Total Maximum Daily Loads of Nitrogen and Phosphorus for Back River in Baltimore City and Baltimore County, Maryland

FINAL

Prepared by:

Maryland Department of the Environment
Montgomery Business Park Center
1800 Washington Boulevard, Suite 540
Baltimore MD 21230-1718

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

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List of Abbreviations

BNR	Biological Nutrient Removal
BREM	Back River Eutrophication Model
CBP	Chesapeake Bay Program
CE-QUAL-ICM	Army Corps pf Engineers Water Quality Integrated Compartment Model
CEAM	Center for Exposure Assessment Modeling
CEWES	Army Corps of Engineers Waterways Experiment Station
CH3D-WES	Curvilinear Hydrodynamics in Three Dimensions – Waterways Experiment Station
Chla	Active Chlorophyll *a*
COMAR	Code of Maryland Regulations
CWA	Clean Water Act
CWAP	Clean Water Action Plan
DIN	Dissolved Inorganic Nitrogen
DIP	Dissolved Inorganic Phosphorus
DO	Dissolved Oxygen
DON	Dissolved Inorganic Nitrogen
DOP	Dissolved Organic Phosphorus
ENR	Enhanced Nutrient Removal
EPA	Environmental Protection Agency
FSA	Farm Service Agency
HSPF	Hydrological Simulation Program Fortran
LA	Load Allocation
lbs/yr	Pounds per Year
LPON	Labile Particulate Organic Nitrogen
LPOP	Labile Particulate Organic Phosphorus
m^3/s	Cubic Meters per Second
MD	Maryland
MDA	Maryland Department of Agriculture
MDE	Maryland Department of the Environment
MDP	Maryland Department of Planning
mg/l	Milligrams per Liter
mgd	Million Gallons per Day
MOS	Margin of Safety
MRLC	Multi-Resolution Land Cover
NBOD	Nitrogenous Biochemical Oxygen Demand
NH_3	Ammonia
NOAA	National Oceanic and Atmospheric Administration
NO_{2-3}	Nitrate + Nitrite
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source

ON	Organic Nitrogen
OP	Organic Phosphorus
PO_4	Ortho-Phosphate
RPON	Refractory Particulate Organic Nitrogen
RPOP	Refractory Particulate Organic Phosphorus
SOD	Sediment Oxygen Demand
TMDL	Total Maximum Daily Load
USGS	United States Geological Survey
WQIA	Water Quality Improvement Act
WQLS	Water Quality Limited Segment
WWTP	Waste Water Treatment Plant
μg/l	Micrograms per Liter

EXECUTIVE SUMMARY

This document establishes Total Maximum Daily Loads (TMDLs) for nitrogen and phosphorus in the tidal stream segment of the Back River (basin number 02130901). The Back River drains into the Chesapeake Bay and is part of the Patapsco/Back River Tributary Strategy Basin. The tidal stream segment of the Back River (basin number 02130901) was first identified on the 1996 303(d) list submitted to EPA by the Maryland Department of the Environment (MDE) as being impaired by nutrients due to signs of eutrophication, expressed as high chlorophyll *a* levels. 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 the excessive growth of aquatic plants. These plants eventually die and decompose, leading to bacterial consumption of dissolved oxygen (DO). For these reasons, this document proposes to establish TMDLs for the nutrients nitrogen and phosphorus in the Back River. The Back River was also identified on the 303(d) list as being impaired by bacteria (fecal coliform), toxics (PCBs), metals (Zinc) and suspended sediments. The impairments due to these contaminants have been or will be addressed in separate analyses by MDE.

The water quality goal of these TMDLs is to reduce high chlorophyll *a* concentrations that reflect excessive algal blooms, and to maintain the dissolved oxygen criterion at a level whereby the designated uses for the Back River will be met. The TMDLs for the nutrients nitrogen and phosphorus were determined using a time-variable, three-dimensional water quality eutrophication model package, which includes the water quality model, Corps of Engineers-Water Quality-Integrated Compartment Model (CE-QUAL-ICM), a sediment process model, and the hydrodynamic model, Curvilinear Hydrodynamic in Three Dimensions (CH3D). Loading caps for total nitrogen and total phosphorus entering the Back River are established for low flow conditions and for annual average flow conditions.

The low flow TMDL for nitrogen is 113,321 lbs/month, and the low flow TMDL for phosphorus is 7,995 lbs/month. These TMDLs apply during the period May 1 through October 31. The allowable loads have been allocated between point and nonpoint sources. The nonpoint sources are allocated 1,345 lbs/month of total nitrogen, and 34 lbs/month of total phosphorus. The point sources, including a National Pollutant Discharge Elimination System (NPDES) wastewater treatment plant (WWTP) loads and NPDES stormwater loads are allocated 111,299 lbs/month of nitrogen, and 7,888 lbs/month of phosphorus. An explicit margin of safety makes up the remainder of the nitrogen and phosphorus allocations.

The average annual TMDL for nitrogen is 1,773,100 lbs/yr, and the average annual TMDL for phosphorus is 99,171 lbs/yr. The allowable loads have been allocated between point and nonpoint sources. The nonpoint source loads are allocated 26,323 lbs/year of total nitrogen and 1,239 lbs/year of total phosphorus. The point sources, including a NPDES wastewater treatment plant (WWTP) loads and NPDES stormwater loads are allocated 1,737,626 lbs/year of total nitrogen and 96,896 lbs/year of total phosphorus. An explicit margin of safety makes up the balance of the allocation.

Four factors provide assurance that these TMDLs will be implemented. First, National Pollutant Discharge Elimination System (NPDES) permits (including both wastewater treatment plants and stormwater permits) and point source loading goals under the Chesapeake Bay Program's Enhanced Nutrient Removal Strategy (ENR) will play important roles in assuring implementation. Second, Maryland has several well-established programs that will be drawn upon, including Maryland's Tributary Strategies for Nutrient Reductions developed in accordance with the Chesapeake Bay Agreement. Third, Maryland's Water Quality Improvement Act 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 assure that routine future monitoring and TMDL evaluations are conducted.

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 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 water body 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 include activities such as swimming, drinking water supply, and shellfish propagation and harvest. Water quality criteria consist of narrative statements and numeric values designed to protect the designated uses. Criteria may differ among waters with different designated uses.

The tidal stream segment of the Back River (basin number 02130901) was first identified on the 1996 303(d) list submitted to EPA by the Maryland Department of the Environment (MDE) as being impaired by nutrients due to signs of eutrophication, expressed as high chlorophyll *a* levels. 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 the excessive growth of aquatic plants. These plants eventually die and decompose, leading to bacterial consumption of dissolved oxygen (DO). For these reasons, this document proposes to establish TMDLs for the nutrients nitrogen and phosphorus in the Back River. The Back River was also identified on the 303(d) list as being impaired by bacteria (fecal coliform), toxics (PCBs), metals (Zinc) and suspended sediments. The impairments due to these contaminants have been or will be addressed in separate analyses by MDE.

2.0 SETTING AND WATER QUALITY DESCRIPTION

2.1 General Setting and Source Assessment

The Back River Watershed is located in the western shore region of Maryland, northeast of the Baltimore Harbor and it drains into the Chesapeake Bay (Figure 1). It is located on the western shore of the Upper Chesapeake Bay about 160 miles from the Virginia Capes at the entrance to the Bay. It is a relatively small estuary, with average depths of approximately 25 feet (near the mouth), nine feet (lower estuary), and five feet (upper estuary). The tidal range in the estuary is approximately 1.2 feet (Maryland Environmental Service, 1974).

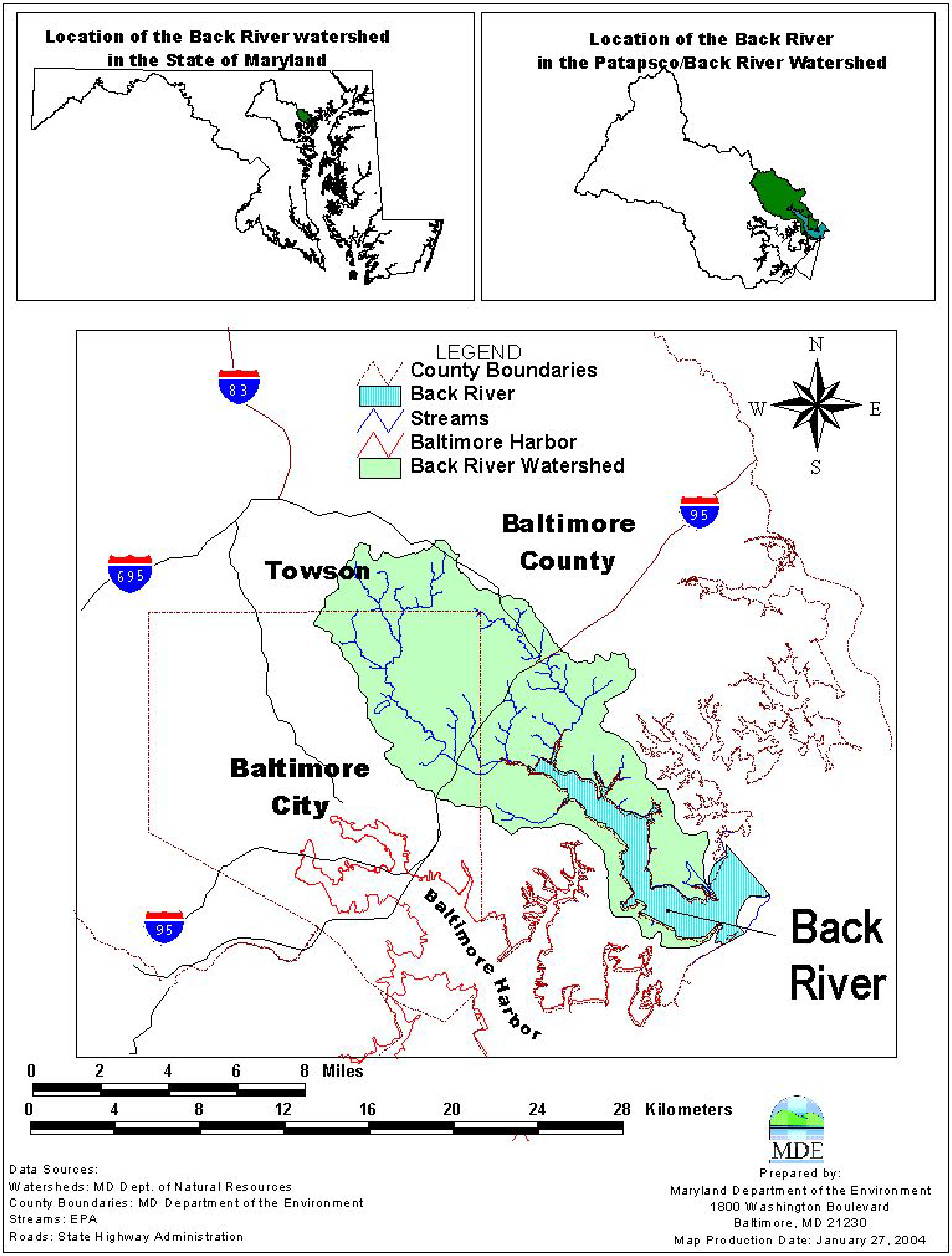


Figure 1: Location Map of Back River Drainage Basin

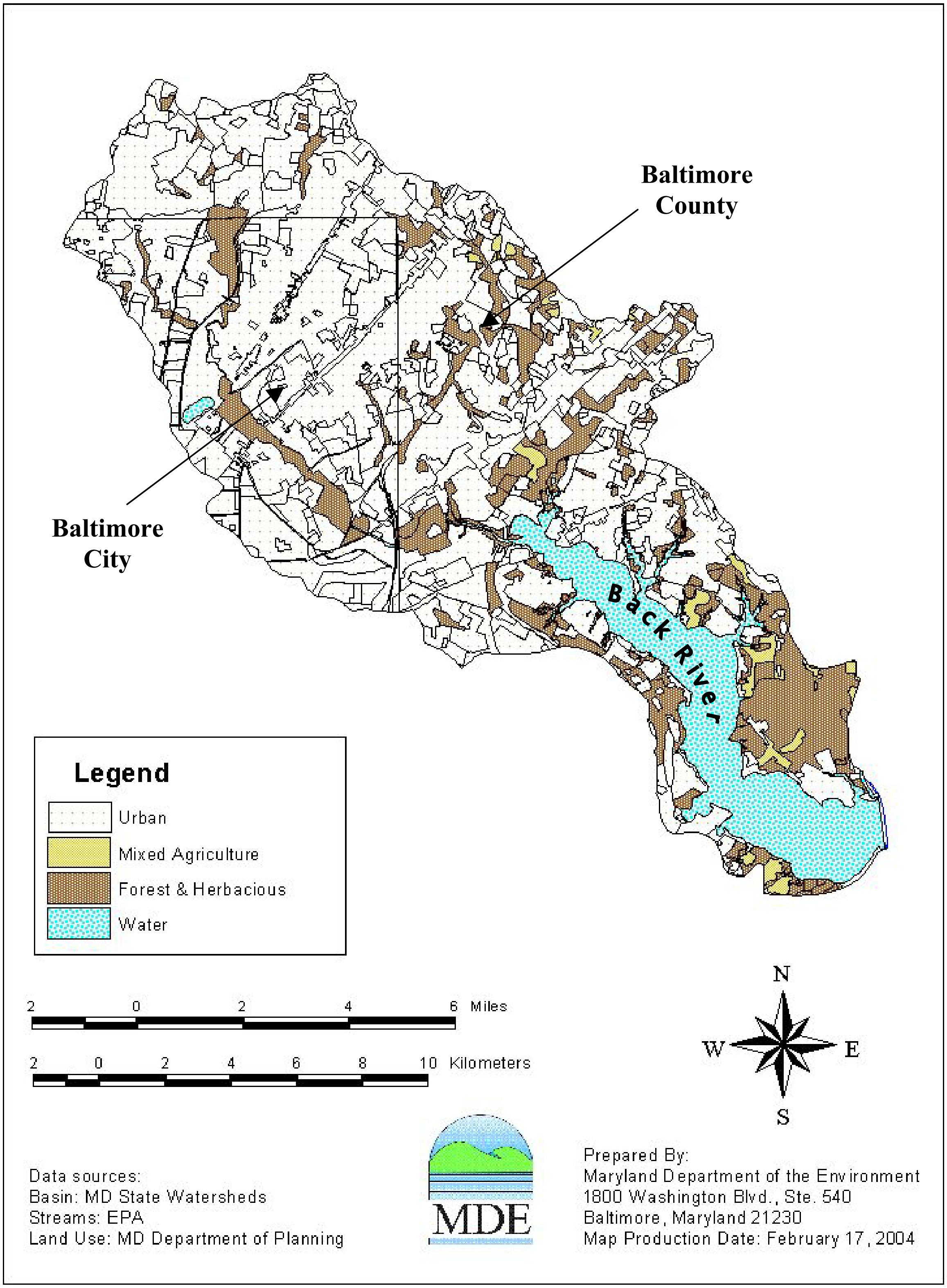


Figure 2: Predominant Land Uses in the Back River Drainage Basin

2.2 Land Use

Land Use in the Back River Watershed is primarily urban but also consists of some forested areas, rural areas and farms, suburban areas, and industrial areas. The Back River Watershed has an area of approximately 39,075 acres or 158.1 square kilometers. The land uses in the watershed consist of urban (28,037 acres or 71.7 %), and non-urban which comprises mixed agriculture and forest and other herbaceous (6,753 acres or 17.3 %) and water (4,295 acres or 11.0 %). The land use is based on 1997 Maryland Office of Planning land use/land cover data. Figure 3 shows the relative amounts of the different land uses in the Back River Watershed.

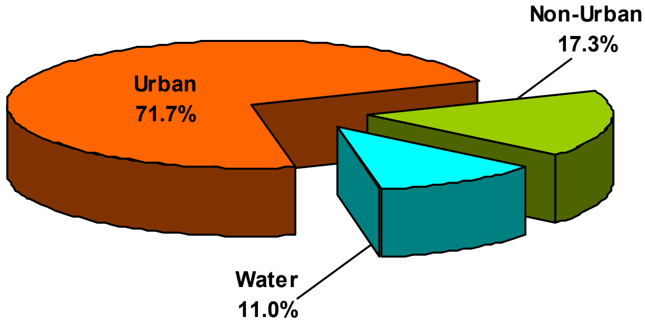


Figure 3: Proportions of Land Use in the Back River Drainage Basin

2.3 Geology

The Back River Watershed lies within the Piedmont and 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. These crystalline formations decrease in elevation from northwest to southwest and eventually extend 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 of the piedmont province (*Coastal Environmental Services, 1995*).

2.4 Point Sources: Wastewater Treatment Plants Loads

The model was calibrated using point source loading data and flows from the period 1992-1997. The Back River WWTP is the only municipal point source that currently discharges into the Back River, and which was discharging during the model calibration period. Eastern Stainless is the only industrial point source that discharged into the Back River during the 1992-1997 period. The estimated average annual nitrogen and phosphorus loads from the Back River WWTP for the 1992 to 1997 period is *4,080,417 lbs/yr or 1,854,735 kg/yr and 84,427 lbs/yr or 38,375 kg/yr, respectively.* This information was obtained from discharge monitoring reports stored in MDE's point source database. The Back River WWTP average annual point source loads for 1992 to 1997 are presented in Table 1.

Table 1: Back River WWTP Flows and Loads for the Period 1992 to 1997

Back River Flows and Point Source Loads					
Year	**Flow**	**TN**		**TP**	
	mgd	lbs/yr	kg/day	lbs/yr	kg/day
1992	107	4,587,967	5,771	194,534	241
1993	117	4,521,061	5,691	79,674	99
1994	113	4,335,097	5,477	71,456	91
1995	104	3,985,318	5,005	63,574	79
1996	115	4,081,197	5,084	57,872	72
1997	86	2,971,863	3,703	39,451	49
Average	107	4,080,417	5,122	84,427	105

These average annual flows and point source load estimates represent actual discharge into the Back River from the WWTP from 1992 to 1997. It is important to note that this WWTP, while not discharging at its maximum flow capacity during this period, had nitrogen concentrations around 12 mg/l – 12.5 mg/l, higher than current nitrogen concentrations. The Biological Nutrient Removal (BNR) process went into operation in July 1998, the year after the model calibration period and concentrations since then are lower, averaging 8-9 mg/l. In the same context, the phosphorus concentrations discharged from 1992 to 1997 are higher than the current permitted concentrations. For the Back River WWTP, the average annual load, with current permit flow and concentrations, could decrease to 3,167,002 lbs/yr from 4,080,417 lbs/yr of total nitrogen and to 79,175 lbs/yr from 84,427 lbs/yr of total phosphorus assuming the plant is discharging at its maximum allowable current permit flow of 130 MGD and the current goal concentration for TN of 8 mg/l and TP permit limit concentration of 0.2 mg/l. The flow discharged from the Back River WWTP into Back River does not represent the total output of the Back River WWTP. Of the 180 MGD design capacity of the plant, 50-70 MGD are discharged into Outfall 002, to be used by Bethlehem Steel (currently International Steel Group, ISG) as cooling water, and then discharged into Bear Creek and other tributaries of the Baltimore Harbor.

The Eastern Stainless point source discharged into Back River an average TN load of 62,755 lbs/yr and an average TP load of 106 lbs/yr from 1992 to 1997.

2.5 Nonpoint Source Loads and Urban-Stormwater Loads

Nonpoint source loads and urban-stormwater loads entering the Back River 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, which are linked to a three-dimensional, time variable hydrodynamic model and a water quality model designed specifically for the Back River. The water quality model is used to determine the maximum load of nutrients that can enter Back River while maintaining the water quality criteria associated with the designated use of Back River. The water quality modeling framework is shown in Section 4.2. The simulation of the Back River Watershed 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 was estimated from the Maryland Department of Planning (MDP) land use data, the 1997 Agricultural Census Data, and the Farm Service Agency (FSA). 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 low flow conditions. Details of the HSPF watershed model developed to estimate these urban and non-urban loads can be found in “Patapsco/Back River Watershed HSPF Model Report, (MDE, 2001)”.

Figure 4 shows the relative amounts of nitrogen and phosphorus nonpoint, point source and urban loadings during the 1995 to 1997 period for the Back River.

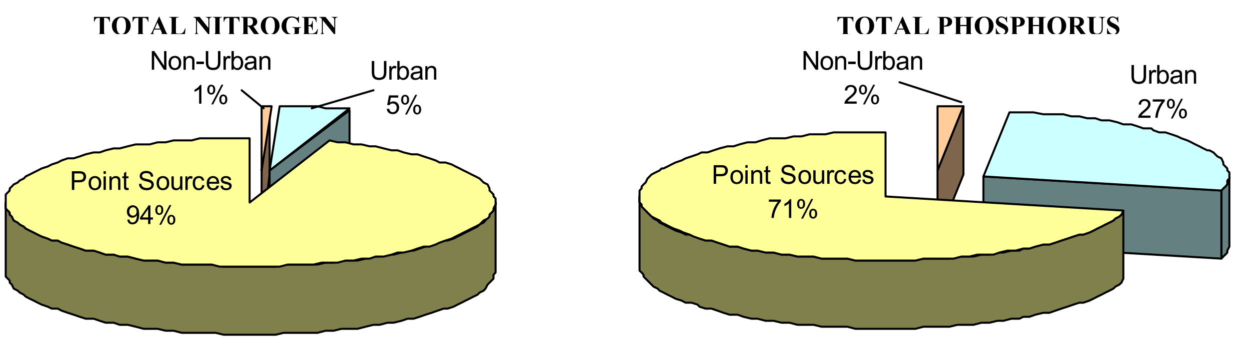


Figure 4: Percentages of Average Annual Nitrogen and Phosphorus Loads from WWTP point sources, urban and non-urban sources in the Back River between 1995 and 1997

2.6 Water Quality Characterization

Historical and recent data show clear indications of extreme eutrophication in the Back River. Some of the highest chlorophyll-*a* concentrations observed in the entire Chesapeake system have been routinely recorded in the Back River (Boynton *et al*., 1998). Abnormally high chlorophyll *a* concentrations, 200-300 µg/l, were observed in the upstream reaches of this river. In contrast, the chlorophyll *a* levels in Baltimore Harbor, just 10 km south of Back River, are 50-100 µg/l, which are also much higher than the values usually observed in the Chesapeake Bay. As for the DO concentrations, hypoxia/anoxia have rarely occurred in Back River although large diel excursions of DO have been documented (Boynton *et al*., 1998).

There are 10 water quality stations located in the Back River that were surveyed during the model calibration period 1992 to 1997. One of these is a Chesapeake Bay Program long-term monitoring station. Five are MDE water quality stations and four more stations are Baltimore City stations. The reader is referred to Figure 5 for the locations of the water quality sampling stations. Table 2 presents the distance of each station from station M01 located at the mouth of the river.

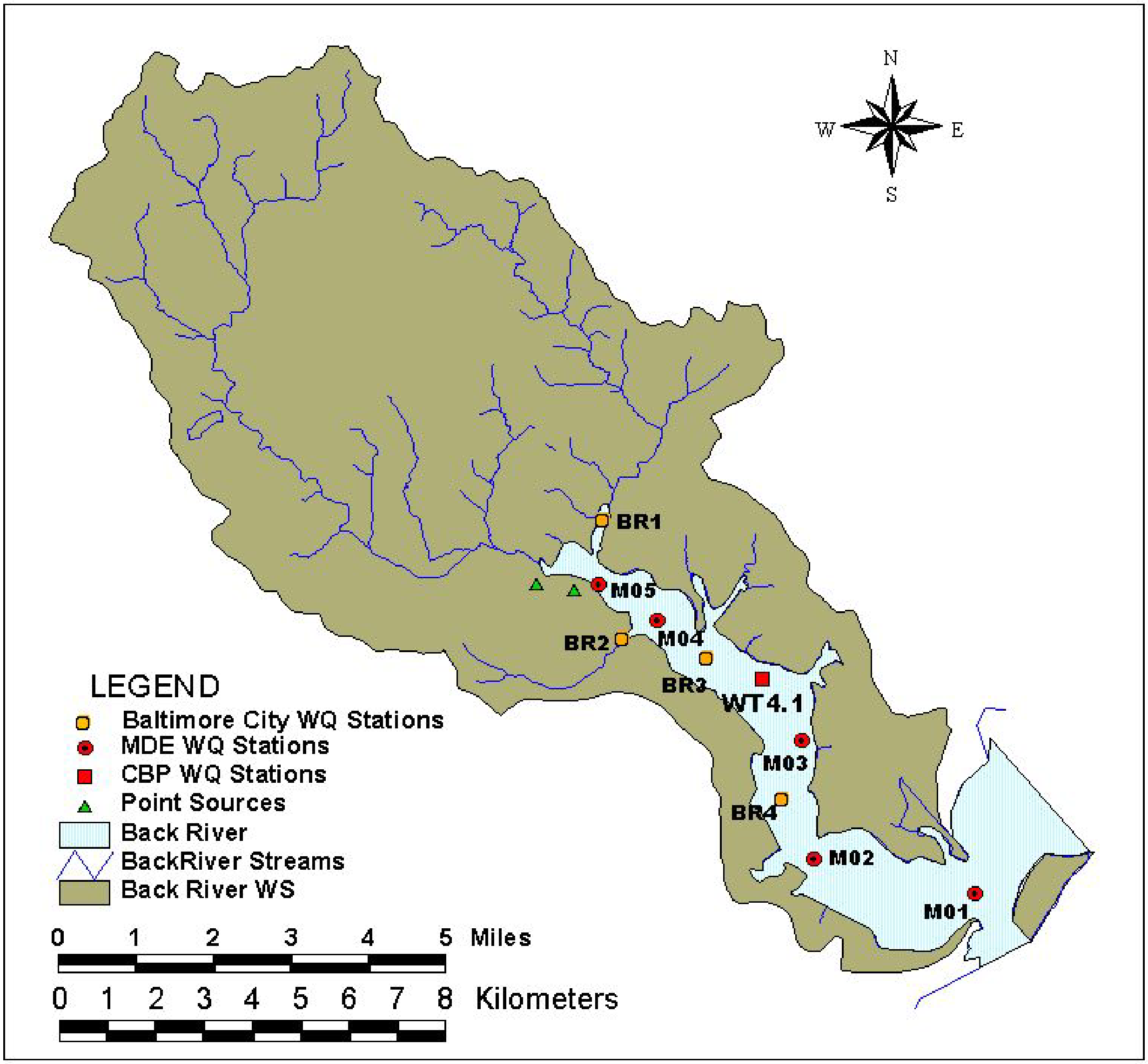


Figure 5: Location of Water Quality Stations in the Back River

Table 2: Location of Water Quality Monitoring Stations

Water Quality Station	Kilometers from the Mouth of the River
BACK RIVER	
M01 (mouth)	0
M02	3.6
BR4	4.5
M03	6.1
WT4.1 (middle)	7.1
BR3	7.5
M04 / BR2	8.5 / 9.5
M05 / BR1 (head)	10.0 / 11.2

Data for the 1992-1997 period have been selected for the development of the eutrophication model for subsequent nutrients TMDLs analysis. During this period, monitoring was sponsored by the Chesapeake Bay Program (CBP), MDE, and the City of Baltimore.

The Chesapeake Bay Program has maintained a long-term water quality sampling station (WT4.1) in the Back River since 1984 to monitor its physical, chemical, and biological parameters. MDE also monitored the Back River intensively at the other five stations during the period March 1994 to May 1995 for parameters similar to those monitored by the CBP. Baltimore City (BC) also sponsored monitoring at sites located close to the MDE surveys during the period June to December 1993, 1994, 1995, 1996 and 1997 for similar parameters. A detailed list of all the parameters measured in these surveys can be found in the Back River section of the report "The development of a water quality model for Baltimore Harbor, Back River and the adjacent Upper Chesapeake Bay" Part II: "Biological, chemical and physical characteristics of the Baltimore Harbor and Back River in the Upper Chesapeake Bay, (Wang *et al*, 1999)".

The water quality time series for chlorophyll *a*, DO, TN and TP for the period 1992 to 1997 of the CBP long-term station WT 4.1 in the Back River are presented in Figures 6, 8, 10, and 12. The water quality longitudinal profiles of the river showing MDE and BC data for the same parameters at stations M01 (mouth), M02, BR4, M03, WT 4.1, BR3, M04 and M05 (upstream) are also presented in figures 7, 9, 11, and 13. Stations BR1 and BR2 located outside the model domain near stations M05 and M04 respectively, were included in the data set as follows: water quality data at station BR1 was included with data from station M05, and data from station BR2 was included with data from station M04. Please note the not all stations show data for all the parameters shown. The discussion below is a summary of the data from these monitoring programs for the period used in the development of the eutrophication model. Detailed analyses and interpretation of the results are presented in the Back River section of the report "The development of a water quality model for Baltimore Harbor, Back River and the adjacent Upper Chesapeake Bay" Part II: "Biological, chemical and physical characteristics of the Baltimore Harbor and Back River in the Upper Chesapeake Bay", (Wang *et al*, 1999) and in Part A of Appendix 1.

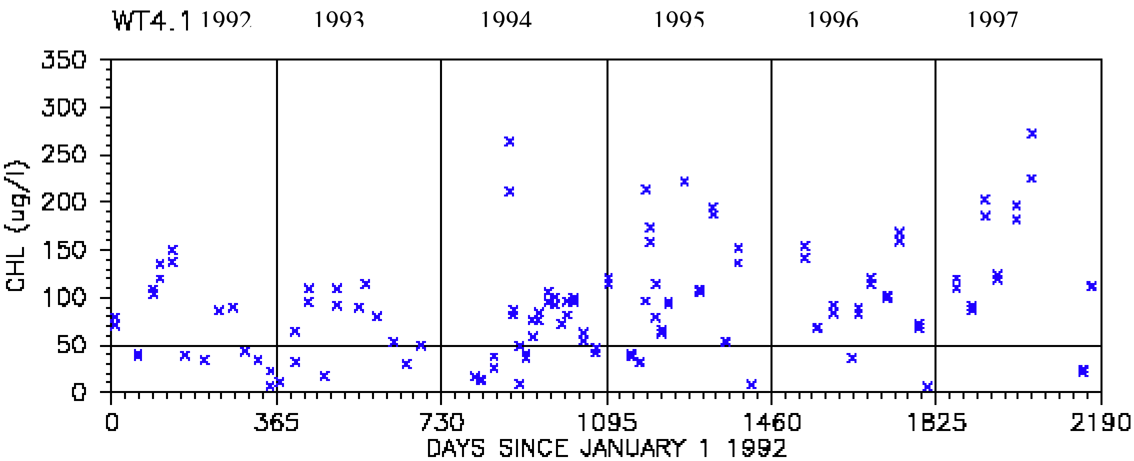


Figure 6: Time Series of Chlorophyll *a* Data at Back River Station WT 4.1

Figure 6 presents the time series of chlorophyll *a* concentrations in the Back River from January 1992 to December 1997 for the CBP long-term monitoring station WT4.1, a seven-year period that includes wet and dry years. WT4.1 is located in the middle of the Back River, approximately 7.8 km from the mouth. Chlorophyll *a* concentrations throughout the water column are above 50 µg/l every year with maximum concentrations close to 300 µg/l during the summers of 1994 and 1997. Chlorophyll *a* concentrations have a seasonal pattern: higher during the warmer months and lower during the coldest months.

Figure 7 below presents a longitudinal profile of chlorophyll *a* from May 1 to October 31, and from January 1 to April 30/November 1 to December 31 of 1995, 1996 and 1997 in the Back River. Water quality data for BC stations BR1 and BR2 were combined with the data from MDE stations M05 and M04, respectively. The figures show symbols representing the mean values of chlorophyll *a* concentrations with minimum/maximum value bars at each station and period in the Back River. The numbers on the upper part of each graph represents the number of samples averaged at each particular station.

A difference of chlorophyll *a* distribution between the May-October period and the November-April period was observed in the surface water along the longitudinal profile of the river system as shown in the figure. Highest chlorophyll *a* concentrations in surface water were located at the head of the river throughout the May 1 to October 31 period and concentrations decreased downstream. In 1995, chlorophyll *a* values were the highest of the three years with concentrations decreasing in 1996 and 1997. Spring algal blooms developed throughout the water column and the chlorophyll *a* concentrations were relatively high throughout both periods.

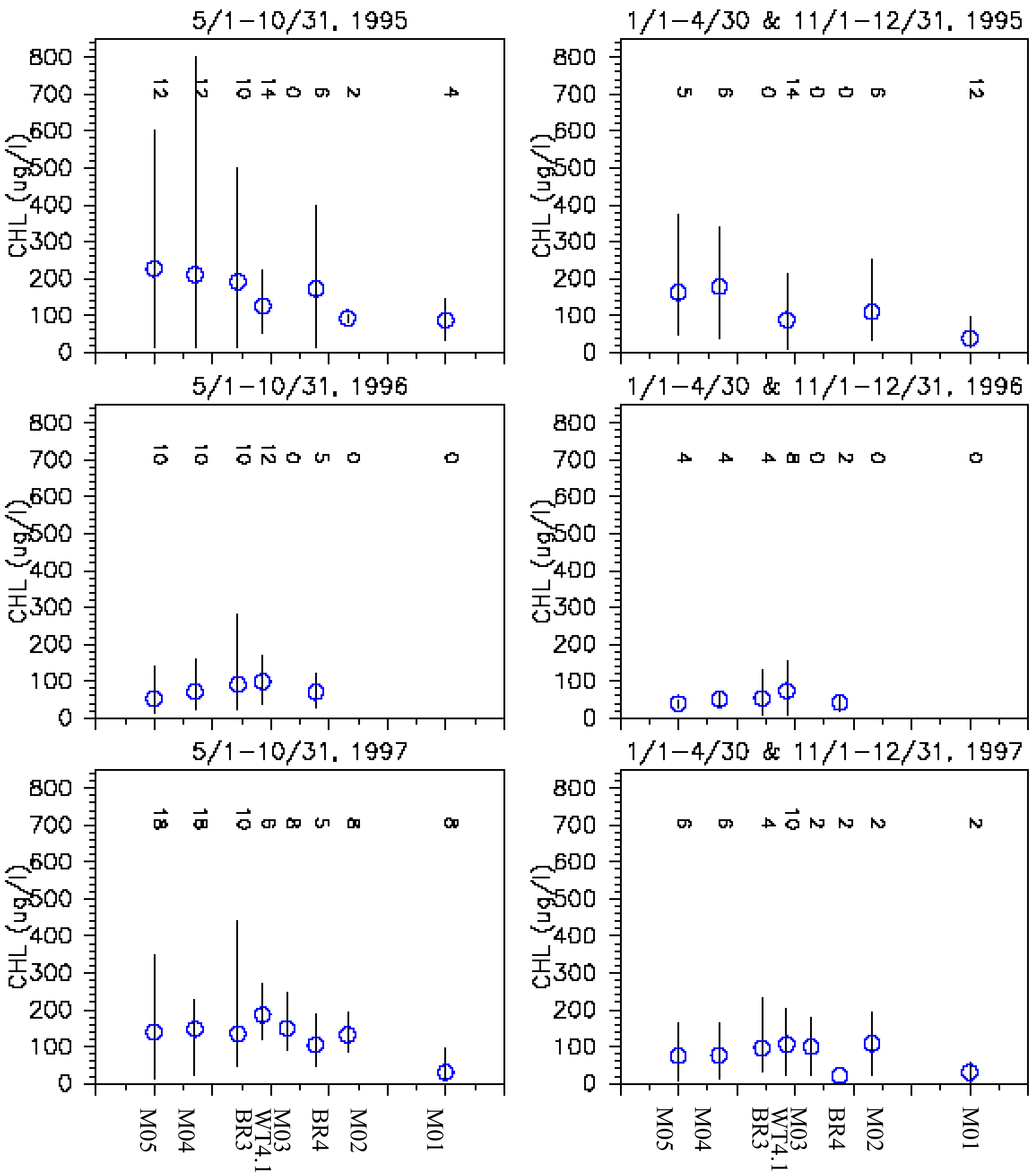


Figure 7: Longitudinal Profile of Chlorophyll *a* During the Period of May 1 to October 31, and during the periods of January 1 to April 30 and November 1 to December 31 of 1995, 1996 and 1997 in the Back River.

A similar time series for DO concentrations at station WT4.1 is depicted in Figure 8. It shows that the observed DO levels at station WT4.1 do not fall below 5.0 mg/l, except in the summer of 1992. The DO ranged from 3.8 to 18.8 mg/l with average DO concentrations close to 10 mg/l. The DO concentrations fall slightly every summer to levels close to 5.0 mg/l but only fell below

5.0 mg/l in 1992. DO concentrations in 1997 appear to be slightly elevated relative to prior years, consistent with reduced nutrient loads as shown in Table 1.

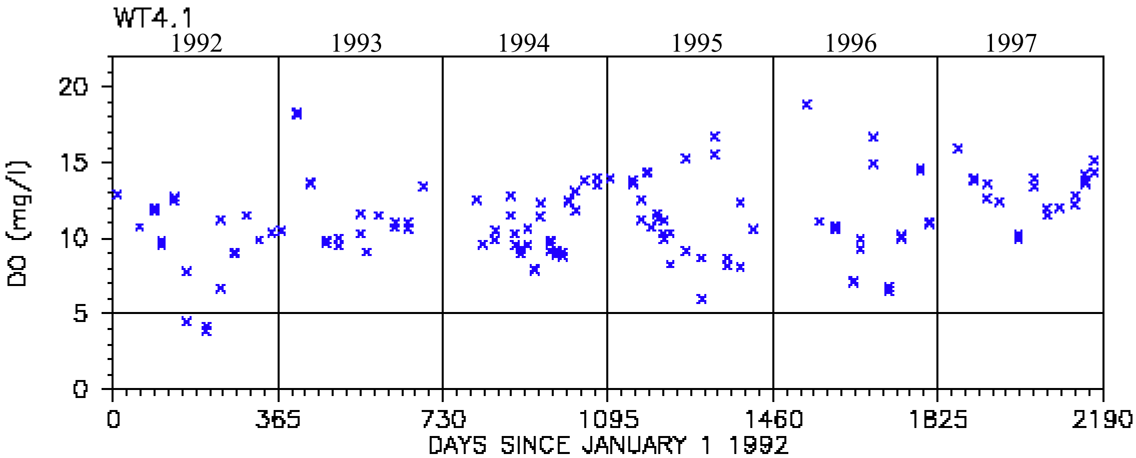


Figure 8: Time Series of Dissolved Oxygen Data at Back River Station WT 4.1

Figure 9 presents a longitudinal profile of chlorophyll *a* from May 1 to October 31, and from January 1 to April 30/November 1 to December 31 of 1995, 1996 and 1997 in the Back River. The figures show symbols representing the mean values of chlorophyll *a* concentrations with minimum/maximum value bars at each station and period in the Back River. The numbers on the upper part of each graph represents the number of samples averaged at each particular station. There was no significant seasonal variation in the Back River system. DO levels remained high at the region. DO concentrations increased upstream during the warmer months but slightly decreased or remained constant heading upstream during the colder months.

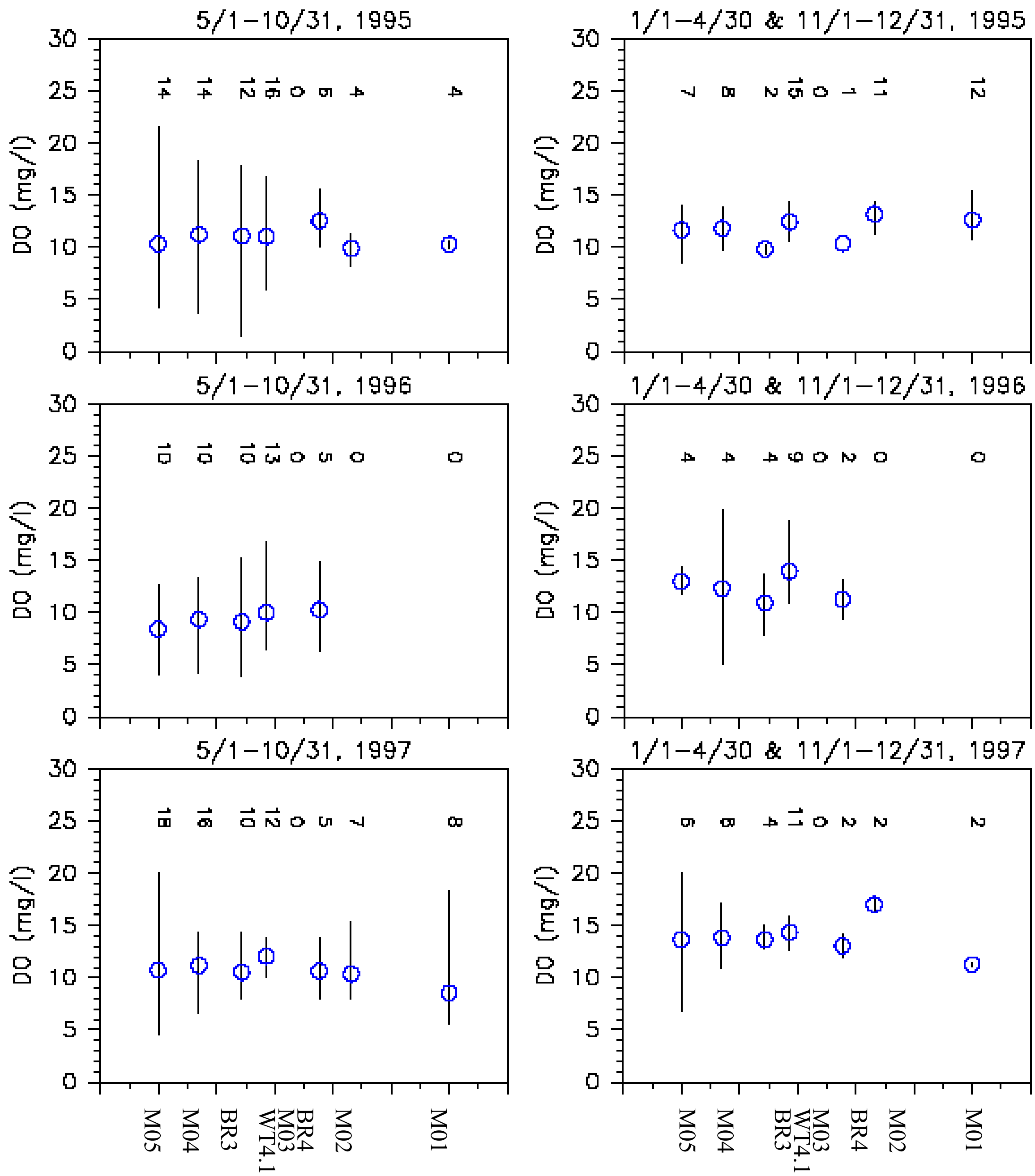


Figure 9: Longitudinal Profile of Dissolved Oxygen (DO) During the Period of May 1 to October 31, and during the periods of January 1 to April 30 and November 1 to December 31 of 1995, 1996 and 1997 in the Back River.

Figure 10 presents a time series of Total Nitrogen (TN), Total Dissolved Nitrogen (TDN) and Particulate Nitrogen (PN) levels measured during the 1992-1997 period at station WT 4.1 in the Back River. The TN levels of most samples are below 9 mg/l with the highest values near 10 mg/l only in the winter of 1993 and spring of 1995. The dissolved species (TDN) of this total nitrogen, which includes NH_4 and NO_{23}, represents approximately 70-75% of the TN in the water column (between 2 and 6 mg/l), while the PN accounts for approximately 25% of the total nitrogen (between 0 and 3 mg/l for most samples).

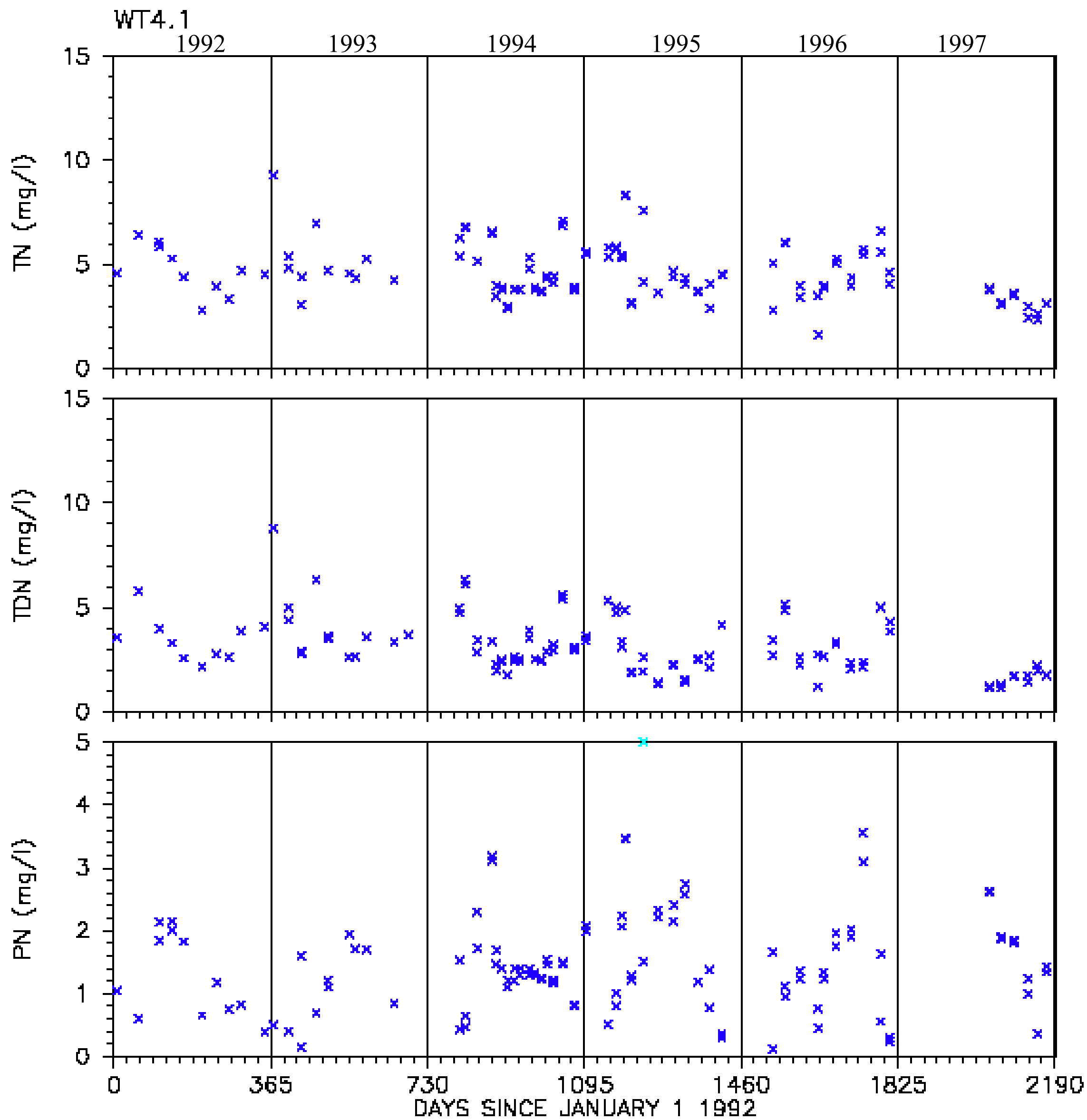


Figure 10: Time Series of Total Nitrogen (TN), Total Dissolved Nitrogen (TDN) and Particulate Nitrogen (PN) Data at Back River Station WT 4.1

Figure 11 presents the longitudinal profile of TN during the period of May 1 to October 31, and during the period of January 1 to April 30/November 1 to December 31 of 1995, 1996 and 1997 in the Back River. The figures show symbols representing the mean values of chlorophyll *a* concentrations with minimum/maximum value bars at each station and period in the Back River. The numbers on the upper part of each graph represents the number of samples averaged at each particular station. In general, TN concentrations are higher upstream and appear to decrease over time when comparing 1995 with 1996 and 1997 values. TN concentrations do not show any seasonality, with average values in the warmer months very similar to those in the colder months.

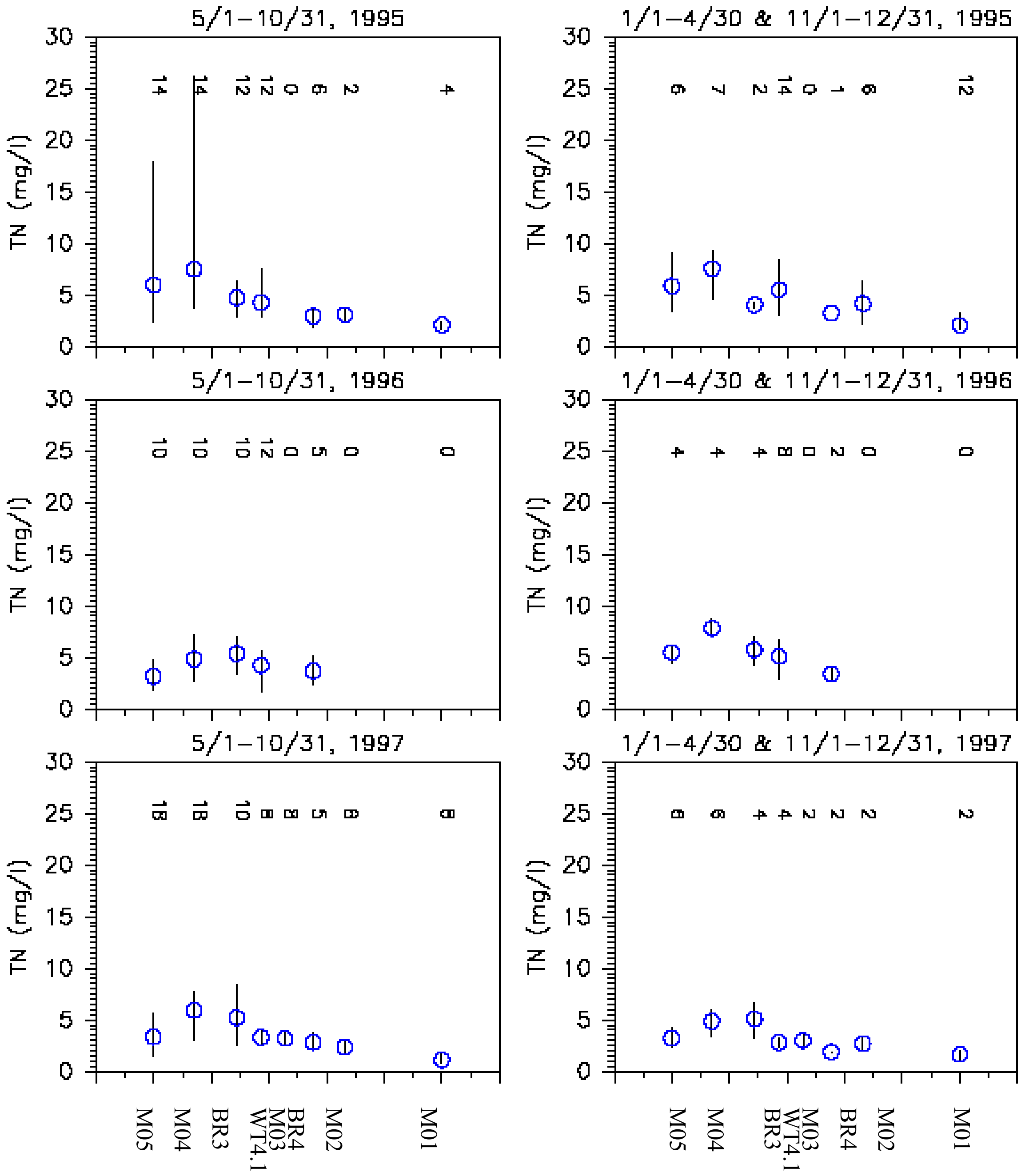


Figure 11: Longitudinal Profile of TN During the Period of May 1 to October 31, and during the periods of January 1 to April 30 and November 1 to December 31 of 1995, 1996 and 1997 in the Back River.

Figure 12 present time series of Total Phosphorus (TP), Total Dissolved Phosphorus (TDP) and Particulate Phosphorus (PP) levels measured during the 1992-1997 period at station WT4.1 in the Back River. The TP levels of most samples are between 0.1 mg/l and 0.5 mg/l, with a one time highest value near 1.1 mg/l, in the spring of 1995. The reason for this high TP concentration is unclear. The total dissolved phosphorus (TDP) of this total phosphorus represents a smaller percentage of the TP than the percentage of PP in the water column. This suggests a higher concentration of phosphorus in the suspended solids of the system than in dissolved form.

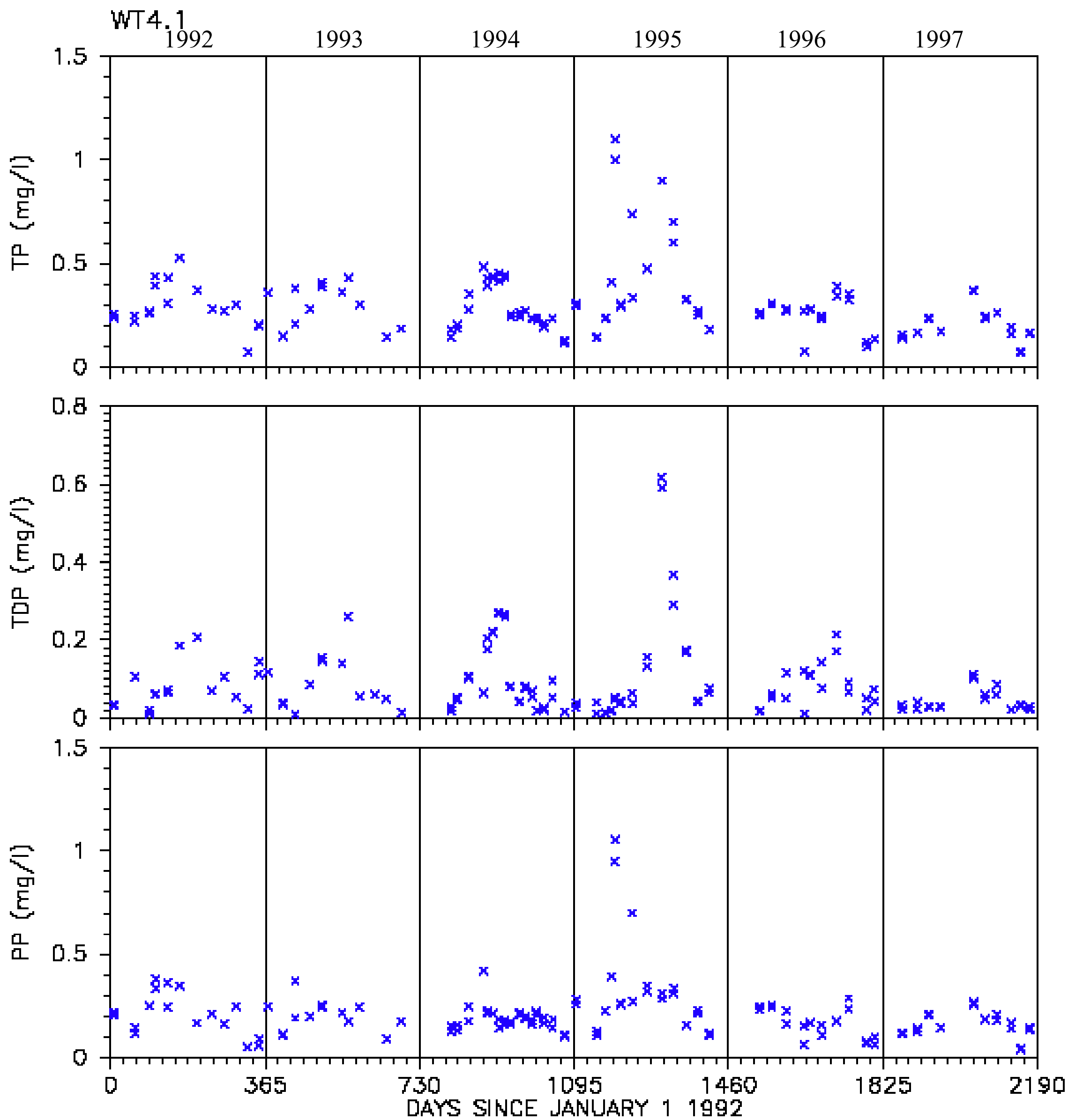


Figure 12: Time Series of TP, TDP, and PP Data at Back River Station WT 4.1

Figure 13 presents the seasonal variation of TP during the period of May 1 to October 31, and during the period of January 1 to April 30/November 1 to December 31 of 1995, 1996 and 1997 in the Back River. The figures show symbols representing the mean values of chlorophyll *a* concentrations with minimum/maximum value bars at each station and period in the Back River. The numbers on the upper part of each graph represents the number of samples averaged at each particular station.

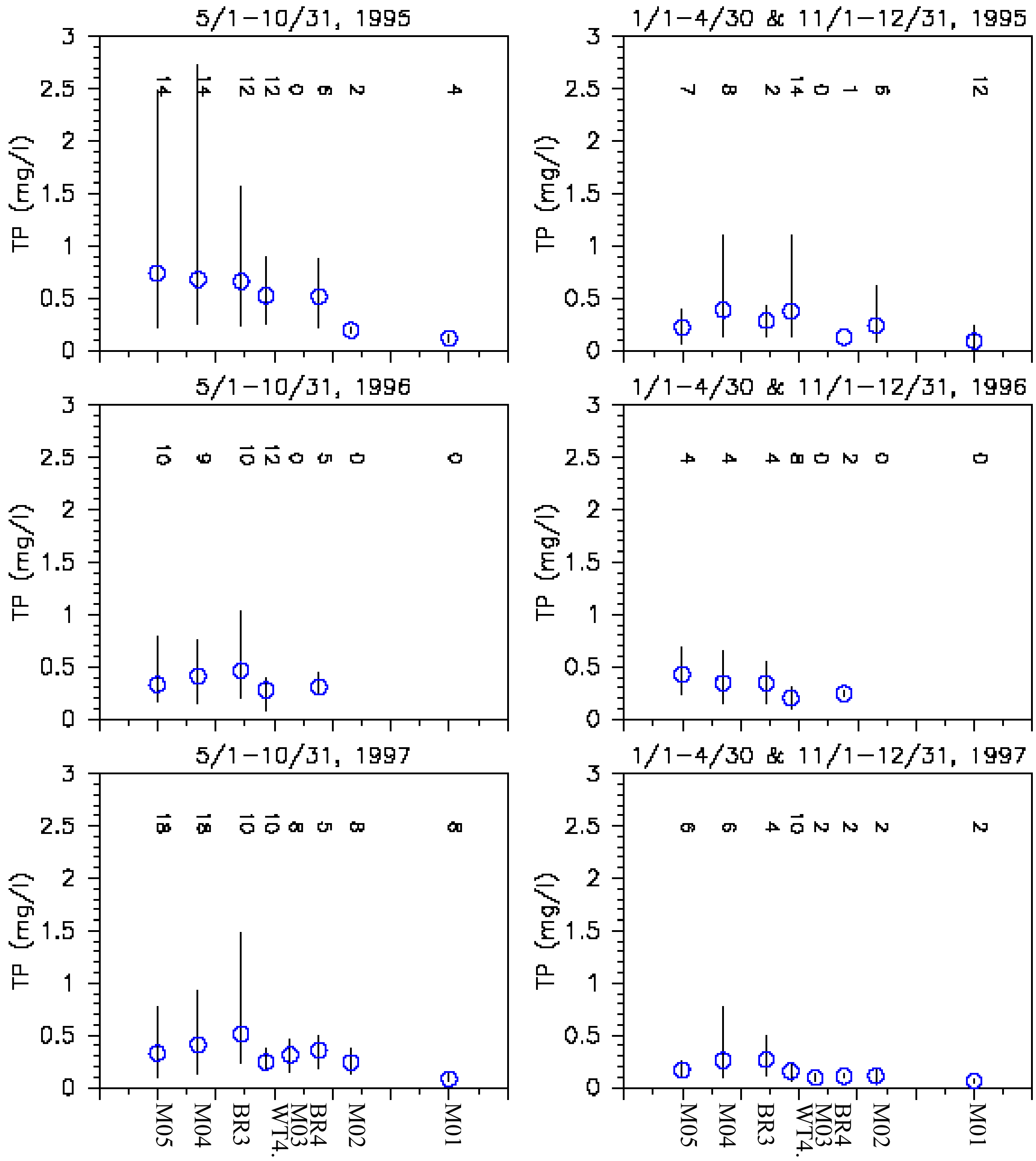


Figure 13: Longitudinal Profile of TP during the period of May 1 to October 31, and during the periods of January 1 to April 30 and November 1 to December 31 of 1997 in the Back River.

TP concentrations are higher at the upstream stations compared to the downstream stations. These TP concentrations are higher during the warmer months than concentrations observed during the colder months, especially during 1995. Seasonality is not so obvious in 1996 but it is significant again in 1997. In general, TP concentrations seem to decrease slightly over time.

2.7 Water Quality Impairment

The Maryland Water Quality Standards Surface Water Use Designation [Code of Maryland Regulations (COMAR) 26.08.02.07] for the tidal waters of the Back River is Use I - water contact recreation, fishing, and protection of aquatic life and wildlife. The water quality impairment of the Back River system being addressed by this TMDL analysis consists of a higher than acceptable level of chlorophyll *a* (See Section 2.6 figures). The substances causing this water quality exceedance are the nutrients - nitrogen and phosphorus. Excessive nitrogen and phosphorus over-enrich aquatic systems. The nutrients act as a fertilizer leading to the excessive growth of aquatic plants. These plants eventually die and decompose, leading to bacterial consumption of dissolved oxygen (DO).

According to the numeric criteria for DO for Use I waters, concentrations may not be less than 5.0 mg/L at any time unless resulting from natural conditions (COMAR 26.08.02.03.A(2)). The achievement of 5.0 mg/L is expected in the well-mixed surface waters and throughout the water column of the Back River system.

Maryland's General Water Quality Criteria prohibit pollution of waters of the State by any material in amounts sufficient to create a nuisance or interfere directly or indirectly with designated uses. See Code of Maryland Regulations (COMAR) 26.08.02.03B(2). Excessive eutrophication, indicated by elevated levels of chlorophyll *a*, can produce nuisance levels of algae and interfere with designated uses such as fishing and swimming. The chlorophyll *a* concentration in the upper reaches of Back River regularly exceeds the desired level of 50 µg/L. These levels have been associated with excess eutrophication.

3.0 TARGETED WATER QUALITY GOAL

The objective of the nutrient TMDLs established in this document is to assure the chlorophyll *a* levels support the Use I designations for the tidal waters of the Back River. Specifically, the TMDLs for nitrogen and phosphorus in Back River are intended to control excessive algal growth. Excessive algal growth can lead to violations of the numeric DO criteria, associated fish kills, and the violation of various narrative criteria associated with nuisances, such as odors, and impedance of direct contact use and the loss of habitat for the growth and propagation of aquatic life and wildlife.

In summary, the TMDLs for nitrogen and phosphorus are intended to:

1. Assure a minimum DO concentration of 5.0 mg/l is maintained throughout the tidal waters of the Back River; and

2. Resolve violations of narrative criteria associated with excess nutrient enrichment of the Back River, as reflected in chlorophyll *a* levels greater than 50 µg/l in the Back River system.

The dissolved oxygen level is based on specific numeric criteria for Use I waters set forth in the COMAR 28.08.02. The chlorophyll *a* level is based on the designated uses of Back River, 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). These guidelines acknowledge it is acceptable to maintain chlorophyll *a* concentrations below a maximum of 100 µg/L, with a target threshold of less than 50 µg/L.

4.0 TOTAL MAXIMUM DAILY LOADS AND ALLOCATIONS

4.1 Overview

The following section describes the modeling frameworks for simulating nutrient loads, hydrology, and water quality responses. The second sections summarize the scenarios that were explored using the model. The third section describes how the nutrient TMDLs and load allocations for point sources and nonpoint sources were developed for the Back River. The assessment investigates water quality responses using 1995 to 1997 stream flow and different nutrient loading conditions. The fourth section presents the modeling results in terms of a TMDL and allocate the TMDL between point sources and nonpoint sources. The last section explains the rationale for the margin of safety. Finally, the pieces of the equations are combined in a summary accounting of the TMDL for seasonal low flow conditions and for average annual flows.

4.2 Analysis Framework

4.2.1 Computer Modeling Framework

To develop a TMDL, a linkage must be defined between the selected targets or goals and the identified 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. The relationship can vary seasonally, particularly for nonpoint sources, with factors such as precipitation. Once defined, the linkage yields the estimate of total loading capacity or TMDL (U.S. EPA, 1999).

The Department chose a time variable water quality model as the analysis tool to link the nutrient source loadings to the DO criteria and chlorophyll *a* goal. The computational framework chosen for the Back River TMDLs is the three-dimensional, time-variable water quality model CE-QUAL-ICM package. This water quality simulation package provides a generalized framework for modeling contaminant fate and transport in surface waters and is based on the unstructured cell-centered finite-volume approach (Cerco and Cole, 1995). CE-QUAL-ICM was originally developed by U.S. Army Corps of Engineers Waterways Experiment Station (CEWES), Vicksburg, MS (Cerco and Cole, 1995) for the Chesapeake Bay. This eutrophication model package, which includes a sediment flux sub-model, incorporates twenty-two water quality constituents in the water column and in the 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)".

The CE-QUAL-ICM model is externally coupled with the three-dimensional, time-variable hydrodynamic model CH3D-WES (Curvilinear Hydrodynamic in Three Dimensions), which was developed at the U.S. Army Engineer Waterways Experiment Stations. As its name indicates, CH3D-WES makes hydrodynamic computations on a curvilinear or boundary-fitted platform grid that provides enhancement to fit the deep navigation channel and the irregular shoreline. The CH3D-WES simulates physical processes such as tides, wind, density effects (salinity and temperature), freshwater inflows, turbulence, and the effect of the earth's rotation. The outputs include three-dimensional velocities, water surface elevation, salinity, temperature, and the turbulent mixing coefficients, which in turn are used to drive the water quality model CE-QUAL-ICM, (Johnson *et al*., 1991).

Since many studies have shown significant influence of Chesapeake Bay water on its tributaries, the spatial domain of the Back River Eutrophication Model (BREM) extends longitudinally from the mouth of the Susquehanna River about 90 miles seaward to the mouth of the Patuxent River, which is defined as the upper Chesapeake Bay. Back River is a relatively small estuary located on the western shoreline of the upper Chesapeake Bay. This modeling domain is represented by CE-QUAL-ICM model segments. A diagram of the model segmentation is presented also in Wang *et al*, (2004). There are 3,758 active horizontal cells and a maximum of 19 vertical layers, resulting in 16,149 computational cells. The grid resolution is 1.52 m in the vertical, approximately 0.2 km laterally and 0.4 km longitudinally. Freshwater flows and nonpoint loadings from watersheds are evenly distributed into the adjacent water quality model cells.

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

The water quality model CE-QUAL-ICM described above was calibrated to reproduce observed water quality characteristics for 1992 to 1997 conditions. The calibration of the model for these six years establishes an analysis tool that may be used to assess a range of scenarios with differing flow and nutrient loading conditions. Observed 1992 to 1997 water quality data were used to support the calibration process, as explained further in Wang *et al*, (2004).

4.2.2 TMDL Analysis Framework

The nutrient TMDL analysis consists of two broad elements: an assessment of low flow loading conditions and an assessment of average annual loading conditions. Both the low flow and the average annual flow TMDL analysis investigate the critical conditions under which symptoms of eutrophication are typically most acute, i.e. for average annual flow in dry years or very wet years and/or for low flow, especially late summer when flows are very low, when this system is poorly flushed and when sunlight and temperatures are most conducive to excessive algal production.

The eutrophication model simulates twenty-two state variables, constituting five interacting systems: e.g., phytoplankton dynamics, nitrogen cycle, phosphorus cycle, silicate cycle, and oxygen dynamics. The water column eutrophication model solves the mass-balance equation for each state variable and for each model cell. A detailed description of the water column eutrophication model can be found in Cerco and Cole (1994).

Stream flow used in the calibration of the model was based on the three-dimensional, time-variable hydrodynamic model CH3D-WES developed at the US Army Engineer Waterways Experiment Station. The numerical grid employed in the model domain is shown in Wang *et al*, (2004). The number of cells and the grid resolution are the same as those of the water quality eutrophication model as described above. The detailed description of this model can be found in Johnson *et al*. (1991).

There were only two point sources of nutrients in the Back River watershed during the 1992-1997 model calibration period: the Back River municipal WWTP located in Baltimore County and one minor industrial discharge, Eastern Stainless. The Eastern Stainless plant stopped discharging into the Back River in 1999 and it is only considered in the calibration of the model. The Back River treatment plant had a flow that averaged 107 mgd or 4.7 m^3/s during the 1992-1997 model calibration period, and the flow from the Eastern Stainless plant was very small, approximately 0.2 mgd or 0.0088 m^3/s. (See Section 2.1, General Setting and Source Assessment for more discussion). The Back River WWTP and the Esatern Stainless plant have been accounted for at the water quality model cells 3617 and 3634 of the eutrophication model, respectively.

As stated above, the stormwater loads and nonpoint source loads estimation is described in Section 4.3. In brief, the HSPF model, which simulates the fate and transport of pollutants over the entire hydrologic cycle, was used to estimate nutrient loads from the watershed sub-basins. See "Patapsco/Back River Watershed HSPF Model Report, (MDE, 2001)".

The concentrations of the nutrients (nitrogen and phosphorus) are modeled in their speciated forms. Nitrogen is simulated as ammonium nitrogen (NH_4), nitrate+nitrite nitrogen (NO_{2-3}), refractory particulate organic nitrogen (RPON), labile particulate organic nitrogen (LPON), and dissolved organic nitrogen (DON). Phosphorus is simulated as total phosphate (PO_4t), refractory particulate organic phosphorus (RPOP), labile particulate organic phosphorus (LPOP), and dissolved organic phosphorus (DOP). NH_4, NO_{2-3}, DON and $PO_{4,}$ and DOP represent the dissolved forms of nitrogen and phosphorus. The dissolved forms of nutrients are the forms more readily available for biological processes such as algae growth, which affect chlorophyll *a* levels and DO concentrations.

4.3 Scenario Descriptions

The Back River eutrophication model was applied to investigate different nutrient loading scenarios under the stream flow conditions of the period between 1995 to 1997. These analyses allow a comparison of conditions, when water quality problems exist with future conditions that project the water quality response to various simulated load reductions of the impairing substances. By modeling three years consecutively, the analyses account for seasonality, a necessary element of the TMDL development process. The analyses are grouped according to *baseline conditions* and *future conditions,* the latter being associated with the TMDLs. Both scenarios were used to estimate low flow and average annual TMDLs.

Observed water quality and hydrological data collected in the last three years of the five-year model calibration period – 1995 through 1997 – were used to establish the baseline conditions. The baseline conditions are intended to provide a point of reference by which to compare the future scenarios that simulate conditions of a TMDL. The baseline conditions correspond roughly to the notion of "current conditions"; however, these current conditions have limitations. The notion of "current" is unstable and confusing because there is no single reference point in time over the long process of TMDL analysis, review and approval.

The baseline condition for urban-stormwater loads and nonpoint source loads typically reflects an approximation of loads during the monitoring time frame, in this case, the last three years of the calibration period (1995 to 1997). Baseline point source loads were also estimated using 1995 to 1997 discharge monitoring data for nutrients and flow. The baseline condition reflects a fixed current condition. Specific baseline loading assumptions for the point sources are presented in Wang *et al*, (1999).

4.3.1 Baseline Conditions Scenario

The baseline conditions scenario represents the observed conditions of the stream 1995 to 1997. This scenario simulates these three consecutive years, each with different flow and nutrient loadings. Simulating the system for three years accounts for different loading conditions and different hydrological conditions, addressing likely critical conditions of the system. For example, the 1995 – 1997 period simulates an average year (1995), a very wet year (1996) and a dry year (1997), and the summer months when the river system is poorly flushed, and sunlight and warm water temperatures are most conducive to creating the water quality problems associated with excessive nutrient enrichment. The hydrodynamics of the system was simulated using the CH3D-WES model and it is described in more detail in Wang *et al*, (1999).

The urban-stormwater concentrations and the nonpoint nutrient concentrations for the calibration and baseline scenario were estimated from the HSPF model of the Back River watershed, using observed data collected from 1995 to 1997. The HSPF simulates stormwater and nonpoint loads and integrate all natural and human induced sources, including direct atmospheric deposition, and loads from septic tanks, which are associated with river base flow during low flow conditions.

The 1995 to 997 point sources loadings used in this scenario were the same as in the calibration of the model. The WWTP discharge and the industrial discharge monitoring information were obtained from discharge monitoring reports stored in MDE's point source database. For more details on the calibration/baseline conditions scenario, please refer to Wang *et al*, (1999).

4.3.2 Baseline Condition Scenario Results

Results for this scenario, the calibration of the model, of which the three last years also represent the baseline conditions scenario, are summarized in Figures 14 to 17. Only DO and chlorophyll *a* calibration time series for water quality station WT4.1, and longitudinal profiles of the Back River for the same parameters are shown below. Model calibration results showing the other parameters time series and longitudinal profiles are presented in Part B of Appendix 1.

Figures 14 to 17 represent the 1992 – 1997 calibration of the model and also serve to show the 1995-1997 period used as the baseline condition scenario. As shown in figures 14 and 15, under the 1995-1997 baseline conditions, chlorophyll *a* concentrations throughout the length of the river exceed 50 µg/l, with values reaching close to 300 µg/l. Figures 16 and 17 show average DO concentrations remain above the water quality criterion of 5.0 mg/l throughout the entire length of the river and throughout the simulation period with minimum values below 5.0 mg/l at the headwaters near the Back River WWTP (For all other stations figures, see Appendix 1B).

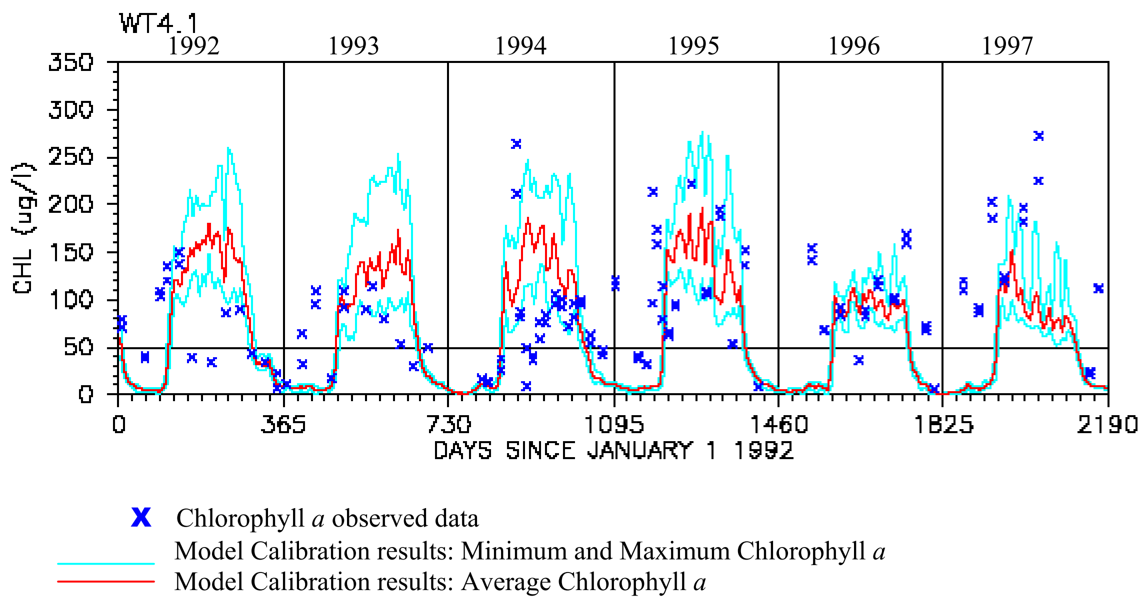
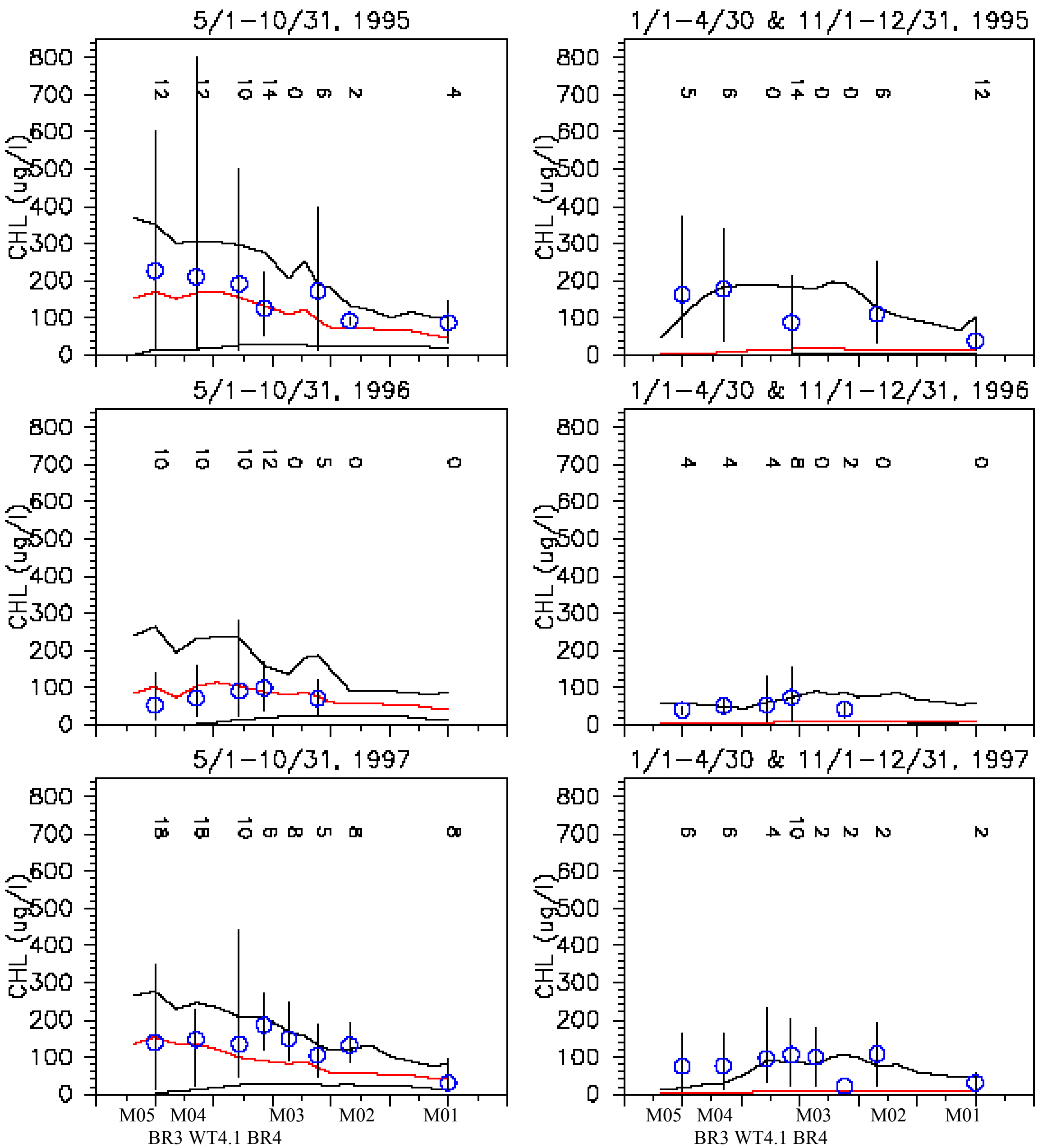
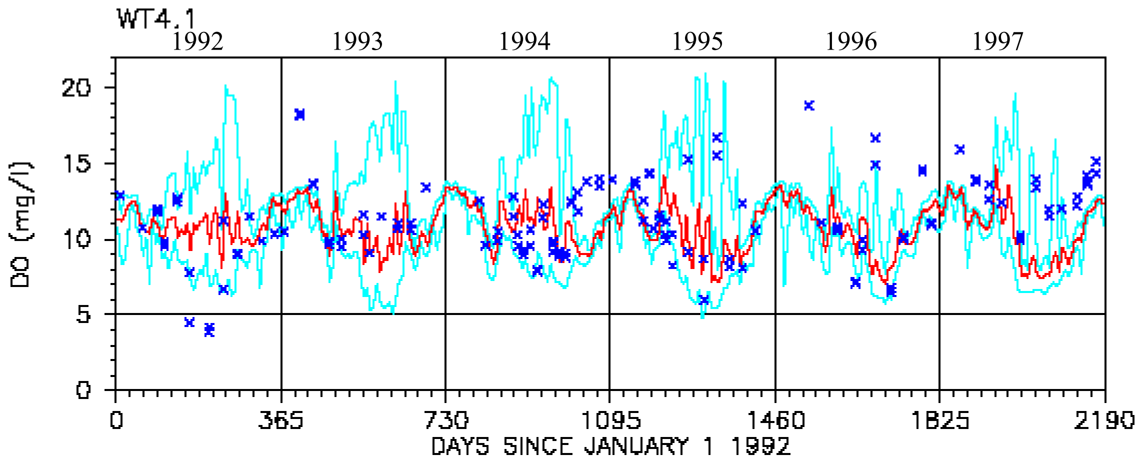


Figure 14: Station WT4.1: Model Results for the Calibration (1992 to 1997) and Baseline Conditions Scenario (1995 to 1997) for Chlorophyll *a* in the Back River



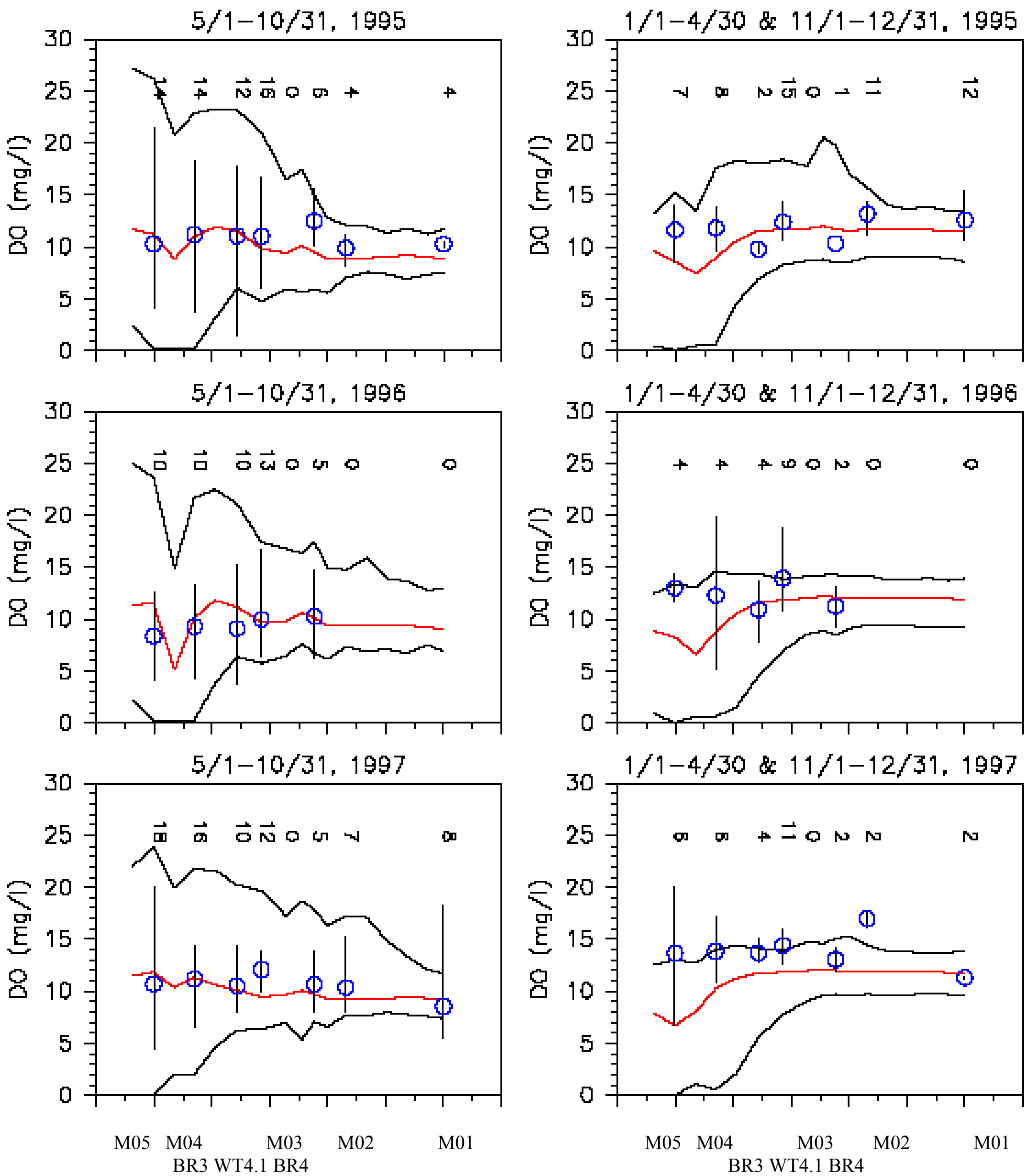
O Average Chlorophyll *a* observed data
Model Calibration results: Minimum and Maximum Chlorophyll *a*
Model Calibration results: Average Chlorophyll *a*

Figure 15: Longitudinal Profile of the Calibration (1992 to 1997) and/or Baseline Conditions (1995 to 1997) for Chlorophyll *a* in the Back River



Observed data
Model Calibration results: Weekly Minimum and Maximum DO
Model Calibration results: Weekly Average DO

Figure 16: Station WT4.1: Model Results for the Calibration (1992 to 1997) and/or Baseline Conditions Scenario (1995 to 1997) for DO in the Back River



o Average DO observed data

Model Calibration results: Weekly Minimum and Maximum DO

Model Calibration results: Weekly Average DO

Figure 17: Longitudinal Profile of the Calibration (1992 to 1997) and/or Baseline Conditions (1995 to 1997) for DO in the Back River

4.3.3 Future Conditions (TMDLs) Scenario

This scenario provides an estimate of future conditions of the Back River system at maximum allowable average annual and summer (May 1st to October 31st) loads. The scenario uses the same flows and hydrological and environmental conditions as the calibration/baseline scenario, but simulates a maximum design flow with lower concentrations of PS nitrogen and phosphorus discharges and a 15% reduction in nitrogen and phosphorus urban loads for the four subwatersheds of the Back River system. This future conditions scenario was used to estimate both low flow and average annual flow TMDLs.

In summary, the future conditions scenario represents a reduction in the point source nutrient loadings and a reduction taken from the baseline urban loads estimated by the HSPF watershed model, as described in "Patapsco/Back River Watershed HSPF Model Report", (MDE, 2001).

In this scenario, the point source loads from the Back River WWTP were set at very stringent limits necessary to meet water quality criteria. These point source loads (Back River WWTP only) were based on the NPDES permit flow of 130 MGD and concentrations of TN equal to 4 mg/l annual average (3 mg/L in May - October, 5 mg/L in November – April) and current NPDES permit limit for TP of 0.2 mg/l.

The nonpoint source load reduction was applied to urban-stormwater loads only. Urban areas account for approximately 80% of the total area of the Back River watershed, with corresponding urban-stormwater loads representing 87.4% of the annual average TN loads from the watershed (not including treatment plants loads), 94.4% of the annual average TP, 91.0% of the summer TN and 97.7% of the summer TP. Therefore, non-urban loads, including agricultural and forest loads represents a minor contribution to the total load.

Urban-stormwater TN and TP loads for this scenario were reduced by 15% from the baseline urban-stormwater loads in order to reach the water quality goals for Chesapeake Bay waters. This reduction is based on a combination of Best Management Practices (BMPs) efficiencies over the different land uses in the Back River watershed and followed the same assumptions made by the Chesapeake Bay Program and MD's Tributary Strategies. The urban-stormwater load reduction was also based on the combination of management programs implemented in both jurisdictions comprised by the watershed (Baltimore City and Baltimore County) during and after the 1995 – 1997 period. These management programs are still being implemented in the watershed and already account for reductions in nutrients loadings. For example, the 2003 Municipal Stormwater Discharge Permit (NPDES) Annual Report from Baltimore County shows among several projects that in the Back River watershed, nine stormwater retrofit/conversion projects, addressing 598 acres of drainage area have either been completed or are in the design stage. Also in the Baltimore County part of the Back River watershed, seven stream restoration projects addressing 7,181 linear feet of degraded stream channel have either been completed or are in the design phase (Baltimore County NPDES Municipal Stormwater Discharge Permit, 2003 Annual Report (June 15, 2003). From a similar report from Baltimore City Department of Public Works, there are currently five stormwater projects being initiated in the City's Back River watershed; three stormwater retrofits, which are in the design phase (costs: $1,500,000 and $1,000,000 and $174,000), one stream channel study ($205,788), and one monitoring station that is under construction ($100,000) (City of Baltimore, NPDES Stormwater Permit Program Annual Report. May 3, 2004).

4.3.4 Future Condition (TMDLs) Scenario Results

Figures 18 to 23 below represent the results of the TMDLs scenario.

As shown in the figures, under the nutrient load reduction conditions described above for this scenario, rolling monthly average chlorophyll *a* concentrations remain below 50 µg/l along the entire simulation period and throughout length of the Back River. The chlorophyll *a* attainment was checked using time series of "rolling monthly average Chla concentrations" against the 50 µg/l goal. For DO, the attainment was also checked comparing time series of minimum DO concentrations against the DO criteria of 5 mg/l. The comparison shows the nutrient load reductions result in little change, maintaining the minimum DO concentrations above 5 mg/l along the length of the river.

For the Back River WWTP, the total nitrogen concentration for this scenario is set at a level determined by the Enhanced Nutrient Removal Strategy (ENR) to a maximum of 5.0 mg/l from November 1 to April 30th and a maximum of 3.0 mg/l from May 1st to October 31st. The total phosphorus is set at the current permit limit of 0.2 mg/l, with a maximum allowable flow of 130 mgd, which corresponds to the current permit flow of the facility that can be discharged into the Back River. The Eastern Stainless industrial plant does not discharge any longer into the Back River and was not considered for this scenario.

Model results for the TMDL scenario are summarized in Figures 18 to 23. Only DO and chlorophyll *a* TMDLs time series for water quality stations M01 (mouth of the river), WT4.1 (long term station, middle of the river) and M05 (upstream of the river), are shown below. Model results for all parameters associated with this scenario can be found in Part C of Appendix 1.

As seen in the figures below, under the TMDLs scenario conditions, the minimum DO in the Back River during the 1995-1997 period is above 5.0 mg/l and monthly average chlorophyll *a* concentrations is below the goal of 50 µg/l. Using rolling monthly average chlorophyll *a* values as a statistical tool to estimate chlorophyll *a* criteria attainment, the TMDL scenario model results show the river maintains chlorophyll *a* attainment, below 50 µg/l, throughout the TMDL period of 1995 to 1997. Chlorophyll *a* rolling monthly average values were used to estimate criteria attainment. The system shows a maximum chlorophyll *a* monthly rolling average of 49.8 µg/l for May 1 to October 31 at station M05, the most critical location in the estuary. Minimum DO levels also are always above 5.0 mg/l at all locations and throughout the 1995-1997 TMDL scenario period.

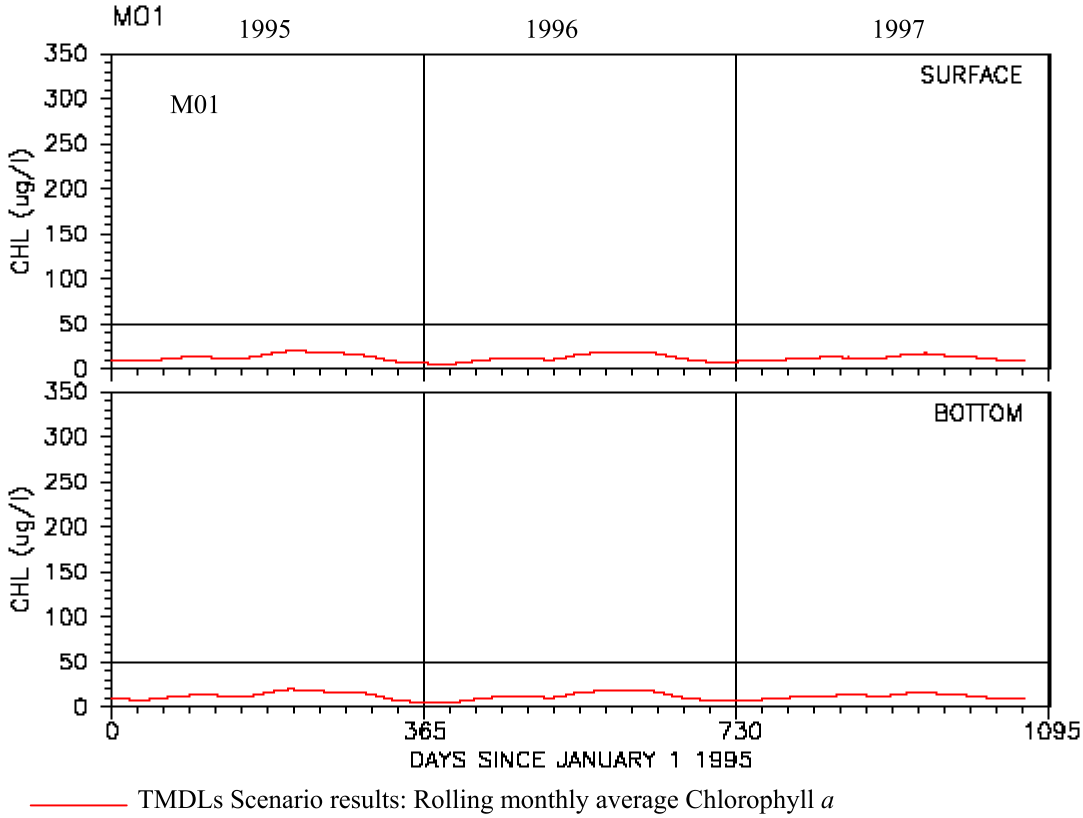


Figure 18: Station M01: Model Results for the TMDLs Scenario for Chlorophyll *a*

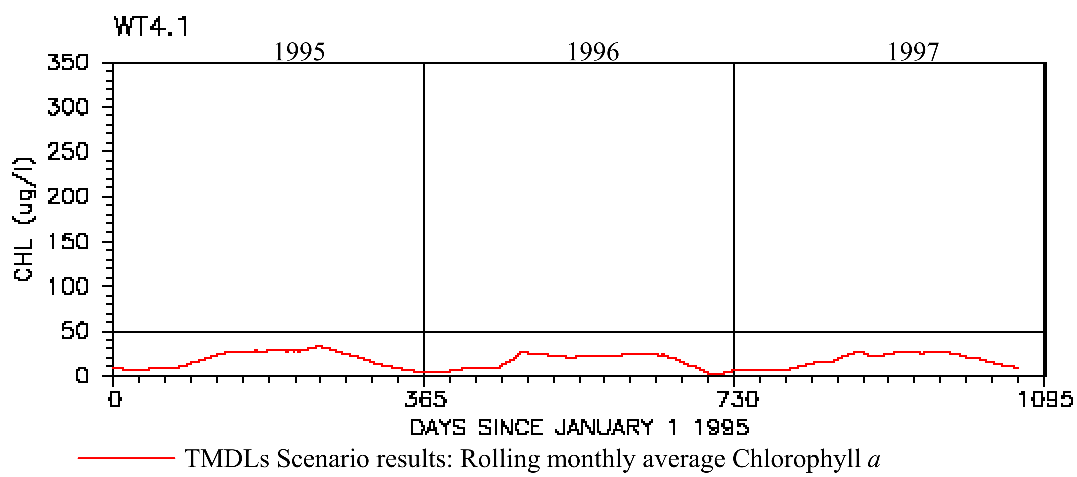
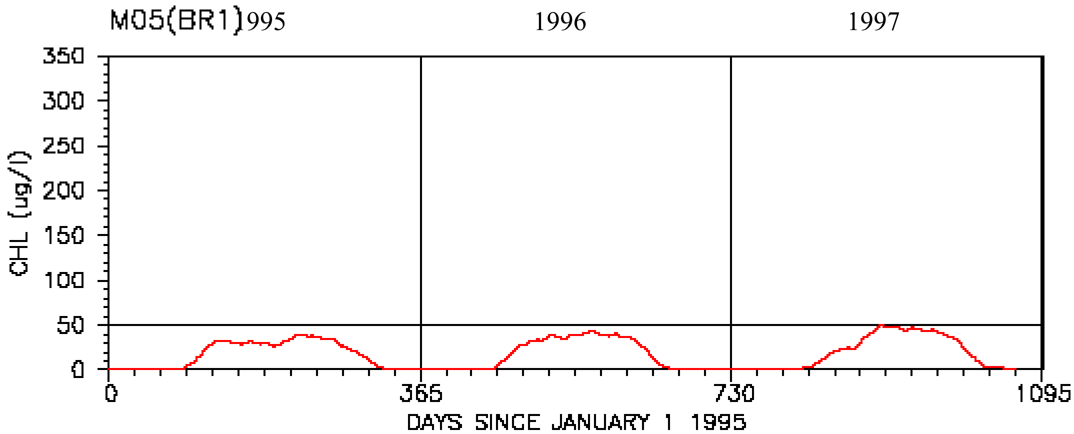
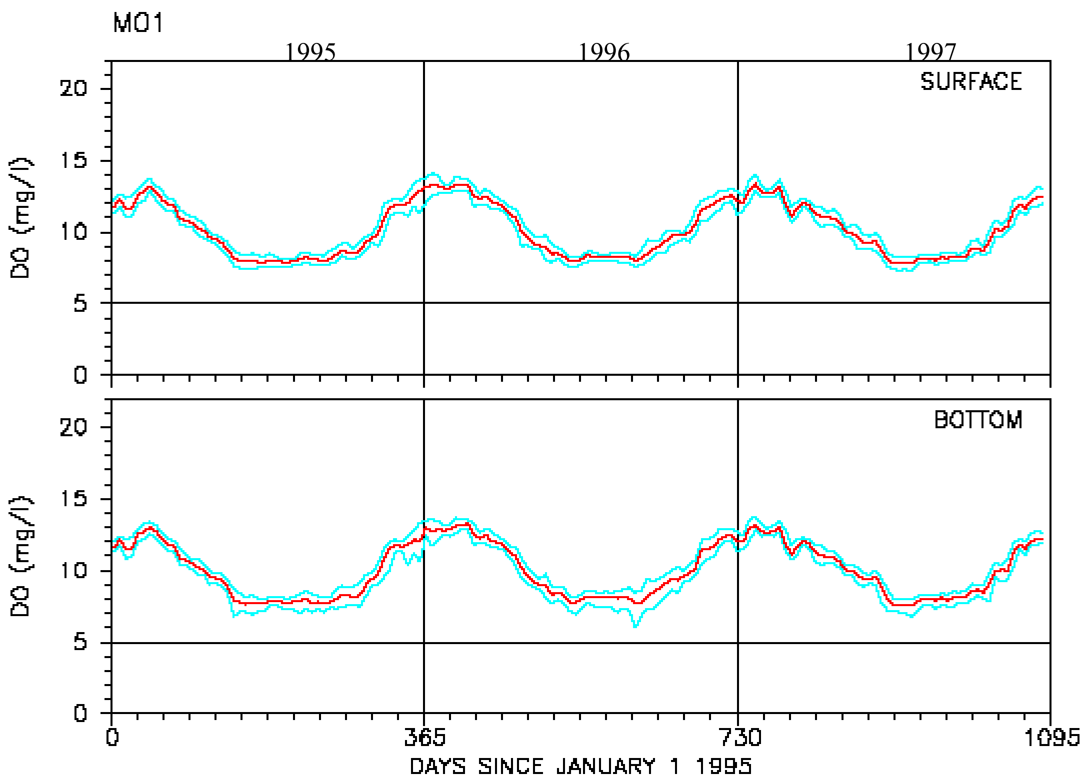


Figure 19: Station WT4.1: Model Results for the TMDLs Scenario for Chlorophyll *a*



TMDLs Scenario results: Rolling monthly average Chlorophyll *a*

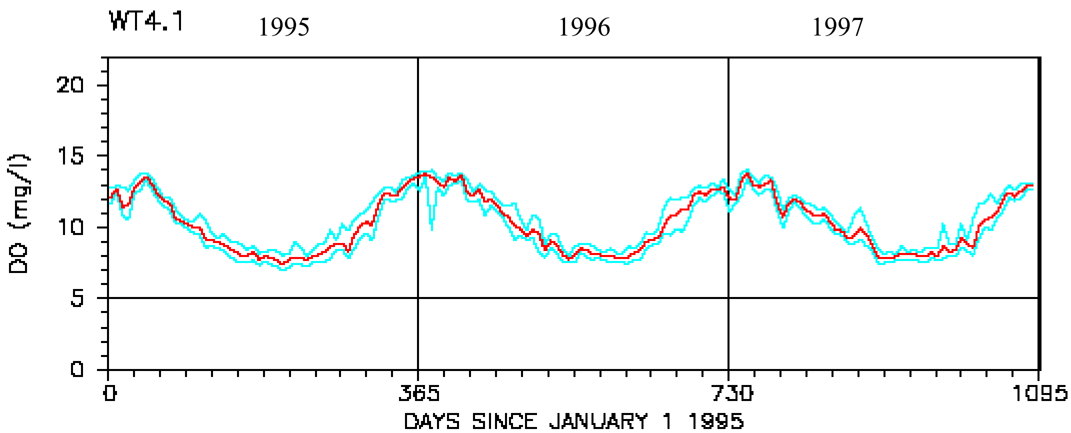
Figure 20: Station M05: Model Results for the TMDLs Scenario for Chlorophyll *a*



TMDLs Scenario results: Weekly Minimum and Maximum DO

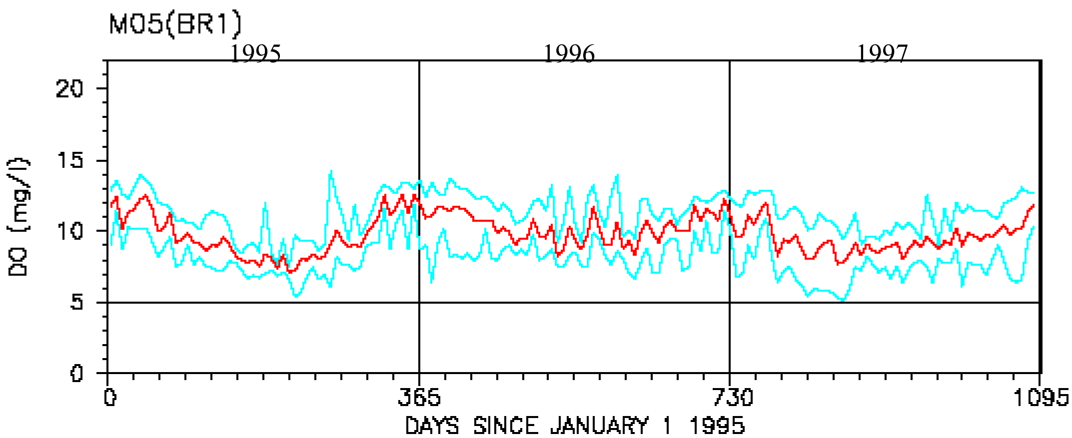
TMDLs Scenario results: Weekly Average DO

Figure 21: Station M01: Model Results for the TMDLs Scenario for Dissolved Oxygen



TMDLs Scenario results: Weekly Minimum and Maximum DO
TMDLs Scenario results: Weekly Average DO

Figure 22: Station WT4.1: Model Results for the TMDLs Scenario for Dissolved Oxygen



TMDLs Scenario results: Weekly Minimum and Maximum
TMDLs Scenario results: Weekly Average DO

Figure 23: Station M05: Model Results for the TMDLs Scenario for Dissolved Oxygen

4.4 TMDL Loading Caps

This section presents the TMDLs for nitrogen and phosphorus. The outcomes are presented in terms of an average annual TMDL and a low flow TMDL. The TMDLs were estimated based on the nutrient loadings as explained in Section 4.3 and the resulting water quality of the Back River for the simulated years 1995, 1996 and 1997. This period was selected to estimate the TMDLs because it covers a period with a dry year as well as wet year, accounting for seasonality and critical conditions. The low flow TMDLs are stated in monthly terms because this critical condition occurs for a limited period of time. The detailed calculation of TMDL loading caps can be found in Part D of Appendix 1.

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

Low Flow TMDLs:

NITROGEN TMDL 113,321 ***lbs/month***

PHOSPHORUS TMDL 7,995 ***lbs/month***

The average annual TMDLs for nitrogen and phosphorus are:

Average Annual TMDLs:

NITROGEN TMDL 1,773,100 ***lbs/year***

PHOSPHORUS TMDL 99,171 ***lbs/year***

4.5 Load Allocations Between Point Sources and Nonpoint Sources

During the 1995 to 1997 period, the watersheds draining into the Back River had two permitted point sources discharging nutrients directly to the river. For the TMDL scenario, only the Back River WWTP is given an allocation. The Eastern Stainless plant has not discharged into the Back River since 1999. The allocations described in this section demonstrate how the TMDLs can be implemented to achieve water quality criteria in local waters and Chesapeake Bay waters. Specifically, these allocations show that the sum of nitrogen and phosphorus nutrient loadings to the Back River from existing point and nonpoint sources can be maintained safely within the TMDLs established herein. The State reserves the right to adjust future allocations provided such adjustments are consistent with achieving water quality standards.

4.5.1 Low Flow TMDL Allocations

Low flow TMDL allocations are intended for the period of May 1st to October 31st.

Load Allocations (LA)

- **Nonpoint Source Loads**
  The nonpoint loads of nitrogen and phosphorus simulated in the TMDLs scenario represent the same loads as in the calibration/baseline scenario for both the low flow period and the remaining months of the year from 1995 to 1997. Nonpoint source loads including agricultural loads and forest loads are assigned to the TMDL as LA. The calibration/baseline scenario loads were based on the MDE HSPF model of the Back

River watershed. The modeling of the watershed accounted for both "natural" and human-induced components, including atmospheric deposition and septic loadings. Details on the HSPF model can be found in "Patapsco/Back River Watershed HSPF Model Report", (MDE, 2001).

Waste Load Allocations (WLA)

- **Stormwater Loads**
  In November 2002, EPA advised States that NPDES-regulated stormwater discharges must be addressed by the wasteload allocation (WLA) component of a TMDL. See 40 C.F.R. § 130.2(h). NPDES-regulated stormwater discharges may not be addressed by the load allocation (LA) component of a TMDL. EPA also provided guidance on ways to reflect the stormwater wasteload allocation (WLA) in a TMDL. As explained in Section 4.3.3, the stormwater discharges loads of nitrogen and phosphorus simulated in the Back River TMDL scenario represent a 15% reduction in TN and TP from baseline urban-stormwater loads for both the low flow and the remaining months of the year. Urban-stormwater loads are now part of the WLA.

  Current stormwater Phase I individual permits and new stormwater Phase II permits will be considered point sources subject to WLA assignment in the TMDL, instead of LA assignment as in the past. EPA recognizes that limitations in the available data and information usually preclude stormwater allocations to specific outfalls. Therefore, the Agency guidance allows this stormwater WLA to be expressed as a gross allotment, rather than individual allocations for separate pipes, ditches, construction sites, etc. Available information for the Back River allows the stormwater WLA for this analysis to be defined separately for Baltimore City and Baltimore County; however, these WLAs aggregate municipal and industrial stormwater, including the loads from construction activity.

  Waste load allocations from point source dischargers are usually based on the relative contribution of pollutant load to the waterbody. Estimating a load contribution to a particular waterbody from the stormwater Phase I and II sources is imprecise, given the variability in sources, runoff volumes, and pollutant loads over time. Therefore, the stormwater WLA portion of the TMDL is based on the best loadings estimate currently available.

- **Wastewater Treatment Plants Loads**
  In addition to nonpoint source loads and stormwater point sources, waste load allocations to the Back River WWTP for these low flow TMDLs plus a 5% MOS, estimated as explained in the next section, make up the balance of the total allowable load.

  The Back River WWTP maximum allowable current permit flow of 130 MGD is used for this scenario, with concentrations set to achieve water quality goals to a maximum of total nitrogen of 3 mg/l from May 1^{st} to October 31^{st}. Total phosphorus limit is 0.2 mg/l year round. As explained before, the Eastern Stainless industrial plant did not discharge into Back River since 1999, and it is not considered in the TMDLs scenario. All significant point sources are addressed by this allocation and are described further in the technical memorandum entitled "*Significant Nutrient Point Sources in the Back River Watershed"*. The nitrogen and phosphorus allocations for low flow conditions are presented in Table 3.

The TMDL including loads from stormwater discharges are expressed as:

TMDL = WLA [non-stormwater point sources + regulated stormwater point source] + LA + MOS

Table 3: Low Flow Allocations

	Total Nitrogen *(lbs/month)*	**Total Phosphorus *(lbs/month)***
Nonpoint Source[1]	1,345	34
Point Source[2]	111,299	7,888
MOS[3]	677	73
Total	113,321	7,995

1. Excluding urban-stormwater loads.
2. Including urban-stormwater loads.
3. Representing 5% of baseline urban/stormwater loads.

4.5.2 Average Annual TMDL Allocations

Load Allocations (LA)

- **Nonpoint Source Loads**
  The average annual nonpoint nitrogen and phosphorus allocations are represented as the average of the HSPF simulated loads from 1995 to 1997. The nonpoint loads simulated in the HSPF model account for both "natural" and human-induced components. Nonpoint source loads include agricultural loads, forest loads and atmospheric.

Waste Load Allocations (WLA)

- **Stormwater Loads**
  The stormwater discharge loads of nitrogen and phosphorus simulated in the TMDLs scenario represent a 15% reduction in TN and TP from baseline urban-stormwater loads for the average annual TMDL scenario. Urban-stormwater loads are now part of the WLA.

- **Wastewater Treatment Plants Loads**
  Waste load allocations to the Back River WWTP plus a 5% MOS for the average annual conditions make up the balance of the total allowable load.

The Back River WWTP flow is the same as set for the low flow TMDLs allocations. TN concentration was set to a maximum of total nitrogen of 5 mg/l from November 1st to April 30th and to a maximum of 3 mg/l from May 1st to October 31st as indicated above. The load from urban-stormwater discharge is incorporated into the point source load as part of the annual waste load allocations. The point sources are addressed by this allocation and are described further in the technical memorandum entitled, *"Significant Nitrogen and Phosphorus Nonpoint Sources and Point Sources in the Back River Watershed*." The nonpoint and point source nitrogen and phosphorus allocations for average annual flow conditions are shown in Table 4.

Table 4: Average Annual Allocations

	Total Nitrogen *(lbs/yr)*	**Total Phosphorus *(lbs/yr)***
Nonpoint Source[1]	26,323	1,239
Point Source[2]	1,737,626	96,896
MOS[3]	9,151	1,036
Total	1,773,100	99,171

1. Excluding urban-stormwater loads.
2. Including urban-stormwater loads.
3. Representing 5% of baseline urban/stormwater loads.

4.6 Margins of Safety

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 exact nature and magnitude of pollutant loads from various sources and the specific impacts of those pollutants on the chemical and biological quality of complex, natural water bodies. 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 reserve a portion of the loading capacity as a separate term in the TMDL (i.e., TMDL = Load Allocation (LA) + Waste Load Allocation (WLA) + MOS). The second approach is to incorporate the MOS as conservative assumptions used in the TMDL analysis.

Maryland has adopted a MOS for these TMDLs using the above-mentioned first approach. The reserved load allocated to the MOS was computed as 5% of the urban-stormwater loads for nitrogen and phosphorus. For the low flow and the average annual flow TMDLs in the Back River, this MOS also represents a 5% of the total urban-stormwater loads. These explicit nitrogen and phosphorus margins of safety are summarized in Table 5.

Table 5: Low Flow and Average Annual Margins of Safety (MOS)

	Total Nitrogen	Total Phosphorus
MOS Low Flow	677 lbs/month	73 lbs/month
MOS Annual	9,151 lbs/yr	1,036 lbs/yr

4.7 Summary of Total Maximum Daily Loads

The Low Flow TMDLs, applicable from May 1 – October 31 for the Back River follow:

For Nitrogen:

TMDL (*lbs/month*)	=	LA	+	WLA	+	MOS
113,321	=	**1,345**	+	**111,299**	+	**677**

For Phosphorus:

TMDL (*lbs/month*)	=	LA	+	WLA	+	MOS
7,995	=	**34**	+	**7,888**	+	**73**

The average annual flow TMDLs for the Back River follow:

For Nitrogen

TMDL (*lbs/year*)	=	LA	+	WLA	+	MOS
1,773,100	=	**26,323**	+	**1,737,626**	+	**9,151**

For Phosphorus (*lbs/year*):

TMDL (*lbs/year*)	=	LA	+	WLA	+	MOS
99,171	=	**1,239**	+	**96,896**	+	**1,036**

Where:

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

Average Daily Loads:

On average, the low flow TMDLs will result in loads of approximately 3,777 lbs/day of nitrogen and 266 lbs/day of phosphorus. Similarly, the average annual flow TMDLs will result in loads of approximately 4,852 lbs/day of nitrogen and 271 lbs/day of phosphorus.

5.0 ASSURANCE OF IMPLEMENTATION

This section provides the basis for reasonable assurances that the nitrogen and phosphorus TMDLs will be achieved and maintained. For both TMDLs, Maryland has several well-established programs that will be drawn upon: the Water Quality Improvement Act of 1998 (WQIA), the Clean Water Action Plan (CWAP) framework, and the Chesapeake Bay Agreement's Tributary Strategies for Nutrient Reduction. Also, Maryland has adopted procedures to assure that future evaluations are conducted for all TMDLs that are established.

The implementation of point source nutrient controls will be executed through ENR strategy and NPDES permits. The ENR program provides cost-share grant funds to local governments to retrofit or upgrade wastewater treatment plants (WWTP) to remove a greater portion of nutrients from discharges. 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. The NPDES permits for the Back River WWTP will include nutrient goals that have been established, and, upon completion of the upgrade, the permittee shall make a best effort to meet the load goals, which provide a reasonable assurance of implementation. The NPDES permits should also be consistent with the assumptions made in the TMDL (e.g., flow, nutrients effluent concentrations, CBOD, DO, etc.).

Maryland's WQIA 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 to be done by 2005. Maryland's CWAP has been developed in a coordinated manner with the State's 303(d) process. All Category I watersheds identified in Maryland's Unified Watershed Assessment process are totally coincident with the impaired waters list for 2002 approved by EPA. The State is giving a high-priority for funding assessment and restoration activities to these watersheds.

In 1983, the States of Maryland, Pennsylvania, and Virginia, the District of Columbia, the Chesapeake Bay Commission, and the U.S. EPA joined in a partnership to restore the Chesapeake Bay. In 1987, through the Chesapeake Bay Agreement, Maryland made a commitment to reduce nutrient loads to the Chesapeake Bay. In 1992, the Bay Agreement was amended to include the development and implementation of plans to achieve these nutrient reduction goals. Maryland's resultant Tributary Strategies for Nutrient Reduction provide a framework supporting the implementation of nonpoint source controls in the Patapsco/Back Tributary Strategy Basin, which includes the Back River watershed. Maryland is in the forefront of implementing quantifiable nonpoint source controls through the Tributary Strategy efforts. This will help to assure nutrient control activities are targeted to areas in which nutrient TMDLs have been established.

In November 1990, EPA required jurisdictions with a population greater than 100,000 to apply for NPDES Permits for stormwater discharges. In 1983, the EPA Nationwide Urban Runoff Program found that stormwater runoff from urban areas contains the same general types of pollutants found in wastewater, and that 30% of identified cases of water quality impairment were attributable to stormwater discharges. The two jurisdictions where the Back River watershed is located, Baltimore City and Baltimore County, are required to participate in the stormwater NPDES program, and have to comply with the NPDES Permit regulations for stormwater discharges. Several management programs have been implemented in different areas served by the County and the City municipal separate storm sewer system. These jurisdiction-wide programs are designed to control stormwater discharges to the maximum extent practicable.

It is reasonable to expect that nonpoint loads can be reduced during low flow conditions. The nutrient loads sources during low flow include dissolved forms of the impairing substances from groundwater, the effects of agricultural ditching and animals in the stream, and deposition of nutrients and organic matter to the stream bed from higher flow events. When these sources are controlled in combination, it is reasonable to achieve nonpoint reductions of the magnitude identified by this TMDL allocation.

Finally, Maryland uses a five-year watershed cycling strategy to manage its waters. Pursuant to this strategy, the State is divided into five regions and management activities will cycle through those regions over a five-year period. The cycle begins with intensive monitoring, followed by computer modeling, TMDL development, implementation activities, and follow-up evaluation. The choice of a five-year cycle is motivated by the five-year federal NPDES permit cycle. This continuing cycle ensures that every five years intensive follow-up monitoring will be performed. Thus, the watershed cycling strategy establishes a TMDL evaluation process that assures accountability.

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BACK RIVER NUTRIENTS TMDLS

APPENDIX 1

PART A

BACK RIVER NUTRIENTS TMDLS

APPENDIX 1

PART B

BACK RIVER NUTRIENTS TMDLS

APPENDIX 1

PART C

BACK RIVER NUTRIENTS TMDLS

APPENDIX 1

PART D