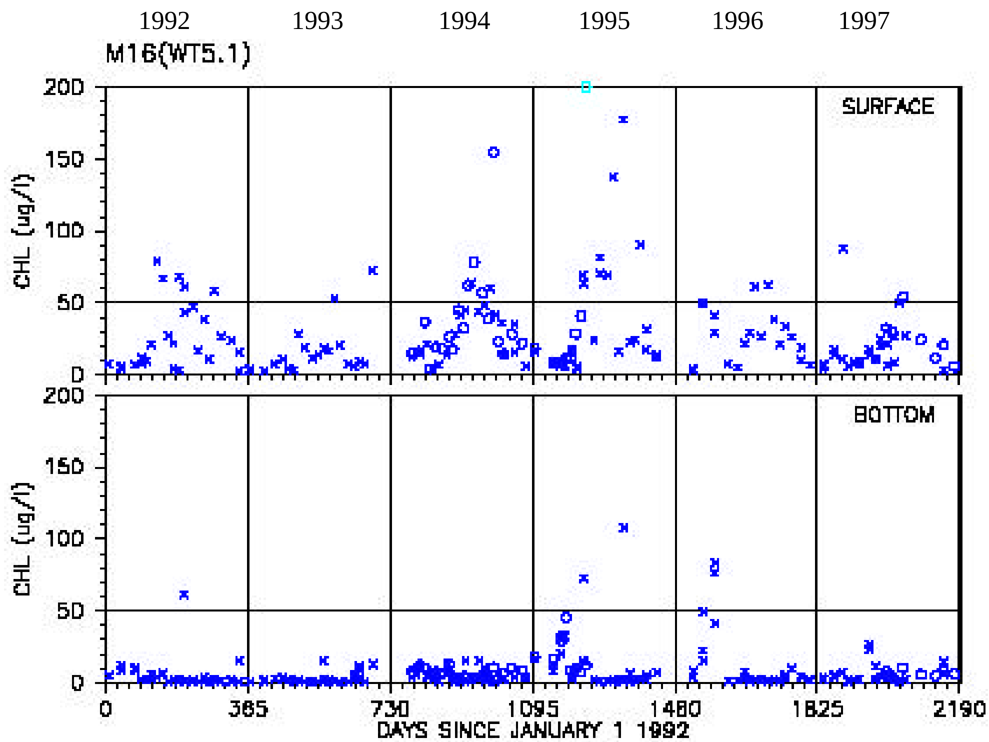



**Figure 5: Location of Water Quality Stations in Baltimore Harbor**

Figure 6 presents the time series of Chl *a* concentrations in the Baltimore Harbor from January 1992 to December 1997 for the CBP long-term monitoring station WT5.1 (MDE Station M16) located in the middle of the Harbor, approximately 8.8 km from the Harbor's mouth.




X CBP Observed Chlorophyll *a* Data

• MDE Observed Chlorophyll *a* Data

**Figure 6: Time Series of Chlorophyll *a* Data at Baltimore Harbor Station WT5.1 / M16**

As Figure 6 shows, surface Chl *a* concentrations include observations that are above 50 µg/l every year, with a seasonal pattern of higher values during warmer months and lower values during colder months. Concentrations rarely exceed 100 µg/l, except in the summers of 1994 and 1995 when maximum concentrations were close to 200 µg/l. Bottom Chl *a* is normally below 20 µg/l, except during the springs of 1995 and 1996 where concentrations reached 100 µg/l and 85 µg/l, respectively (probably weather-related, as several snowstorms may have resulted in unusual patterns of thermal stratification).

A time series for surface and bottom DO concentrations at station WT5.1 is depicted in Figure 7, showing that the observed surface DO levels did not fall below 5.0 mg/l. The surface DO ranged from 5.2 mg/l to 18.0 mg/l with average DO concentrations around 10 mg/l. There is some degree of seasonal variation with higher DO values during winter months and lower values during summer months, due to seasonal changes in temperature. The bottom water DO concentrations range from 0 mg/l to 11 mg/l and display a distinct seasonal pattern. Anoxic conditions can be observed at the bottom waters starting as early as April in some years and lasting until the end of summer every year. During early fall, DO levels start to increase rapidly, reaching the 5.0 mg/l level by November.

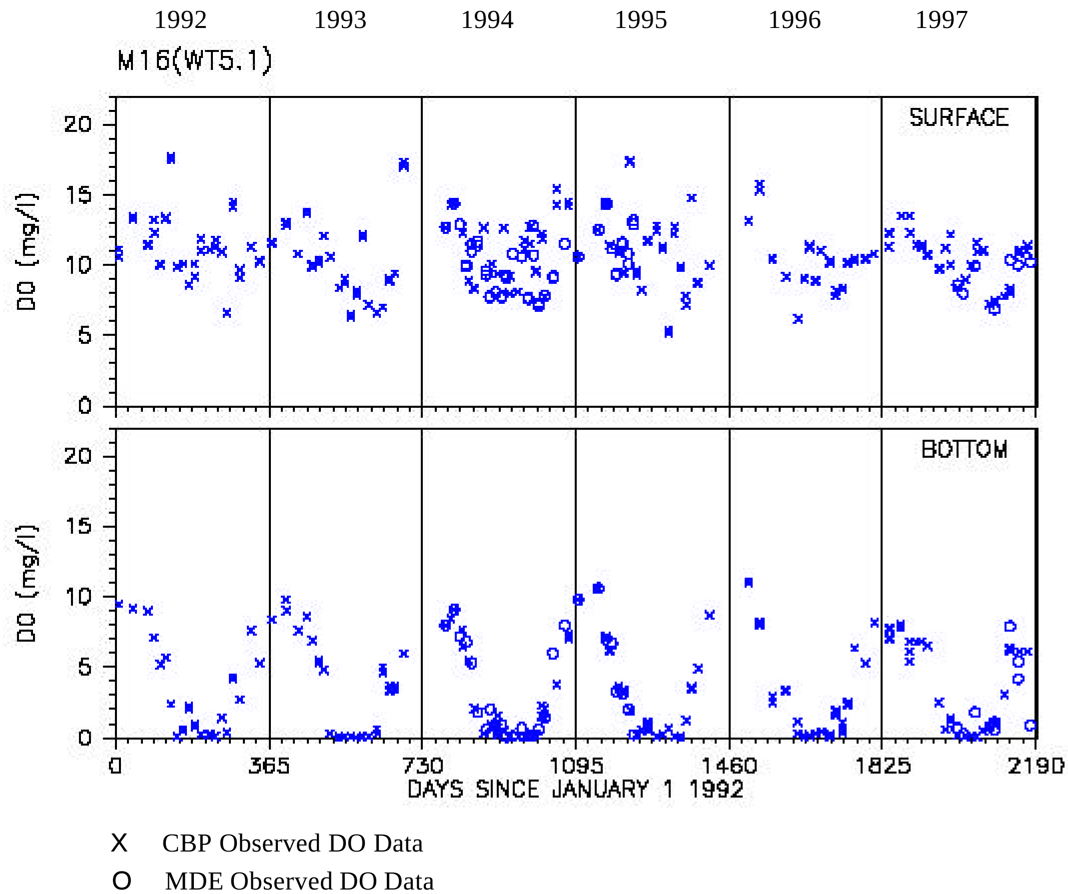



**Figure 7: Time Series of DO Data at Baltimore Harbor Station WT 5.1 / M16**

## 2.3 Water Quality Impairment

The Maryland Water Quality Standards Stream Segment Designation [Code of Maryland Regulations (COMAR) 26.08.02.08K(2)(b)] for the Patapsco River Mesohaline (PATMH) (not including Bodkin Creek) is Use II: Tidal Waters: Support of Estuarine and Marine Aquatic Life and Shellfish Harvesting. Designated Uses present in the Baltimore Harbor Segment are: 1) Migratory Spawning and Nursery, 2) Shallow Water Submerged Aquatic Vegetation, 3) Open Water Fish and Shellfish, 4) Seasonal Deep Water Fish and Shellfish, and 5) Deep Channel. No areas in the Harbor are designated as Shellfish Harvest Use areas.

The designated uses described above and the associated criteria are the result of MDE's adoption of water quality standards developed by the Chesapeake Bay Program. MDE adopted the standards in the fall of 2005 and the Baltimore Harbor TMDL represents the second application of these standards to Maryland's estuarine waters.

### 2.3.1 Dissolved Oxygen Criteria

Table 6 presents descriptions of the numeric DO criteria for designated uses present in the Harbor. The DO level is based on specific numeric criteria for Use II waters set forth in the COMAR 26.08.02.03-3C(2)(8). However, due to data limitations MDE will follow EPA guidance and assess the DO attainment based on 30-day component of the Open Water Use designated use for the Migratory Fish Nursery and Spawning Use, and Seasonal Shallow Water Submerged Aquatic Vegetation designated uses. The Deep Water Use will also be assessed using a 30-day methodology, however the requisite concentration is different from the Open Water Use.

**Table 6: Dissolved Oxygen Criteria and Time Periods for the Designated Use Subcategories**

| Designated Use II Subcategory | Period | Dissolved Oxygen Criteria |
|---|---|---|
| Seasonal Migratory Fish Spawning and Nursery | February 1 through May 31 inclusive | ▪ Open Water criteria apply |
| Seasonal Shallow Water Submerged Aquatic Vegetation | April 1 through October 31 inclusive | ▪ Open Water criteria apply |
| Open Water Fish and Shellfish | January 1 through December 31 inclusive | ▪ 5.0 mg/l 30-day average |
| Seasonal Deep Water Fish and Shellfish | June 1 through September 30 inclusive | ▪ 3.0 mg/l 30-day average* |
| Seasonal Deep Channel Refuge | June 1 through September 30 inclusive | ▪ ≥ 1 mg/l instantaneous minimum |

* Allows a restoration variance of up to 7% applied spatially or temporally in combination from June 1 through September 30

### 2.3.2 Chlorophyll *a* Criteria

The Chl *a* concentration goal used in this analysis are based on guidelines set forth by Thomann and Mueller (1987) and by the EPA Technical Guidance Manual for Developing Total Maximum Daily Loads, Book 2, Part 1 (1997). The Chl *a* narrative criterion (COMAR 26.08.02.03-3C(10) state: "Chlorophyll *a* - Concentrations of chlorophyll *a* in free-floating microscopic aquatic plants (algae) shall not exceed levels that result in ecologically undesirable consequences that would render tidal waters unsuitable for designated uses." The Thomann and Mueller guidelines acknowledge that "'Undesirable' levels of phytoplankton [Chl *a*] vary considerably depending on water body." MDE has determined, per Thomann and Mueller, that it is acceptable to maintain Chl *a* concentrations below a maximum of 100 µg/L, and to target, with some flexibility depending on waterbody characteristics, a 30-day rolling average of approximately 50 µg/L.

Consistent with the guidelines set forth above, MDE's interpretation of narrative criteria for Chl *a* in the Baltimore Harbor is comprised of the following water quality goals:

(1) Ensure that instantaneous concentrations remain below 100 µg/L at all times and
(2) Minimize exceedances of the 50 µg/L, 30-day rolling average, to a frequency that will not result in ecologically undesirable conditions.

The water quality impairment being addressed by this TMDL analysis consists of DO concentrations less than the numeric criteria presented in Section 2.3.1 and Chlorophyll *a* (Chl *a*) concentrations above the MDE interpretation of the narrative criteria presented in Section 2.3.2 (See Figures 6&7). The achievement of the DO and Chl *a* criteria is required for all the uses throughout the water column of the Baltimore Harbor system. In the Harbor, data are not sufficient to assess the 7-day average and instantaneous minimum DO criteria for attainment of the designated uses; thus, the calibrated model results are used to evaluate conditions.

## 3.0 TARGETED WATER QUALITY GOAL

The objective of the nutrient TMDLs established in this document is to ensure that DO and Chl *a* concentrations in the Baltimore Harbor meet the criteria associated with specific designated uses. Specifically, the TMDLs for nitrogen and phosphorus are intended to control excessive algal growth and increase DO concentrations in areas not currently meeting water quality criteria.

## 4.0 TOTAL MAXIMUM DAILY LOADS DEVELOPMENT AND ALLOCATION

### 4.1 Overview

The following sections describe the modeling frameworks for simulating nutrient loads, hydrology, and water quality responses. Section 4.2 summarizes the TMDL analysis framework and model calibration. Section 4.3 describes the scenarios and results that were generated using the modeling framework. Sections 4.4–4.5 describe how the nutrient TMDLs and load allocations for point sources and nonpoint sources were developed for the Baltimore Harbor. Section 4.6 explains the rationale for the margin of safety and the last section summarizes the TMDLs for the growing season and average annual conditions.

### 4.2 Analysis Framework

#### 4.2.1 Computer Modeling Framework

To develop a TMDL, a linkage must be defined between the selected water quality targets or goals and the identified pollutant sources. This linkage establishes the cause-and-effect relationship between the sources of the pollutant of concern and the water quality response of the impaired water quality segment to that pollutant. For nonpoint sources, the relationship can vary seasonally due to factors such as precipitation. Once defined, the linkage yields the estimate of total loading capacity or TMDL (EPA, 1999).

MDE chose a set of time-variable models as the analysis tool to link the sources of nutrient loadings to the DO criteria and chlorophyll *a* goal. The computational framework chosen for the

Baltimore Harbor nutrients TMDLs is the three-dimensional, time-variable Baltimore Harbor Eutrophication Model (BHEM). This water quality simulation package provides a generalized framework for modeling nutrient fate and transport in surface waters (Cerco and Cole, 1995). The BHEM package includes a watershed model, a hydrodynamic model, a water quality model and a sediment flux sub-model, and represents twenty-two water quality parameters from the water column and sediment bed. For detailed information, please refer to the report "The Development of a Water Quality Model for Baltimore Harbor, Back River and the Adjacent Upper Chesapeake Bay" (Wang *et al.*, 2004).

Since many studies have shown the significant influence of the Chesapeake Bay on its tributaries, the spatial domain of the BHEM extends longitudinally from the mouth of the Susquehanna River about 90 miles seaward (south) to the mouth of the Patuxent River, which is defined as the upper Chesapeake Bay. Baltimore Harbor is located on the western shoreline of the upper Chesapeake Bay. This modeling domain is represented by BHEM model segments. A diagram of the model segmentation is presented in Wang *et al* (2004).

The water quality model, Corps of Engineers Water Quality Compartment Model (CE-QUAL-ICM), is externally coupled with the three-dimensional, time-variable hydrodynamic model, Curvilinear Hydrodynamic in Three Dimensions, (CH3D). As its name indicates, CH3D makes hydrodynamic computations on a curvilinear or boundary-fitted platform grid that allows the model to accurately represent the deep navigation channel and irregular shoreline. The CH3D simulates physical processes such as tides, wind, density effects (salinity and temperature), freshwater inflows, turbulence, and the effect of the earth's rotation. The model outputs are used to drive the water quality model (Johnson *et al.*, 1991).

The sediment flux model developed by DiToro and Fitzpatrick (1993), and coupled with CE-QUAL-ICM for Chesapeake Bay water quality modeling efforts, is used in the present model application. The state variables, resulting fluxes, and complete model documentation can be found in Wang *et al* (2004), and also in DiToro and Fitzpatrick (1993).

The stormwater load and nonpoint source loading estimation was conducted using a HSPF watershed model, which simulates the fate and transport of pollutants over the entire hydrologic cycle. Details of this effort are described in Section 2.1.4.2. For detailed information, see "Patapsco/Back River Watershed HSPF Model Report" (MDE, 2001).

The BHEM package described above was calibrated to reproduce observed water quality characteristics for 1992-1997 conditions. The calibration of the model for these six years establishes an analytical tool that may be used to assess a range of scenarios with differing flow and nutrient loading conditions. For a detailed explanation of the calibration of the watershed model, hydrodynamic model, water quality model and sediment flux model please refer to MDE, 2001 and Wang *et al.,* (2004).

#### 4.2.1.1 Eutrophication Model Calibration

The calibration and verification of the BHEM modeling package was reviewed and accepted by various modeling technical groups, *i.e.*, Chesapeake Bay Program Modeling Subcommittee and Baltimore Harbor Stakeholder Advisory Group. The calibration of the eutrophication model is the process of modifying the model input parameters until the model output matches the set of observed water column data in an optimal way. Observed water quality, hydrological, and loading data collected during the period 1992-1997 were used to calibrate the BHEM. Figures 8 and 9 show the results of the model calibration for chlorophyll *a* and DO at station WT5.1 in both surface and bottom water. Additional time series and longitudinal data profiles from the MDE and CBP stations for various nutrient parameters may be found in Wang *et al* (2004) and are also available upon request and through the MDE TMDL website as supporting documentation. The time series data files are too large to incorporate as appendices to this report.

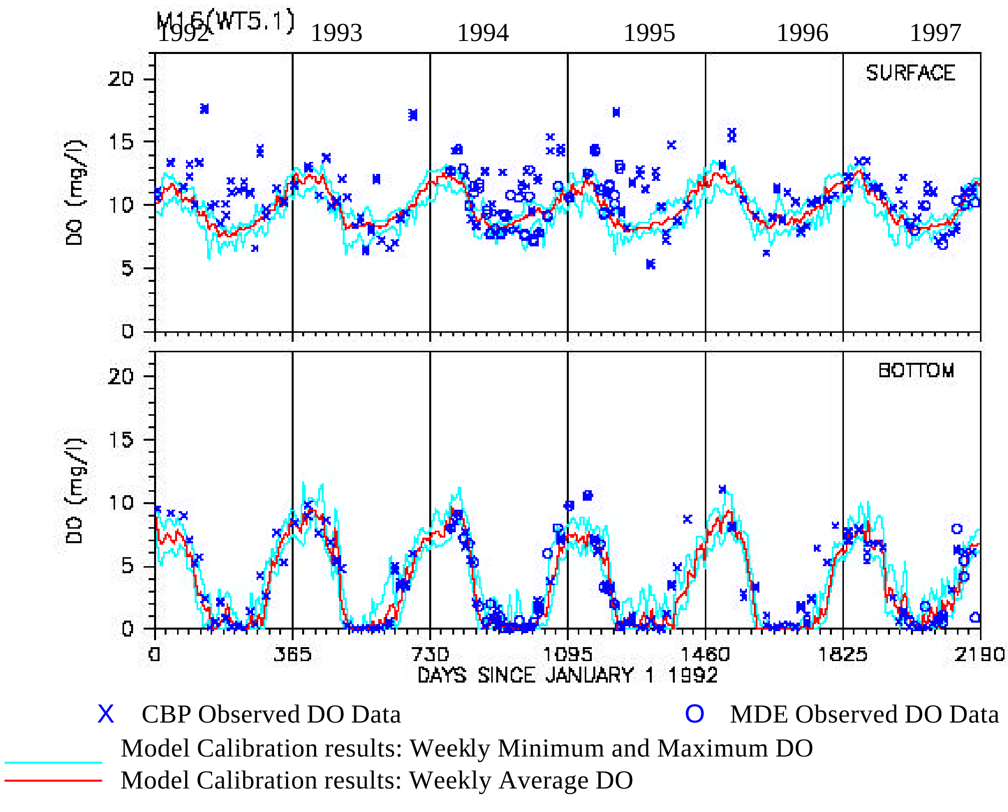
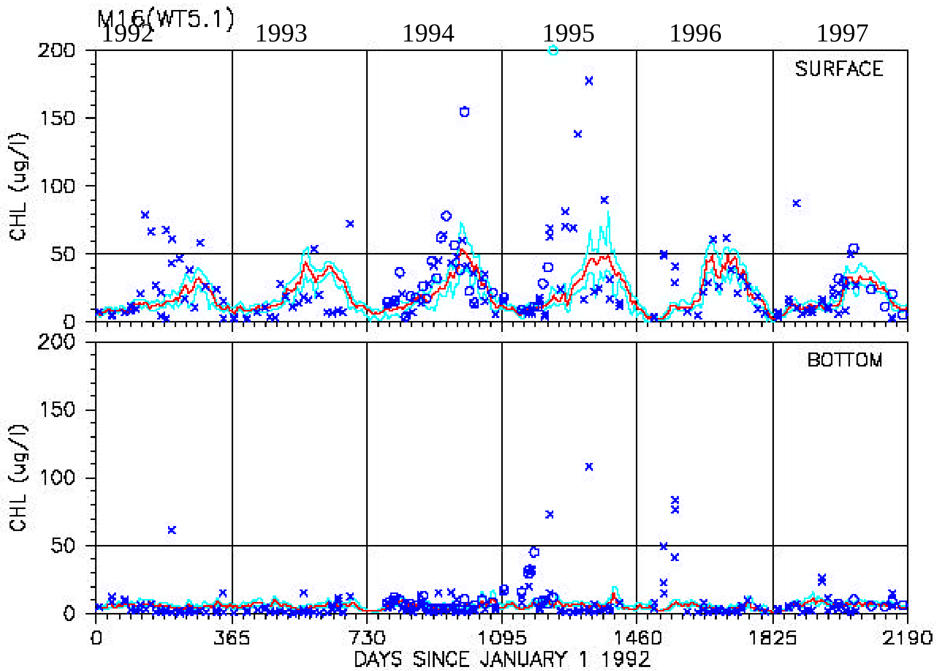



**Figure 8: Time Series of Model Calibration Results of DO in Harbor Station WT5.1**




X CBP Observed Chlorophyll *a* Data O MDE Observed Chlorophyll *a* Data

Model Calibration results: Weekly Minimum and Maximum Chlorophyll *a*

Model Calibration results: Weekly Average Chlorophyll *a*

**Figure 9: Time Series of Model Calibration Results of Chl *a* in Harbor Station WT5.1**

### 4.2.2 TMDL Analysis Frame work

The nutrient TMDL analysis consists of two broad elements: an assessment of growing season loading conditions and an assessment of average annual loading conditions. Both the growing season and the average annual flow TMDL analyses investigate the critical conditions under which symptoms of eutrophication are typically most acute. During excessively dry or wet years the flux in loadings impact water quality significantly. Additionally, water quality is impacted during late summer when flows are low, the system is poorly flushed, and sunlight and temperatures are most conducive to excessive algal production. The TMDL analysis allows a comparison of current loading conditions to future conditions that project the water quality response to various simulated load reductions of the impairing substances.

#### 4.2.2.1 Dissolved Oxygen Analytical Framework

In April 2003, the CBP published its approach to assessing the attainment of water quality criteria designed to protect the living resources of the Chesapeake Bay and its tidal tributaries, as defined by their respective designated uses. In 2005, MDE adopted the CBP DO criteria and its associated attainment methodology, utilizing DO biological reference curves to represent the spatial and temporal distribution of DO concentrations. MDE is applying this methodology using Cumulative Frequency Distributions (CFDs) for the Baltimore Harbor generated from model output, and compared against the CBP reference curves, to assess spatial and temporal DO criteria exceedances. This method quantifies the degree of criteria attainment or exceedence by incorporating the percent of area or volume of a region that meets or exceeds the DO criterion for the specific designated uses periods. Using CFDs generated from the model data, the calibrated and verified assessment results express exceedances above the reference curve (violations of the allowable criteria limit) as percentages of the total time-volume for the area. These percentages are then used to determine whether a load reduction (TMDL) is required to meet the designated use.

The CFDs are derived from empirical, biology-based field data wherever possible. The DO criteria are intended have several duration curves that reflect *in situ* conditions: 30-day mean, 7-day mean, 1-day mean and the instantaneous minimum. However, given the limitations in directly monitoring at the temporal scales required for assessing attainment of the instantaneous minimum, 1-day mean and 7-day mean criteria, EPA indicates that the states can waive attainment assessments for these criteria until monitoring at the required temporal scales is implemented or apply statistical methods to estimate probable attainment (EPA, April 2003). For these reasons, MDE will assess the DO attainment for only the 30-day component of the Open Water Use and Deep Water Use DO criteria in the Baltimore Harbor. For the Migratory Fish Nursery and Spawning Use, EPA indicates that until more data are collected to better assess the attainment of the 7-day mean and instantaneous minimum criteria of this designated use, the Open Water DO reference curve should be applied. For the Migratory Fish Nursery and Spawning Use attainment analysis, MDE utilized the Open Water DO reference curve and model output associated with the Migratory Fish Nursery and Spawning Use period. Figure 10 below is an example of the CBP DO reference curve adopted by MDE. (For more information on monitoring, assessment of DO criteria attainment, and CBP DO reference curves, please refer to the CBP document entitled "Ambient Water Quality Criteria for the Dissolved Oxygen, Water Clarity and Chlorophyll *a* for the Chesapeake Bay and its Tidal Tributaries" (EPA, 2003).

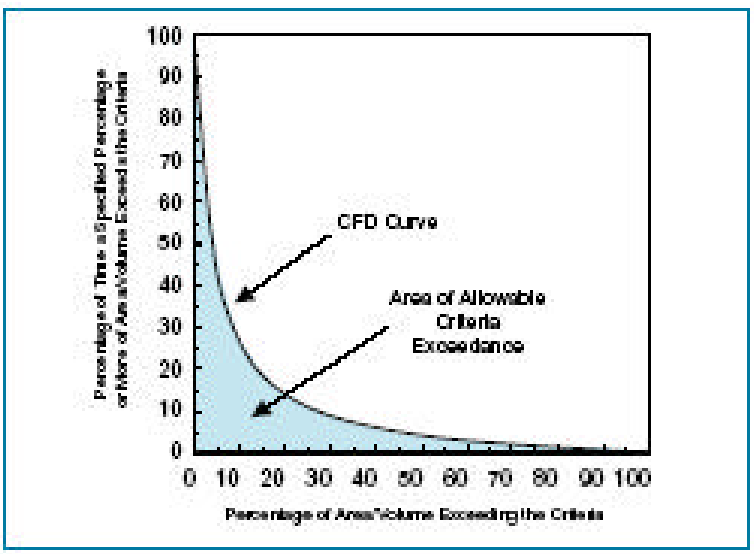



**Figure 10: Cumulative Frequency Distribution curve representing an approximately 10 percent allowable exceedance equally distributed between time and space (EPA, 2003)**

Additionally, the Deep Channel Designated Use area does not have a reference curve. The Deep Channel is defined as the region below the lower boundary of the pycnocline, extending down to the water/sediment interface. The Deep Channel Designated Use is applied from June 1st to

September 30th and requires an instantaneous minimum concentration of 1.0 mg/l. Two factors have prevented the development and application of a “reference curve” approach as used in the other segments of the water column. First, the Deep Channel portion of the Chesapeake Bay has not been monitored as part of the long-term benthic monitoring program and therefore lacks appropriate data for development of a reference curve. Second, the Deep Channel segment of the Chesapeake Bay is considered severely degraded and appropriate reference sites with similar characteristics and non-degraded conditions are not available.

Due to the unavailability of a reference curve to assess attainment, MDE has conducted an analysis to determine the percentage of time when the modeled DO concentration in the Deep Channel was below the 1.0 mg/l instantaneous minimum concentration required by the criteria. The assessment consisted of an evaluation of the modeled scenario DO concentrations versus the instantaneous minimum concentration.

#### 4.2.2.2 Chlorophyll *a* Analytical Framework

Model results were compared to the quantitative implementation of the narrative Chl *a* criteria stated in Section 3.0 as: (1) ensuring that instantaneous concentrations remain below 100 µg/l at all times and (2) minimizing exceedances of the 50 µg/l, 30-day rolling average, to a frequency that will not result in ecologically undesirable conditions.

## 4.3 Scenario Descriptions and Results

The scenarios are grouped according to *baseline conditions, future conditions,* and a m*aximum anthropogenic reduction from Baltimore Harbor scenario.* The baseline condition is intended to provide a point of reference by which to compare future scenarios that simulate conditions of a TMDL. The future conditions scenario is associated with TMDLs, while the maximum anthropogenic reduction from Baltimore Harbor scenario is used as a bounding exercise to determine if it is possible to achieve water quality standards in the Deep Channel portion of the Harbor. The baseline and future conditions scenarios were used to estimate growing season and average annual TMDLs. The period 1995-1997 corresponds to the “baseline” period in analyses described below. The following analyses allow a comparison between current water quality conditions and future conditions that project various simulated load reductions of impairing substances.

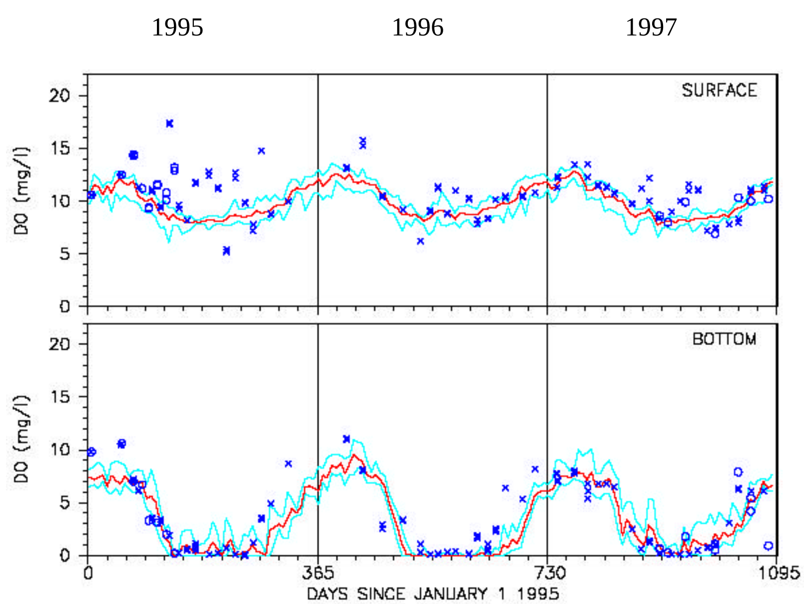
### 4.3.1 Baseline Conditions Scenario

The baseline conditions scenario represents the observed conditions of the Harbor and its tributaries from 1995-1997. Simulating the system for three years accounts for various loading and hydrologic conditions, which represent possible critical conditions and seasonal variations of the system. For example, the 1995-1997 period includes an average year (1995), a wet year (1996) and a dry year (1997). The modeling approach also specifically examines conditions during summer months when the river system is poorly flushed, and sunlight and warm water temperatures are more conducive to creating the water quality problems associated with excessive nutrient enrichment.

The nonpoint nutrient loads, including urban stormwater loads, were estimated from the HSPF model of the Patapsco and Back River watersheds. The HSPF model utilized land use information and hydrology associated with the 1995-1997 period to generate loading estimates for this scenario. The HSPF model simulates stormwater and nonpoint loadings by integrating all natural and human-induced sources, including direct atmospheric deposition and loads from septic tanks. For point source loads, this scenario uses the municipal WWTP and industrial discharge monitoring data from 1995-1997. Additionally, time series and longitudinal data profiles from the MDE and CBP stations for various nutrient parameters are available upon request and through the MDE TMDL website as supporting documentation. The time series data files are too large to incorporate as appendices to this report.

### 4.3.2 Baseline Conditions Scenario Results

Results of DO and Chl *a* concentrations represented in the baseline scenario are summarized in Figures 11 and 12. Figure 11 displays the observed and modeled DO data while Figure 12 displays the observed and modeled Chl *a* concentrations at station WT5.1 in both surface and bottom water.



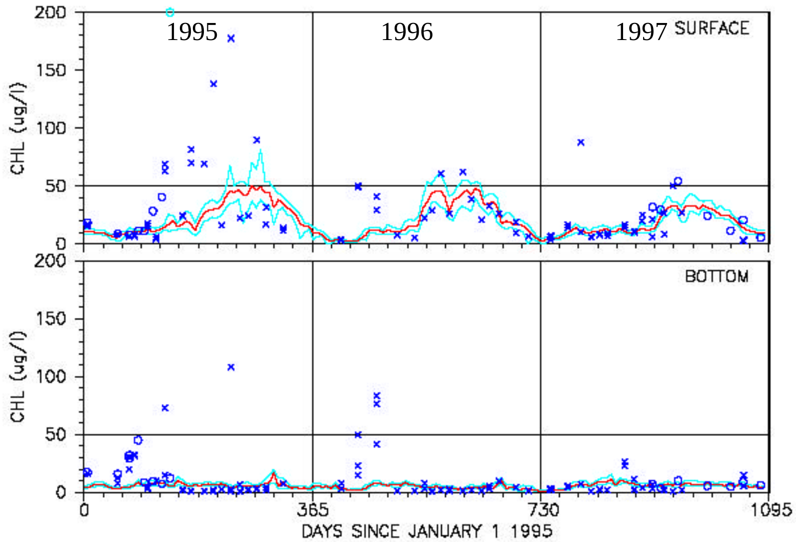

X CBP Observed DO Data

O MDE Observed DO Data

Model Calibration results: Weekly Minimum and Maximum DO

Model Calibration results: Weekly Average DO

**Figure 11: Time Series of Model Results for the Baseline Conditions Scenario for DO in Baltimore Harbor Station WT5.1**




X CBP Chlorophyll *a* Observed data
O MDE Chlorophyll *a* Observed data
Model Calibration results: Minimum and Maximum Chlorophyll *a*
Model Calibration results: 30-day Rolling Average Chlorophyll *a*

**Figure 12: Model Results for the Baseline Conditions Scenario for Chl *a* in Baltimore Harbor Station WT5.1**

#### 4.3.2.1 Dissolved Oxygen Assessment of the Baseline Conditions Scenario

For the DO assessment of the baseline conditions scenario in the Baltimore Harbor, the CBP reference curve approach for the Migratory Fish and Spawning, Open Water and Deep Water Designated Uses was used. Due to limited data in the Baltimore Harbor, the calibrated model output generated during the baseline conditions scenario was used for the attainment analysis. The attainment assessment procedure is as follows: First, using the calibrated model DO output for the baseline conditions scenario period (1995-1997), DO attainment curves are developed for the Migratory Fish and Spawning, Open Water and Deep Water Designated Uses. Second, the reference curves from the CBP are obtained. Third, MDE generated attainment curves for each of the designated use areas are compared to the corresponding CBP reference curves. The results of the comparison allow MDE to quantify the degree of criteria attainment or exceedance based on the amount of area or volume of a specific designated use region.

A summary of the attainment assessment is presented in Table 7. The baseline scenario assessment of the DO criteria attainment for the Migratory Fish Spawning and Nursery Designated Use, which applies from February 1$^{st}$ to May 31$^{st}$, indicates that there is a period of nonattainment in time and volume that represents a 3% exceedance of the criteria (See Appendix A, Figure A4). The assessment of DO criteria attainment for the Open Water Designated Use, which applies from June 1$^{st}$ to September 30$^{th}$ indicates that there is a period of nonattainment in time and volume that represents a 3% exceedance of the criteria (See Appendix A, Figure A5). The assessment of DO criteria attainment for the Open Water Designated Use, which also applies from October $1^{st}$ to January $31^{st}$, indicates that there is a period of nonattainment in time and volume that represents a 2% exceedance of the criteria (See Appendix A, Figure A6). The assessment of the DO criteria attainment for the Deep Water Designated Use, which applies from June $1^{st}$ to September $30^{th}$, indicates that there is a period of nonattainment in time and volume that represents a 23% exceedance of the criteria (See Appendix A, Figure A7).

MDE conducted an analysis of the baseline scenario to determine the percentage of time when the modeled DO concentration in the Deep Channel was below the 1.0 mg/l instantaneous minimum concentration required by the criteria. The assessment consisted of an evaluation of the modeled baseline scenario DO concentrations versus the instantaneous minimum concentration. The result of this assessment indicates that the Deep Channel exceeded the criteria 87% of the time and volume.

The Deep Channel segment of the Baltimore Harbor is considered degraded due to two related factors. The first is the dredging that occurs in the channel, allowing for the passage of ships in and out of the commercial port areas within the Harbor. The dredging has resulted in modifications of the Harbor hydrodynamic circulation patterns that effectively separate the Deep Channel portion of the water column from the remaining water column during the late spring through fall seasons. This occurs due to temperature and salinity barriers that do not allow mixing of surface waters with deep channel waters. Second, maintenance dredging and propeller wash from ship movements result in the periodic disturbance and/or removal of any biological communities that may be established during the interval between dredging events.

**Table 7: Baseline Conditions Scenario: Percent Nonattainment of Dissolved Oxygen Criteria in the Baltimore Harbor**

| Period | Designated Use | % Nonattainment |
|---|---|---|
| February $1^{st}$ to May $31^{st}$ | Migratory Fish Spawning and Nursery | 3% |
| June $1^{st}$ to September $30^{th}$ | Open Water | 3% |
| | Deep Water | 23% |
| | Deep Channel | 87% |
| October $1^{st}$ to January $31^{st}$ | Open Water | 2% |
| February $1^{st}$ to January $31^{st}$ | Open Water | 0% |

#### 4.3.2.2 Chlorophyll *a* Assessment for the Baseline Conditions Scenario

The Chl *a* levels in the baseline conditions scenario output were analyzed using a 30-day rolling average as referenced in Section 2.3. The analysis shows that in both surface and bottom water, Chl *a* concentrations exceeded 50 µg/l during early spring and the summer months of 1995 (see Figure 12) and occasionally were observed to exceed 100 µg/l. Chl *a* rarely exceeded 50 µg/l during 1996 and 1997.

### 4.3.3 Maximum Anthropogenic Reduction from Baltimore Harbor Scenario

Based on the exceedances of the water quality criteria associated with the baseline scenario, particularly in the Deep Channel Designated Use, MDE conducted a scenario run to determine whether the act of removing anthropogenic nutrient sources, both point and nonpoint, would result in the attainment of water quality standards within the Deep Channel Designated Use region of the Baltimore Harbor. This scenario provides an estimate of the water quality response if the maximum amount of anthropogenic nutrient loading reductions were made in the Baltimore Harbor watershed. To conduct this analysis, the water quality model was run with nutrient loads from point and nonpoint sources reduced to zero. The sediment model was allowed to continue running from the initial condition set by the calibration, and the upper Bay loading conditions were based on the calibration period. With all sources of nutrients removed the model was allowed to run for six years to determine the impact on water quality.

### 4.3.4 Maximum Anthropogenic Reduction Scenario Results

Modeled results for the maximum anthropogenic reduction scenario of DO levels in the surface and bottom waters at station WT5.1 are summarized in Figure 13. Under this scenario, the attainment assessment results indicate that DO concentration will be < 1.0 mg/l in the Deep Channel for approximately 57.8% of the time and volume that Deep Channel criteria are in effect. Therefore, the Deep Channel criteria are not achieved in this scenario.

The results of this model scenario predict that with the removal of anthropogenic point and nonpoint sources of nutrients, the Baltimore Harbor will not fully meet the Deep Channel Designated Use water quality standard although all other standards will be met. The constant manipulation and sequential deepening of the channel over time has created a system in which the water in the Harbor channel is effectively sealed off from mixing action during the summer months due to the hydrodynamic circulation pattern. As a result, oxygen is not transferred from the upper portions of the water column into the Baltimore Harbor channel. Consequently, the oxygen that is present in the channel during the winter and spring seasons is being consumed but not replaced during the summer months. The maximum anthropogenic reduction from Baltimore Harbor scenario indicates that the hydrodynamics of the Harbor system create conditions whereby the Harbor channel becomes anoxic for periods during the summer.

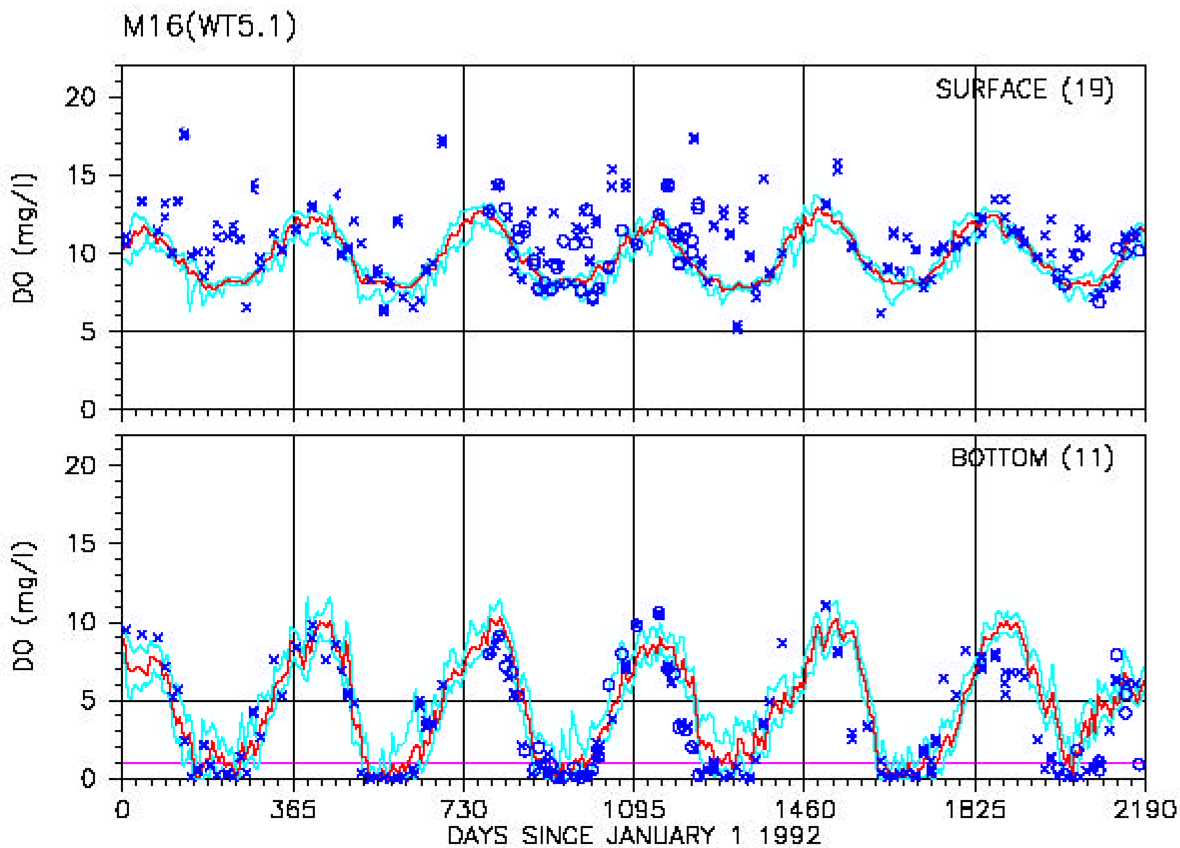



**Figure 13: Maximum Anthropogenic Reduction Scenario model results for DO levels in surface and bottom waters in Baltimore Harbor at Station WT5.1**

### 4.3.5 Future Conditions (TMDL) Scenario

This scenario provides an estimate of future conditions in the Baltimore Harbor system based on a simulation with 1) WWTP discharges set at design flow and nitrogen and phosphorus concentrations based on Maryland's Enhanced Nutrient Reduction (ENR) strategy, 2) industrial discharges based on permitted flow and concentrations of nitrogen and phosphorus reduced based on estimates of loading reductions due to technological improvements, and 3) urban stormwater and agricultural loads for all subwatersheds draining into the Baltimore Harbor reduced by 15%. Based on the results of the Maximum Anthropogenic Reduction Scenario, which indicated the Deep Channel Designated Use would not achieve water quality standards at all times with the removal of all anthropogenic nutrient sources, MDE developed this scenario to represent the current limit of technology for municipal WWTPs, and an aggressive nutrient reduction goal for industrial point sources and nonpoint sources. This scenario was used to estimate both growing season and average annual flow TMDLs.

The point source loads from the Patapsco and Cox Creek WWTPs were based on National Pollutant Discharge Elimination System (NPDES) permit flows and ENR-based concentrations of TN equal to 4 mg/l annual average (3 mg/l in May–October and 5 mg/l in November–April) and TP of 0.3 mg/l. These levels are consistent with Maryland's Tributary Strategy and ENR Policy.

Industrial point source flows and concentrations vary for the different facilities, and their effluent loadings were based on recent performance levels, after having already achieved significant loading reductions since the initial baselines established in 1985. Their recent performance levels were then adjusted based on additional potential loading reductions.

Urban stormwater and agricultural TN and TP loads for this scenario were reduced by 15% from their baseline loads in order to reach the water quality goals for Chesapeake Bay waters. The baseline urban stormwater and agricultural loads are estimated by the HSPF watershed model as described in "Patapsco/Back River Watershed HSPF Model Report" (MDE, 2001). The loading reductions are based on the implementation of urban and agricultural Best Management Practices (BMPs) that are used to reduce pollution from these land uses. The load reduction was quantified based on nutrient removal efficiency ratings that have been developed for various BMPs. This approach is based on the assumptions made by the CBP in its Chesapeake Bay watershed modeling effort and is consistent with the method used to develop Maryland's Tributary Strategies.

The Harbor watershed land uses are comprised of approximately 55% urban, 15% agricultural, and 29% forest. An assessment of the urban and agricultural land use components indicate that the baseline load for urban land use is approximately 43% of the average annual TN load, 75% of the average annual TP load, 49% of the growing season TN load, and 78% of the growing season TP load from watershed land uses. Similarly, the baseline load for agricultural landuse is approximately 33% of the average annual TN load, 12% of the average annual TP load, 24% of the growing season TN load, and 11% of the growing season TP load from watershed land uses. Other non-urban stormwater and non-agricultural nutrient loads, including forest loads, represent the remaining contribution to the total load.

### 4.3.6 Future Conditions (TMDL) Scenario Results

DO and Chl *a* time series results for water quality station WT5.1 for surface and bottom waters for the TMDL scenario are summarized in Figures 14 and 15. As displayed in Figure 14, under the TMDL scenario, the minimum DO concentrations at water quality station WT5.1 are above 6.5 mg/l in the surface water. However, the bottom water DO decreases to below 1 mg/l and approaches 0 mg/l during the summer months. It can be observed that the anoxic condition starts later and ends earlier than in the baseline scenario. As displayed in Figure 15, under the TMDL scenario, Chl *a* concentrations at Water Quality Station WT5.1 remain below 50 µg/l in both the surface and bottom waters. Additional time series and longitudinal data profiles from the MDE and CBP stations for various nutrient parameters are available upon request and through the MDE TMDL website as supporting documentation. The time series data files are too large to incorporate as appendices to this report.

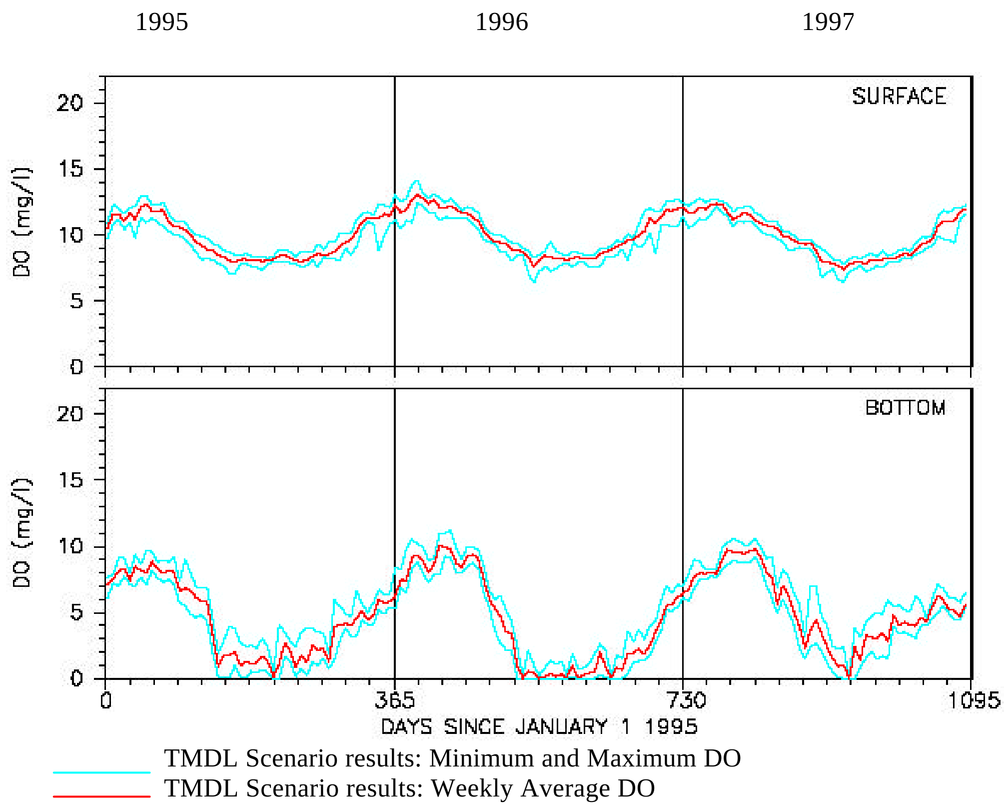



**Figure 14: Time Series of Model Results for the TMDL Scenario for DO at Station WT5.1**

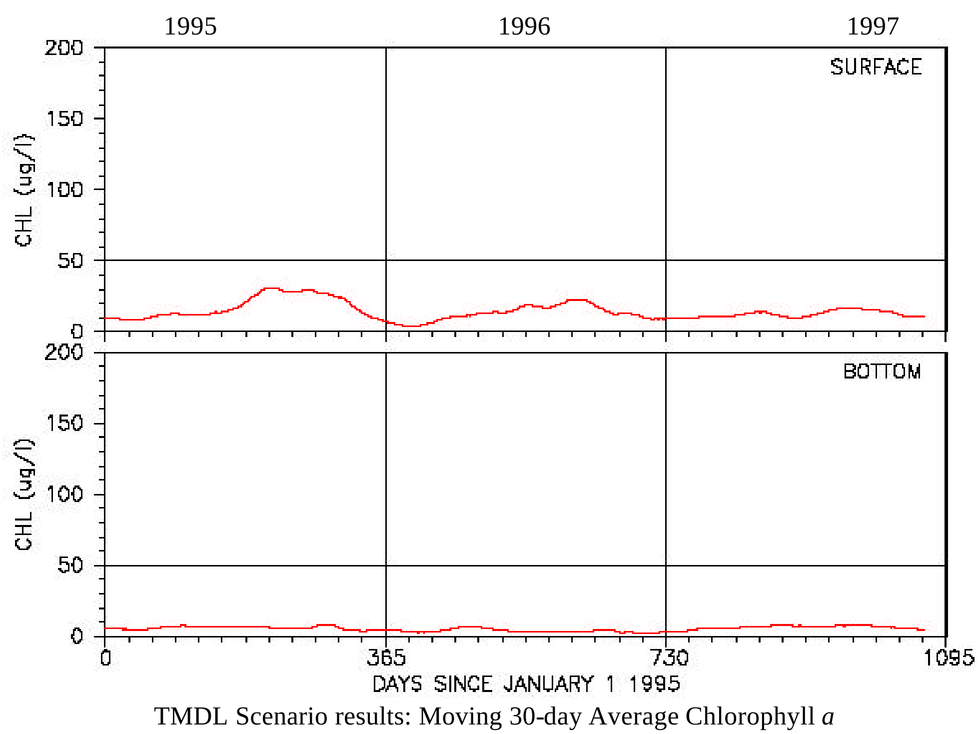



**Figure 15: Time Series of Model Results for the TMDL Scenario for Chl *a* at Station WT5.1**

### 4.3.6.1 Dissolved Oxygen Criteria Attainment Assessment of the Future Conditions (TMDL) Scenario

The DO attainment assessment of the TMDL scenario in the Baltimore Harbor was performed as explained in the baseline conditions scenario assessment (Section 4.3.2.1). The attainment and reference curve assessments generated for the Migratory Fish Spawning and Nursery, Open Water, and Deep Water Designated Uses are provided in Appendix B. The following is a summary of the attainment assessment analysis.

The TMDL scenario assessment of the DO criteria attainment for the Migratory Fish Spawning and Nursery Designated Use, which applies from February 1st to May 31st indicates that the attainment curve is always below the reference curve and that the designated use is met 100% of the time (See Appendix B, Figure B1). The assessment of the DO criteria attainment for the Open Water Designated Use, which applies from June 1st to September 30th and from October 1st to January 31st, indicates that there is a period of nonattainment; however, this period is not significant enough in time or volume affected to cause an exceedance of the criteria, therefore the designated use is being met (See Appendix B, Figures B2 and B3). The assessment of the DO criteria attainment for the Deep Water Designated Use, which applies from June 1st to September 30th, indicates that there is a period of nonattainment in time and volume that represents a 7% exceedance of the criteria (See Appendix B, Figure B4). The Deep Water DO criteria allows a restoration variance of up to 7% applied spatially and/or temporally from June 1 to September 30 (COMAR 26.08.02.03-3 C(8)(e)(vi)); therefore, the assessment of the DO criteria indicates that the designated use is attained. During the remaining months of the year, these areas are designated as Open Water and the criteria are met.

MDE conducted an analysis of the TMDL scenario to determine the percentage of time when the modeled DO concentration in the Deep Channel was below the 1.0 mg/l instantaneous minimum concentration required by the criteria. The assessment consisted of an evaluation of the modeled TMDL scenario DO concentrations versus the instantaneous minimum concentration. The result of this assessment indicates that the Deep Channel exceeded the criteria 78.5% of the time and volume.

During the October 1st to May 31st period the Deep Water and Deep Channel Designated Use areas are considered Open Water Designated Use. Results of the attainment assessment utilizing the reference curve approach indicate that the criteria are achieved. Table 8 presents a summary of the Baltimore Harbor DO attainment assessment for the TMDL Scenario.

**Table 8: TMDL Scenario: Percent Nonattainment of Dissolved Oxygen Criteria in the Baltimore Harbor**

| Period | Designated Use | % Nonattainment |
|---|---|---|
| February 1st to May 31st | Migratory Fish Spawning and Nursery | 0% |
| June 1st to September 30th | Open Water | 0% |
| | Deep Water* | 7% |
| | Deep Channel | 78.5% |
| October 1st to January 31st | Open Water | 0% |

*The Deep Water designated use DO criterion allows a restoration variance of up to 7% applied spatially and/or temporally from June 1 to September 30.

#### 4.3.6.2 Chlorophyll *a* Criteria Attainment Assessment of the Future Conditions (TMDL) Scenario

Under the TMDL scenario, Chl *a* concentrations at Water Quality Station WT5.1 remain below 50 µg/l in both the surface and bottom waters, indicating attainment of the narrative criteria for Chl *a* (see Figure 15 above).

### 4.4 TMDL Loading Caps

The TMDLs for nitrogen and phosphorus are presented below. The detailed calculation of TMDL loading allocations can be found in Appendix C.

For the period of May 1 through October 31, the following TMDLs apply:

***Growing Season TMDLs:***

**NITROGEN TMDL** 2,145,750 *lbs/growing **season***

**PHOSPHORUS TMDL** 149,152 *lbs/**growing season***

The average annual TMDLs for nitrogen and phosphorus are:

***Average Annual TMDLs:***

**NITROGEN TMDL** 5,323,963 ***lbs/year***

**PHOSPHORUS TMDL** 324,309 ***lbs/year***

### 4.5 Load Allocations Between Point Sources and Nonpoint Sources

This section describes one viable allocation of loads between point sources, nonpoint sources, and the margin of safety for the nitrogen and phosphorus TMDLs. A more detailed overview of potential allocations to various sources is provided in the accompanying point and nonpoint Technical Memorandums. The allocations presented are quantified for growing season (May 1st through October 31st) and average annual conditions. The State reserves the rights to revise these allocations provided the allocations are consistent with the achievement of water quality standards.

#### 4.5.1 Growing Season TMDL Allocations

**Load Allocations (LA)**

- **Nonpoint Source Loads**

  The nonpoint source loads represent the loads from agricultural land, forest and other herbaceous land, and septic systems. The nitrogen and phosphorus loading reductions simulated in the TMDL scenario represent a 15% reduction from the baseline agricultural loads and an explicit margin of safety (MOS) that is approximately 5% of the reduced agricultural loads for the growing season period. The other nonpoint source loads such as septic systems and forest loads were not reduced from baseline condition levels. See Appendix C for LA calculations.

**Waste Load Allocations (WLA)**

- **Stormwater Loads**

In November 2002, EPA advised States that Municipal Separate Storm Sewer System (MS4) stormwater discharges must be addressed by the wasteload allocation (WLA) (See 40 C.F.R. § 130.2(h)). Therefore, MS4 communities regulated by NPDES permits will have their loads reflected in the WLA. The urban stormwater loads of nitrogen and phosphorus simulated in the Baltimore Harbor TMDL scenario are reduced 15% from the baseline urban stormwater loads.

The TMDL, including loads from urban stormwater discharges, is now expressed as:

**TMDL = WLA [NPDES point sources* + regulated stormwater point source] + LA + MOS + FA (if applicable)**

*NPDES point sources include municipal and industrial wastewater treatment plants.

Phase I and Phase II MS4's stormwater permits will be considered point sources subject to WLA assignment in the TMDL. EPA recognizes that limitations in the available data and information usually preclude stormwater allocations to specific outfalls. Therefore, EPA guidance allows the urban stormwater WLA to be expressed as a gross allotment, rather than individual allocations for separate pipes, ditches, construction sites, etc.

Estimating a load contribution to a particular waterbody from the stormwater is imprecise, given the variability in sources, runoff volumes, and pollutant loads over time. Therefore, the urban stormwater WLA is based on the best loadings estimate currently available. For the Baltimore Harbor the current data allows the urban stormwater allocation to be defined separately for Baltimore City, Baltimore County, Anne Arundel County, Carroll County, and Howard County. However, it should be noted that these WLAs aggregate municipal and industrial stormwater, including the loads from highways and construction activity.

- **Municipal and Industrial Wastewater Treatment Plants Loads**

During the 1995-1997 baseline conditions period, there were seven permitted point sources discharging nutrients into the Baltimore Harbor. For the TMDLs scenario, all seven point sources were given an allocation. In addition to the seven permitted point sources considered in the baseline scenario, the Cox Creek Dredged Material Containment Facility (DMCF) is included in the TMDL scenario and given an allocation. The Cox Creek DMCF was not discharging during the 1992-1997 period, therefore was not considered in the calibration of the model and the baseline scenario.

The Patapsco and Cox Creek WWTPs maximum allowable current permit flows are used for this scenario. Concentrations were adjusted to reflect Maryland's ENR Strategy of a maximum total nitrogen concentrations of 3 mg/l from May 1$^{st}$ to October 31$^{st}$. Total phosphorus limits are 0.3 mg/l year round. Industrial point source flows and concentrations vary from plant to plant, and are set at levels based on the implementation of best available technologies to achieve water quality criteria in both local and Chesapeake Bay waters. These allocations are also consistent with Maryland's current Tributary Strategy. All significant point sources are addressed by this allocation and are described further in the technical memorandum entitled *"Significant Nutrient Point Sources in the Baltimore Harbor Watershed"*. The nitrogen and phosphorus allocations for growing season conditions are presented in Table 9. See Appendix C for WLA calculations.

**Table 9: Growing Season Allocations**

| | **Total Nitrogen** ***(lbs/growing season)*** | **Total Phosphorus** ***(lbs/growing season)*** |
|---|---|---|
| Nonpoint Source[1] | 459,912 | 12,776 |
| Point Source[2] | 1,642,014 | 113,212 |
| FA | 33,204 | 22,848 |
| MOS[3] | 10,620 | 316 |
| Total | 2,145,750 | 149,152 |

1. Does not include regulated urban stormwater loads.
2. Includes regulated urban stormwater loads.
3. Approximately 5% of the reduced agricultural loads.

### 4.5.2 Average Annual TMDL Allocations

**Load Allocations (LA)**

- **Nonpoint Source Loads**
  The average annual nonpoint source loads represent the average loads from agricultural land, forest and other herbaceous land, and septic systems. The nitrogen and phosphorus loadings simulated in the TMDL scenario represent a 15% reduction from the baseline agricultural loads and an explicit MOS that is approximately 5% of the reduced agricultural loads. Other nonpoint source loads such as septic systems and forest and other herbaceous loads were not reduced from baseline condition levels. See Appendix C for LA calculations.

**Waste Load Allocations (WLA)**

- **Urban Stormwater Loads**

  For the average annual TMDL, the urban stormwater loads of nitrogen and phosphorus simulated in the TMDLs scenario represent a 15% reduction in TN and TP from average annual baseline urban stormwater loads.

- **Municipal and Industrial Wastewater Treatment Plants Loads**

  The Patapsco and Cox Creek WWTPs maximum allowable current permit flows are used. The TN concentration was set to a maximum of 3 mg/l from May 1st to October 31st and 5 mg/l from November 1st to April 30th. The TP concentrations for the two plants were set at 0.3 mg/l year-round. Industrial point source flows and concentrations vary from plant to plant, and they are set at levels based on the implementation of best available technologies to achieve water quality criteria in both local and Chesapeake Bay waters. These allocations are also consistent with Maryland's current Tributary Strategy. All significant point sources are addressed by this allocation and are described further in the technical memorandum entitled *"Significant Nutrient Point Sources in the Baltimore Harbor Watershed"*. The nonpoint and point source nitrogen and phosphorus allocations for average annual load conditions are shown in Table 10. See Appendix C for WLA calculations.

**Table 10: Average Annual Allocations**

| | **Total Nitrogen *(lbs/yr)*** | **Total Phosphorus *(lbs/yr)*** |
|---|---|---|
| Nonpoint Source[1] | 1,246,036 | 34,654 |
| Point Source[2] | 3,976,215 | 243,127 |
| FA | 66,410 | 45,690 |
| MOS[3] | 35,302 | 838 |
| Total | 5,323,963 | 324,309 |

1. Does not include regulated urban stormwater loads.
2. Includes regulated urban stormwater loads.
3. Approximately 5% of the reduced agricultural loads.

### 4.6 Margin of Safety (MOS) and Future Allocation (FA)

A MOS is required as part of a TMDL in recognition of many uncertainties in the understanding and simulation of water quality in natural systems. For example, knowledge is incomplete regarding the magnitude of pollutant loads from various sources due to normal variations in precipitation and process changes, and the specific impacts of those pollutants on the chemical and biological quality of complex, natural waterbodies. The MOS is intended to account for such uncertainties in a manner that is conservative from the standpoint of environmental protection.

Based on EPA guidance, the MOS can be achieved through two approaches (EPA, April 1991). One approach is to explicitly reserve a portion of the loading capacity as a separate term in the TMDL (*i.e.*, TMDL = LA + WLA + MOS). The second approach is to incorporate the MOS as conservative assumptions used in the TMDL analysis (implicit MOS). Maryland has adopted a MOS for these TMDLs using the first approach. For both the growing season and the average annual flow TMDLs, the load allocated to the MOS is approximately 5% of the reduced agricultural loads for nitrogen and phosphorus. The MOS is not considered a part of the reduced agricultural loads; it is a separate term in the TMDL equation. That is, the sum of the MOS and the reduced agricultural loads is equal to the load reduction that was used in the model run to determine the TMDL.  These explicit nitrogen and phosphorus margins of safety are presented in Tables 9 and 10.  See Appendix C for MOS calculations.

Future Allocation represents an allowance for future growth, which accounts for reasonably foreseeable increases in pollutant loads (40 CFR 130.33(b)(9)).  Future growth can be included in the TMDL by reserving a separate allocation for this purpose or by allocating acceptable wasteloads and loads in a way that incorporates potential growth.  In the Baltimore Harbor nutrients TMDL analysis, the first approach is used for the nitrogen and phosphorus TMDLs to address the contingency that a seasonal nitrogen limit based on 3 mg/l of nitrogen and a limit of 0.3 mg/l of phosphorus may not be practical for ENR technology at some facilities.

### 4.7 Summary of Total Maximum Daily Loads

The Growing Season TMDLs, applicable from May 1- October 31, for the Baltimore Harbor:

**For Nitrogen:**

| **TMDL (*lbs/growing season*)** | = | **LA** | + | **WLA** | + | **FA** | + | **MOS** |
|---|---|---|---|---|---|---|---|---|
| **2,145,750** | = | **459,912** | + | **1,642,014** | + | **33,204** | + | **10,620** |

**For Phosphorus:**

| **TMDL (*lbs/growing season*)** | = | **LA** | + | **WLA** | + | **FA** | + | **MOS** |
|---|---|---|---|---|---|---|---|---|
| **149,152** | = | **12,776** | + | **113,212** | + | **22,848** | + | **316** |

The average annual flow TMDLs for the Baltimore Harbor:

**For Nitrogen:**

| **TMDL (*lbs/year*)** | = | **LA** | + | **WLA** | + | **FA** | + | **MOS** |
|---|---|---|---|---|---|---|---|---|
| **5,323,963** | = | **1,246,036** | + | **3,976,215** | + | **66,410** | + | **35,302** |

**For Phosphorus:**

| **TMDL (*lbs/year*)** | = | **LA** | + | **WLA** | + | **FA** | + | **MOS** |
|---|---|---|---|---|---|---|---|---|
| **324,309** | = | **34,654** | + | **243,127** | + | **45,690** | + | **838** |

Where:

TMDL = Total Maximum Daily Load
LA = Load Allocation (Nonpoint Source)
WLA = Waste Load Allocation (Point Source)
MOS = Margin of Safety

**Average Daily Loads:**

The growing season TMDLs will result in average daily loads of approximately 11,662 lbs/day of nitrogen and 817 lbs/day of phosphorus. Similarly, the average annual flow TMDLs will result in average daily loads of approximately 14,586 lbs/day of nitrogen and 889 lbs/day of phosphorus. Since nutrients do not result in acute impacts and the impacts of a given amount of nutrients vary seasonally, these average daily loads are provided for informational purposes, since daily loads will not be a factor controlling the ability to meet the water quality standards.

## 5.0 ASSURANCE OF IMPLEMENTATION

Section 303(d) of the Clean Water Act and current EPA regulations require reasonable assurance that the TMDL load and wasteload allocations can and will be implemented in order to achieve water quality standards. In the Baltimore Harbor, both the TMDL and maximum anthropogenic reduction analyses indicate that reductions of the nutrients nitrogen and phosphorus from all sources, including the elimination of all point and nonpoint sources, do not result in the water quality standards being met in all waters of the Harbor at all times. Under the TMDL scenario the Deep Channel Designated Use region violates the water quality standard 78.5% of time and volume. Under the maximum anthropogenic reduction scenario, the Deep Channel Designated Use region violates the water quality standard 57.8% of time and volume. Under both of these scenarios, however, the water quality standards are achieved for all other designated uses that are applicable in the Harbor.

The implementation of point source nutrient controls that will be an integral component to meet water quality standards in the Harbor will be executed through the State's Enhanced Nutrient Reduction (ENR) strategy and NPDES permits. The ENR program provides grant funds to local governments to retrofit or upgrade WWTPs from BNR to ENR at their currently approved design capacity. Enhanced nutrient removal technologies allow sewage treatment plants to provide a highly advanced level of nutrient removal. The ENR strategy builds on the success of the biological nutrient removal (BNR) program already in place. Currently, the Patapsco WWTP is designing its new ENR facility, Cox Creek WWTP is planning its new ENR facility, and the Back River WWTP (supplier of processing water to ISG) is planning its new ENR facility. The completion of the planning, design, and construction of these facilities will lead to significant reductions in nutrients discharged into Baltimore Harbor. Upon completion of the ENR upgrades, subsequent NPDES permits for the municipal WWTPs will include nutrient loading limits that will be based upon achieving ENR levels of treatment. The significant industrial NPDES (>0.5 mgd) point sources will also have nutrient limits incorporated into subsequent permits that are reissued following the completion of the TMDL. The reissued NPDES permits will attempt to maintain consistency with the assumptions made in the TMDLs (*e.g.*, flow, nutrients effluent concentrations, DO, *etc.*). Deadlines for completion of ENR upgrades will be incorporated into NPDES permits based on the State's ENR upgrades schedule and, if the permitting timeframe is shorter than the ENR schedule, permits will reflect what can reasonably be accomplished with consideration to the complexity of the engineering and the availability of resources.

The implementation of nonpoint source nutrient controls that will be an integral component to achieve water quality standards in the Harbor will be executed through two approaches, stormwater NPDES permits and cooperative agricultural reductions. In November 1990, EPA required jurisdictions with a population greater than 100,000 to apply for NPDES Permits for stormwater discharges. The five jurisdictions where the Baltimore Harbor watershed is located, Baltimore City, Baltimore County, Anne Arundel County, Carroll County and Howard County, are required to participate in the stormwater NPDES program, and must comply with the NPDES Permit regulations for stormwater discharges. Subsequently, stormwater management programs have been implemented by the Counties and the City to control MS4 discharges to the maximum extent practicable. For example, Baltimore County stormwater management program encompasses numerous elements including: erosion and sediment control, post-construction runoff management, controlling pollutants associated with road maintenance activities, public education and outreach, and illicit discharge detection and elimination. Additionally, in targeted watersheds, Baltimore County is required to implement watershed restoration for 10% of the County's total impervious surface cover. Baltimore City is required to implement those watershed restoration activities described above for addressing 20% of the City's impervious surfaces. In order to meet this goal, annually, the City will have at least two restoration projects in study, two in design, and two under construction. A brief description of each project, phase, and cost can be found in the City's NPDES stormwater annual report. Details of the County and City programs elements are available through MDE's Water Management Administration – NPDES Stormwater Program.

Additional significant planned implementation measures in the Baltimore Harbor watershed involve the upgrade or separation of combined sewer systems in the City and the upgrade of sanitary sewer systems in Baltimore County. In 2002, Baltimore City, MDE, and U.S. Environmental Protection Agency (EPA) entered into a civil consent decree to address SSOs and combined sewer overflows (CSOs)[1] within its jurisdictional boundaries. <u>See</u> <u>U.S., et al., v. Mayor and City Council of Baltimore</u>, JFM-02-12524, Consent Decree (entered Sept. 30, 2002). Similarly, in 2005, Baltimore County, MDE and EPA entered into a civil consent decree to address SSOs in the County. <u>See</u> <u>U.S., et al. v. Baltimore County</u>, AMD-05-2028, Consent Decree (entered Sept. 20, 2006). The consent decrees require the City and the County to adopt and implement a long term control plan ("LTCP") to evaluate their sanitary sewer systems and to repair, replace, or rehabilitate the system as indicated by the results of those evaluations, with all work to be completed by January 2016 for Baltimore City and by March 2020 for Baltimore County.

Maryland's Water Quality Improvement Act requires that comprehensive and enforceable nutrient management plans be developed, approved and implemented for all agricultural lands throughout Maryland. This act specifically requires that nutrient management plans for nitrogen be developed and implemented by 2002, and plans for phosphorus be completed by 2005. It is reasonable to expect that nonpoint loads can be reduced during growing season conditions. The nutrient load sources during growing season include dissolved forms of the impairing substances from groundwater, the effects of agricultural ditching and animals in the stream, and deposition of

[1] A "combined sewer system" is a sewer system in which stormwater and sanitary sewerage are conveyed through a common set of pipes for treatment at a wastewater treatment plant. A CSO is an overflow from such a combined system. Baltimore City agreed in the Consent Decree to separate the sanitary and stormwater lines in the small area served by a combined system and has completed that separation.

nutrients and organic matter to the streambed from higher flow events. When these sources are controlled in combination, it is reasonable to achieve agricultural nonpoint reductions of the magnitude identified by this TMDL allocation.

Additionally, Howard County is developing a Watershed Restoration Action Strategy for its portion of the Lower North Branch of the Patapsco River (approximately 38 of 118 square miles). The county will utilize this strategy to identify and prioritize watershed restoration efforts, which will include the reduction of nutrient loads from the watershed.

The legislative and policy-derived programs described above will result in significant nutrient reductions and the achievement of water quality standards for all designated uses in the Baltimore Harbor except the Deep Channel. Based on information generated in the TMDL analysis, MDE is unable to ensure that the Deep Channel Designated Use water quality criterion can be met at all times that it is applicable. The regions to which the Deep Channel designated use applies represent approximately 10% of the area of the Harbor. The region subject to potential non-attainment of criteria represents < 5% of the area of the Harbor. The volume of water that does not meet the dissolved oxygen criteria represents approximately 3% of the total volume of the Harbor.

MDE is unable to assure attainment of the Deep Channel Designated Use due to the effects of 170 years of dredging that has incrementally deepened and expanded the size of the Harbors' navigation channels and their associated turning basins and anchorages. As a result, the Harbor has been hydrologically modified. In a portion of the main navigation channel, from the mouth of the Harbor to Fort McHenry, it has been observed that water from the upper portion of the water column does not mix with the lower portion of the water column. This observed stratification of the water column, and the lack of mixing associated with it, occurs every spring/summer/fall. As a result, there are limited regions within the navigation channel (Deep Channel Designated Use) that do not meet the dissolved oxygen criteria during the observed spring/summer/fall stratification period.

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