Total Maximum Daily Loads of Nitrogen and Phosphorus for the Northeast River in Cecil County, Maryland

FINAL

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List of Abbreviations

μg/l	Micrograms per Liter
CEAM	Center for Exposure Assessment Modeling
CHL*a*	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
EPA	Environmental Protection Agency
EUTRO5.1	Eutrophication Module of WASP5.1
FA	Future Allocation
LA	Load Allocation
lbs/yr	Pounds per Year
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
NO_{2-3}	Nitrate + Nitrite
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source
NREM	Northeast River Eutrophication Model
ON	Organic Nitrogen
OP	Organic Phosphorus
PO_4	Ortho-Phosphate
SOD	Sediment Oxygen Demand
TMDL	Total Maximum Daily Load
USGS	United States Geological Survey
WASP5.1	Water Quality Analysis Simulation Program 5.1
WQIA	Water Quality Improvement Act
WQLS	Water Quality Limited Segment
WWTP	Waste Water Treatment Plant

EXECUTIVE SUMMARY

This document establishes Total Maximum Daily Loads (TMDLs) for nitrogen and phosphorus in the Northeast River (basin number 02-13-06-08). The Northeast River directly drains to the Chesapeake Bay and is a part of the Upper Eastern Shore Tributary Strategy Basin. The river is impaired by the nutrients nitrogen and phosphorus, which cause excessive algal blooms.

The water quality goal of these TMDLs is to reduce high chlorophyll *a* concentrations (a surrogate for algal blooms), and to maintain the dissolved oxygen criterion at a level whereby the designated uses for the Northeast River will be met. The TMDLs for the nutrients nitrogen and phosphorus were determined using the WASP5.1 water quality model. Loading caps for total nitrogen and total phosphorus entering the Northeast River are established for low flow conditions and for annual average flow conditions.

The low flow TMDL for nitrogen is 6,365 lbs/month, and the low flow TMDL for phosphorus is 673 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 1,886 lbs/month of total nitrogen, and 113 lbs/month of total phosphorus. The point sources are allocated 4,316 lbs/month of nitrogen, and 550 lbs/month of phosphorus. Urban land, yet to be developed, is provided a future allocation of 102 lbs/month of nitrogen and 6 lbs/month of phosphorus. The explicit margins of safety make up the remainder of the nitrogen and phosphorus allocations.

The average annual TMDL for nitrogen is 168,344 lbs/yr, and the average annual TMDL for phosphorus is 12,110 lbs/yr. The allowable loads have been allocated between point and nonpoint sources. The nonpoint source loads are allocated 74,749 lbs/year of total nitrogen and 3,763 lbs/year of total phosphorus. The point sources are allocated 84,268 lbs/year of total nitrogen and 7,906 lbs/year of total phosphorus. Urban land, yet to be developed, is provided a future allocation of 5,829 lbs/month of nitrogen and 276 lbs/month of 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 will play a role 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 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 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 Northeast River (basin number 02-13-06-08) 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, suspended sediments, lead, and zinc, with an additional listing of biological impacts added for the non-tidal portion in 2002. 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 aquatic plant growth, which eventually die and decompose, leading to bacterial consumption of dissolved oxygen (DO). For these reasons, this document proposes to establish TMDLs of the nutrients nitrogen and phosphorus in the Northeast River. The suspended sediment, lead, zinc, and biological impact impairments will be addressed at a future date.

2.0 SETTING AND WATER QUALITY DESCRIPTION

2.1 General Setting and Source Assessment

The Northeast River watershed is located in the extreme reaches of the Maryland portion of the upper Chesapeake Bay watershed (Figure 1). It is located in Cecil County and is bounded by the Principio Creek watershed to the west and by the Elk River to the east. Northeast River is tidal (fresh) as far north as the Town of North East where the head of tide intersects the fall line at the confluence of two major streams, the Northeast Creek and the Little Northeast Creek. The fall line intersects most of the central watershed, transversing both the Northeast Creek to the west, and Little Northeast Creek just to the east. The tidal segment of the Northeast River differs from a true estuary in that for the majority of the year there is little intrusion of salt from the lower Chesapeake; thus, there is neither longitudinal nor lateral distribution of salinity. This atypical tidal exchange produces unusual salinity distributions within the Northeast River. The watershed zone is predominately rural in nature (Figure 2), consisting mainly of animal operations (dairy cows and beef cattle farms) with fields dedicated to feed production. Farms are generally quite large in the region. Limited rural residential uses are present. The communities of North East and Charlestown where the Northeast River wastewater treatment plant is found are the major urban areas.

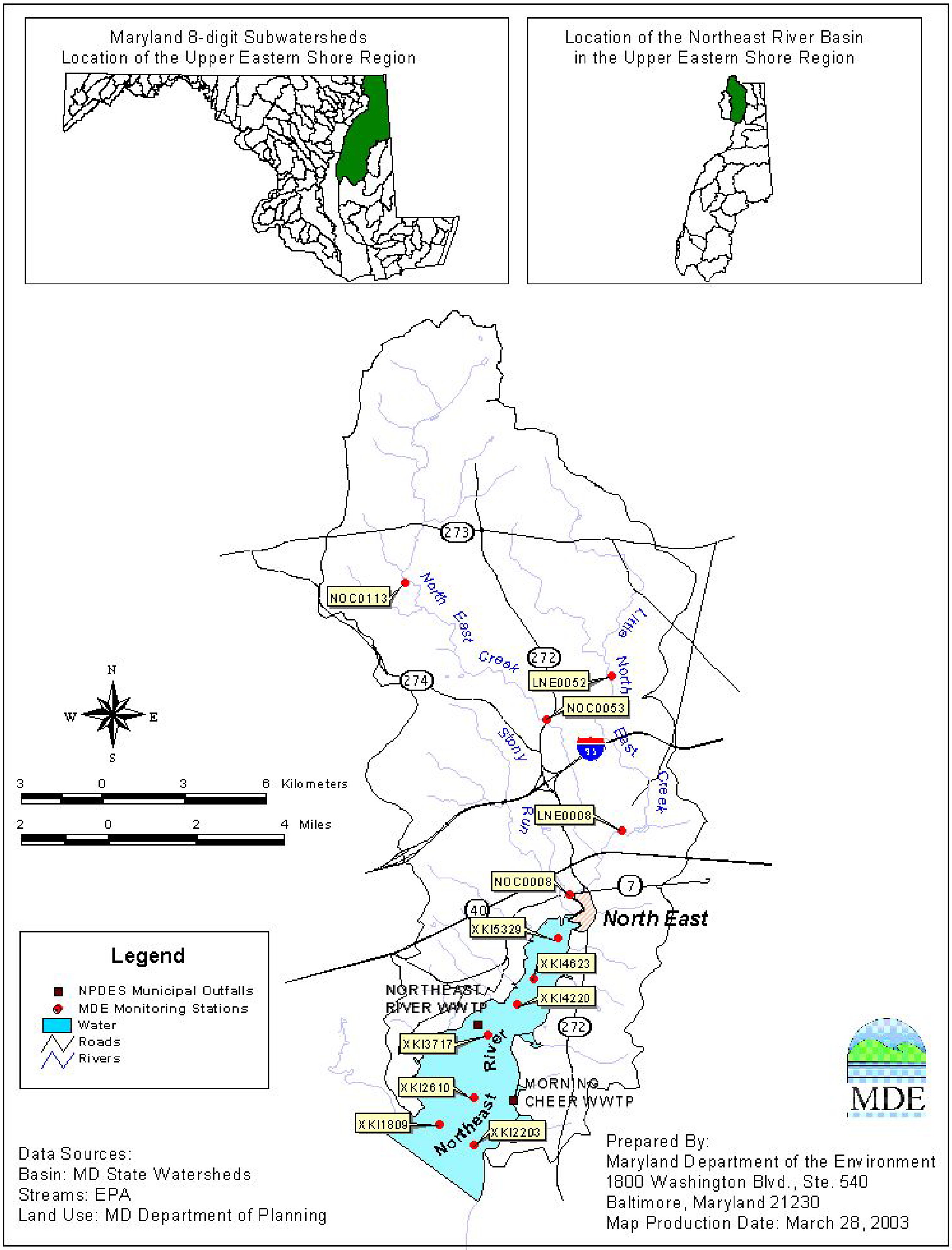

Figure 1: Location Map of the Northeast River Drainage Basin

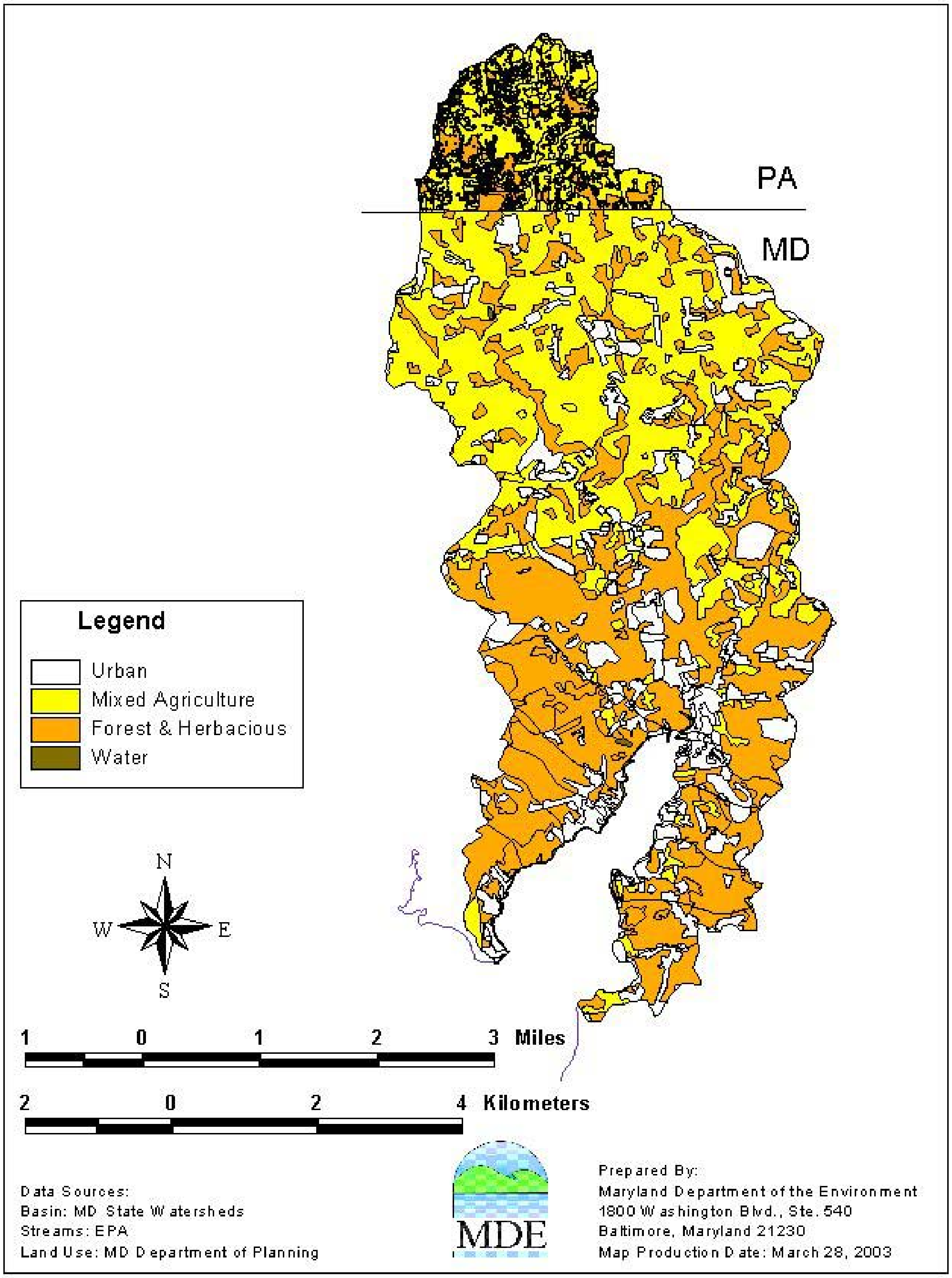

Figure 2: Predominant Land Use in the Northeast River Drainage Basin

The geology and topography, specifically the presence of steep slopes, makes the area very different from the nearby upper Eastern Shore. The steep slope topography and hard rock streambed strata, combined with an abrupt drop to the head of tide, augment the depositional character of Northeast River's tidal zone. Limited commercial fishing is conducted in the tidal zone of the Northeast River. Recreational fishing and general water contact recreation can be found most of the year.

The tidal portion of the river is approximately 5.9 miles (9.4 km) in length, from its confluence with Chesapeake Bay. The Northeast River watershed has an area of approximately 45,557 acres or 184.4 square kilometers. The land uses in the watershed consist of forest and other herbaceous (18,709 acres or 41.1 %), mixed agriculture (18,680 acres or 41.0%), water (132.5 acres or 0.3%), and urban (8,035 acres or 17.6%). The land use is based on 2000 Maryland Department of Planning (MDP) land use/land cover data. Pennsylvania land use is based on Multi Resolution Land Cover (MRLC) Data. Figure 3 shows the relative amounts of the different land uses.

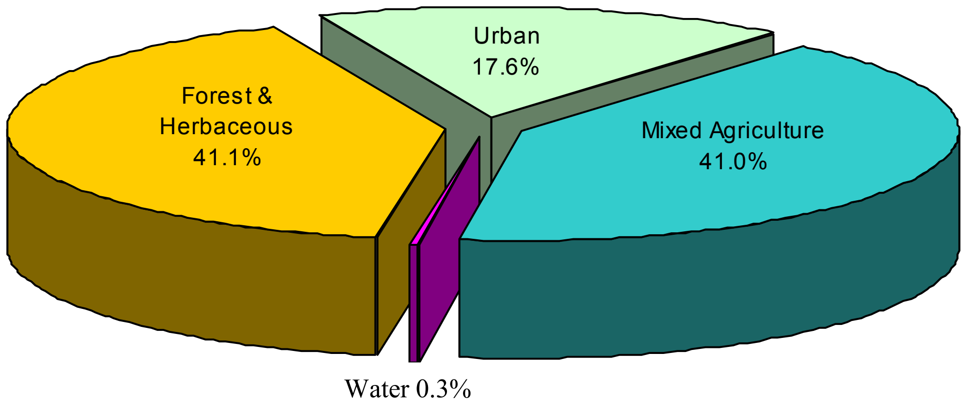

Figure 3: Proportions of Land Use in the Northeast River Drainage Basin

The Northeast River is tidal throughout its navigable reach, which extends from the confluence with Chesapeake Bay to approximately 5 miles (8 km) upstream to the head of tide, located near the Town of North East. The water quality model extends to the non-tidal region for approximately 0.9 miles upstream of the head of tide. The depths of the river range from about 6 inches (0.15 m) in the headwaters to greater than 13-15 feet (3.9-4.5 m) at the middle of the river. At the mouth of the river, the depth ranges from 6-7 feet (1.8-2.1 m).

In the Northeast River watershed, the estimated 1999 average annual total nitrogen (TN) load from nonpoint sources is 224,213 lbs/yr, and the NPS phosphorus load is 10,605 lbs/yr. The estimated 1999 average annual nitrogen load for point sources is 34,206 lbs/yr and the estimated 1999 average annual phosphorus load is 1,700 lbs/yr. These 1999 point source load estimates represent actual discharge nutrient loads from the Northeast River Wastewater Treatment Plant (WWTP) and Morning Cheer WWTP. Please note that these WWTPs do not discharge their maximum capacity all the time. For example, actual discharges in 1999 represent concentrations of total nitrogen between 21 mg/l and 18 mg/l with flows smaller than the permit limit. Similarly, the phosphorus concentrations discharged in 1999 were lower than the current permit limit of 2 mg/l. If operated at maximum allowable current permit flow and nutrients concentrations limits, the average annual point source load from these plants can increase up to 127,275 lbs/yr of TN and 12,687 lbs/yr of total phosphorus (TP) (only the Northeast River WWTP has permitted concentrations, the Morning Cheer WWTP does not have permitted concentrations for TN or TP).

Figure 4 shows the relative amounts of nitrogen and phosphorus NPS and point source loadings in 1999. The NPS loads were determined using the observed data collected by MDE in 1999. The total NPS load was calculated by multiplying the subwatershed flows by its corresponding observed concentrations. For comparison purposes, NPS loads were also estimated using MDE's land use with Chesapeake Bay Program's loading coefficients by land use. MDE's NPS load estimations are about one-half of what is estimated by the Chesapeake Bay Program Watershed Model for this area. It is important to note that the estimated NPS loads for baseline conditions (for low flow and average annual flow) solely serve as a rough basis to compare the NPS reduction needed to reach the TMDL limit. The analysis used to estimate the maximum allowable load to the water body (TMDL) does not depend on the baseline estimate of NPS loads. The NPS loads estimated as explained above account for atmospheric deposition, loads from septic tanks, and loads coming from urban development, agriculture and forestland. These average load values are presented to give the reader a reasonable estimate of the source contributions, and a sense of "current" conditions. The relative contributions of nutrient loads from each land use type, based on the Chesapeake Bay Program model, can be used to estimate NPS load reductions for those land uses.

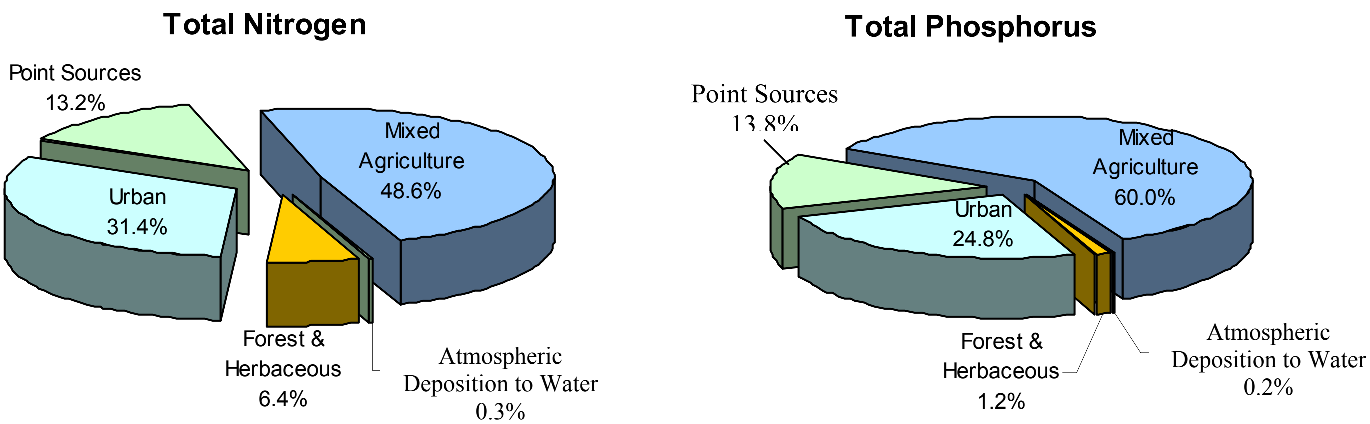

Figure 4: Percentages of Average Annual Nitrogen and Phosphorus Point and Nonpoint Source Loads in 1999

During August 1999, the time period used to calibrate the simulation model, loads from Northeast River WWTP were estimated to contribute 2,649 lbs/month of nitrogen and 153 lbs/month of phosphorus, and loads from Morning Cheer WWTP were estimated to contribute 256 lbs/month and 43 lbs/month, respectively. This information was obtained from discharge monitoring reports stored in MDE's point source database.

Finally, as part of the source assessment, we have considered nutrient loads from the Chesapeake Bay. It is possible that, during high flow events from the Susquehanna River, fresh water intrusions cause algal growth or nutrient-laden sedimentation, which could have secondary effects at later times (e.g. during low flow conditions). The fresh water intrusions from such high flow events are observed in the salinity profile data collected in 1999 (See Appendix A); however, determining the nutrient-related effects is an active area of research that is beyond the scope of this TMDL analysis. Nevertheless, the potential implications of this phenomenon are acknowledged in the section entitled "Assurance of Implementation."

2.2 Water Quality Characterization

Four water quality parameters associated with the observed impairment of the Northeast River - chlorophyll *a* (Chl*a*), DO, dissolved inorganic nitrogen (DIN), and dissolved inorganic phosphorus (DIP) - are presented in Figures 5 through 8. These data were collected by MDE during six water quality surveys conducted in the Northeast River during 1999. Three sets of samples were collected during seasonal low flow periods in summer (20-July-99, 17-Aug-99, 14-Sep-99), and three high flow periods in winter (16-Mar-99, 13-April-99, 11-May-99). The reader is referred to Figure 1 for the locations of the water quality sampling stations. Table 1 presents the distance of each station from the mouth.

Problems associated with eutrophication are most likely to occur during the summer season (July, August, September). During this season there is typically less stream flow available to flush the system, more sunlight to grow aquatic plants, and warmer temperatures, which are favorable conditions for biological processes of both plant growth and decay of dead plant matter. Therefore, the summer season, temperature, flow, sunlight and other parameters associated with represent critical conditions for the TMDL analysis. The TMDL analysis also considers other seasons; however, the data collected during the high flow period (March, April, May) do not show Chl*a* or DO problems. The following graphs present data from the low flow period. Additional data, including that for the high flow periods, are presented in Appendix A.

Table 1: Location of Water Quality Monitoring Stations

Water Quality Station	Kilometers from the Mouth of the Northeast River	LATITUDE	LONGITUDE
XKI1809	0.76	39 31 48.6	75 59 03.5
XKI2203	0.81	39 32 09.4	75 59 47.4
XKI2610	2.00	39 32 36.8	75 59 03.2
XKI3717	3.91	39 33 39.7	75 58 44.1
XKI4200	5.21	39 34 09.8	75 58 03.9
XKI4623	6.17	39 34 36.1	75 57 42.7
XKI5329	7.66	39 35 16.8	75 57 09.6
NOC0008	9.48	39 36 00.5	75 56 54.4
LNE0008	12.50	39 37 04.1	75 55 44.9
NOC0053	16.60	39 38 57.2	75 57 22.3
LNE0052	19.40	39 39 41.2	75 55 55.3
NOC0113	24.60	39 41 17.6	76 00 25.9

Figure 5 presents a longitudinal profile of Chl*a* data sampled during summer 1999, the low flow period. The sampling region covers the entire tidal portion of the Northeast River from the mouth, to the Town of North East on the Little North East Creek. Figure 5 shows that Chl*a* concentrations in the summer are above the maximum desired level of 50 µg/l except at the stations on the Chesapeake Bay CB1.1 and CB2.1 where the concentrations are below the maximum desired level of 50 µg/l. These two stations are part of the water quality monitoring program of the Chesapeake Bay Program, and were used only to estimate boundary conditions for the water quality model. The stations CB 1.1 and CB2.1 are not shown in figure 1, because they are outside of the Northeast River modeling domain. They are located near the mouth of the Susquehanna River and the Elk River respectively. For reasons that will be explained later, only August data (showed in the figure with the line) was used in the TMDL analysis.

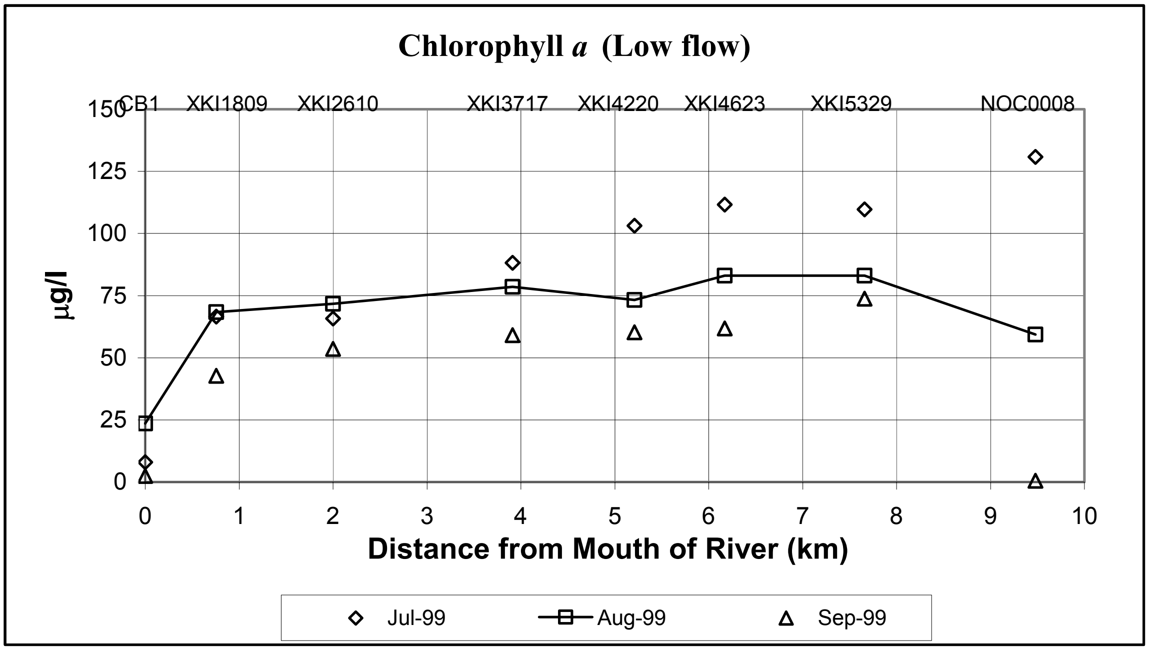

Figure 5: Longitudinal Profile of Chlorophyll *a* Data (Low Flow)

A similar longitudinal profile for DO concentrations is depicted in Figure 6. It shows that the observed DO levels along the whole stretch of the river do not fall below the standard of 5.0 mg/l.

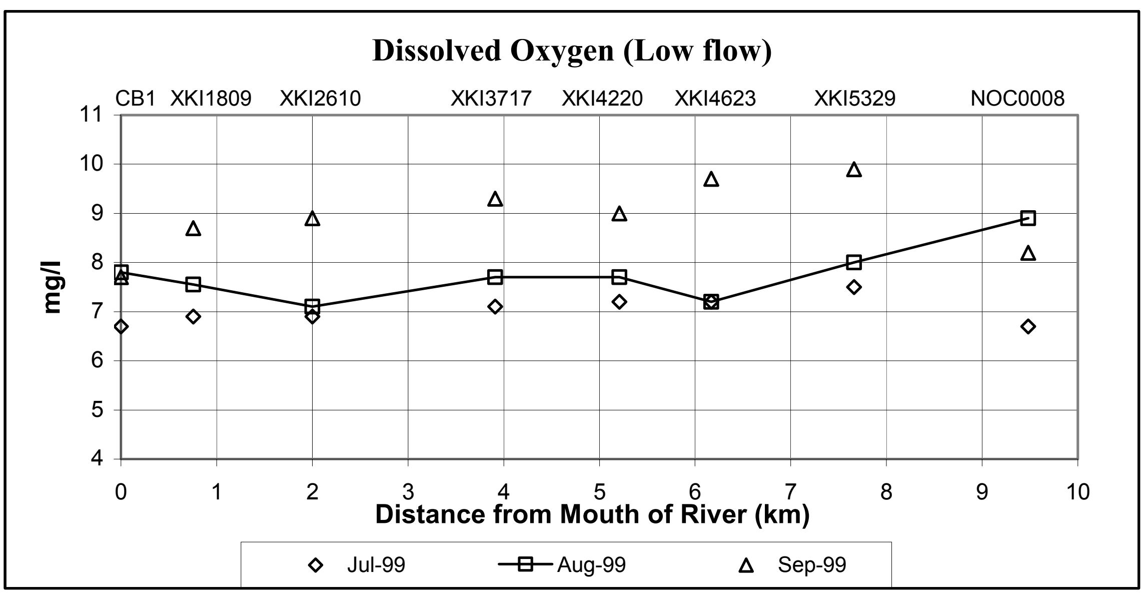

Figure 6: Longitudinal Profile of Dissolved Oxygen Data (Low Flow)

Figure 7 presents a longitudinal profile of DIN levels measured in the samples collected in 1999 during low flow conditions. The levels of most samples are below 0.1 mg/l for most of the river stretch, with the exceptions of several samples near the mouth of the river and the nontidal station (NOC0008) where concentrations are observed to reach values greater than 1.9 mg/l.

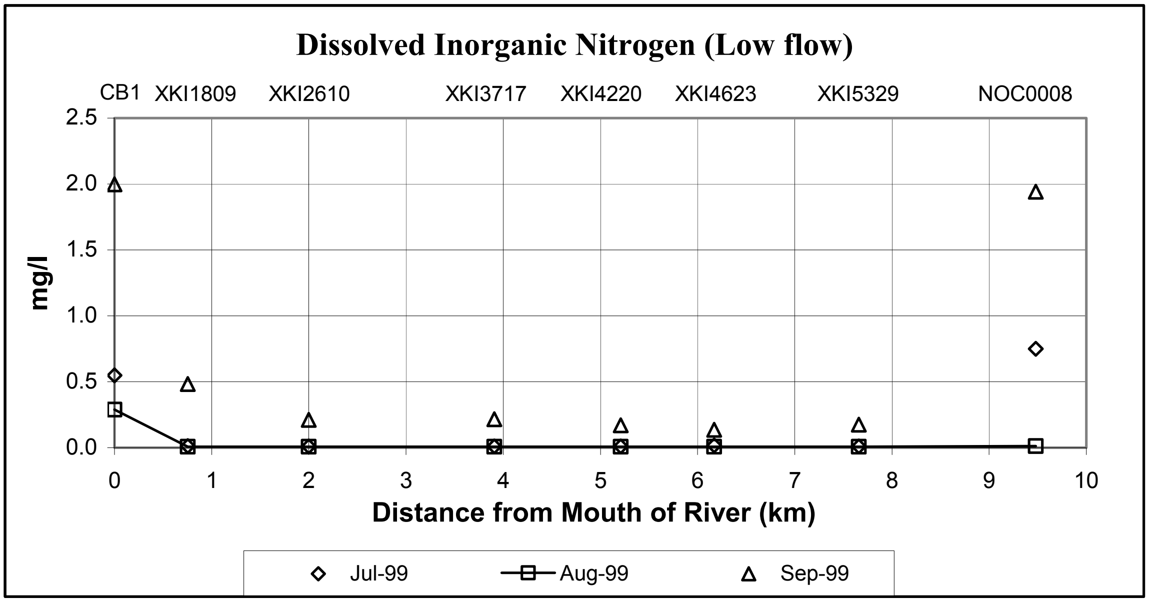

Figure 7: Longitudinal Profile of Dissolved Inorganic Nitrogen Data (Low Flow)

Figure 8 presents a longitudinal profile of DIP as indicated by ortho-phosphate levels measured in samples collected in 1999 during low flow conditions. Most of the observations are below the level of detection (0.01 mg/l). Again, concentrations are observed to increase towards the nontidal part of the river, where they reach a maximum of 0.1 mg/l.

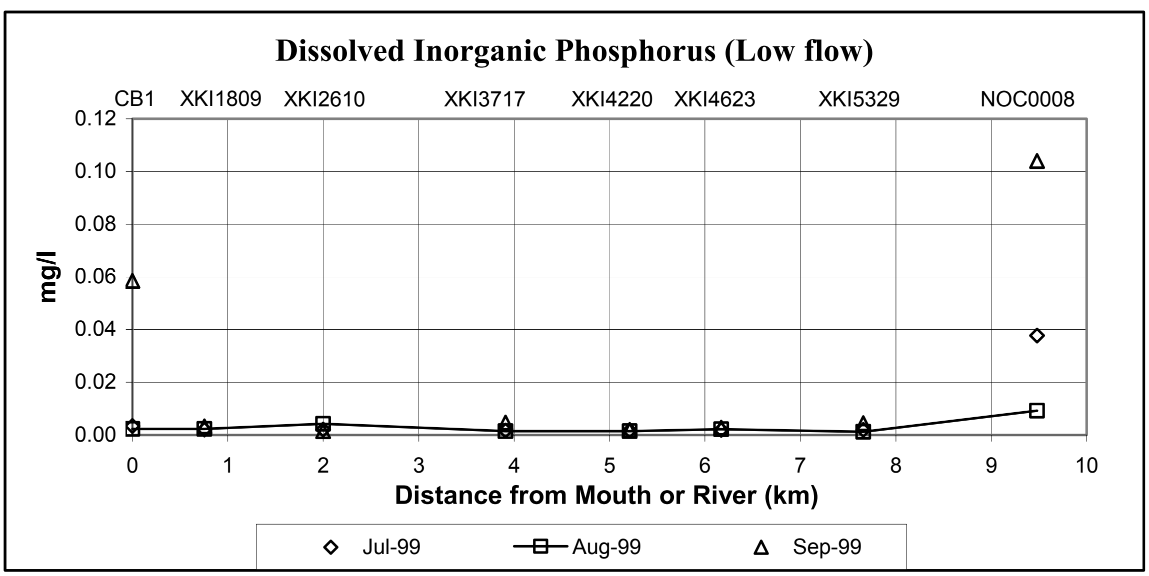

Figure 8: Longitudinal Profile of Dissolved Inorganic Phosphorus Data (Low flow)

2.3 Water Quality Impairment

The Maryland Water Quality Standards Surface Water Use Designation (Code of Maryland Regulations (COMAR) 26.08.02.07) for Northeast River is Use I -*water contact recreation, fishing, and protection of aquatic life and wildlife*. The water quality impairment of the Northeast River system addressed by this TMDL consists of an over-enrichment of nutrients. Nutrient loadings from primarily nonpoint sources have resulted in higher than acceptable Chl*a* concentrations. Point source contributions are less than NPS contributions in the Northeast River. Although DO concentrations were not observed to be below the minimum criteria of 5.0 mg/l in samples taken during the 1999 surveys, the high concentrations of Chl*a* suggest the possibility of low DO concentrations from diurnal variations in oxygen due to algal respiration during non-daylight hours.

Maryland's general water quality criteria prohibit pollution of waters of the State by any material in amounts sufficient to create nuisance or interfere with designated uses (COMAR 26.08.02.03B(2)). The TMDL analysis indicates that nitrogen and phosphorus loadings from nonpoint sources have resulted in Chl*a* concentrations above the desired level of 50 µg/l. The Chl*a* concentration in the upper reaches of the River occasionally exceeds the desired level of 50 µg/l. These levels have been associated with excessive eutrophication.

3.0 TARGETED WATER QUALITY GOAL

The overall objective of the TMDL established in this document is to reduce nitrogen and phosphorus loads to levels that are expected to result in meeting water quality criteria associated with eutrophication that support the Use I designation of the river. Specifically, reduction in the phosphorus and nitrogen loads is 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. As per COMAR 26.08.02.03-3, the DO concentration may not be less than 5 mg/l at any time for the Use I designation.

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

1. Resolve violations of narrative criteria associated with excess nutrient enrichment of the Northeast River system, as reflected in Chl*a* level greater than 50 µg/l in the poorly flushed tidal embayment; and

2. Assure that a minimum DO concentration of 5.0 mg/l is maintained throughout the Northeast River system.

The Chl*a* water quality level is based on the designated uses of Northeast River, guidelines set forth by Thomann and Mueller (1987), and by the EPA Technical Guidance Manual for Developing TMDLs, Book 2, Part 1 (1997).

4.0 TOTAL MAXIMUM DAILY LOADS AND ALLOCATION

4.1 Overview

This section describes how the nutrient TMDLs and load allocations for point sources and nonpoint sources were developed for the Northeast River. The second section describes the modeling framework for simulating nutrient loads, hydrology, and water quality responses. The third and fourth sections summarize the scenarios that were explored using the model. The assessment investigates water quality responses assuming different stream flow and nutrient loading conditions. The fifth and sixth sections present the modeling results in terms of a TMDL and allocate the TMDL between point sources and nonpoint sources. The seventh 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

The computational framework chosen for the Northeast River TMDLs was the Water Quality Analysis Simulation Program version 5.1 (WASP5.1). This water quality simulation program provides a generalized framework for modeling contaminant fate and transport in surface waters and is based on the finite-segment approach (Di Toro *et al.*, 1983). WASP5.1 is supported and distributed by U.S. EPA's Center for Exposure Assessment Modeling (CEAM) in Athens, GA (Ambrose *et al.*, 1988). EUTRO5.1 is the component of WASP5.1 that simulates eutrophication, incorporating eight water quality constituents in the water column and the sediment bed.

The WASP5.1 model was implemented in a steady-state mode. This mode of using of WASP5.1 simulates constant flow, and average water body volume over the tidal cycle. The tidal mixing is accounted for using dispersion coefficients, which quantify the exchange of conservative substances between WASP5.1 model segments. The model simulates an equilibrium state of the water body, which in this case considered low flow and average flow conditions. These conditions are described in more detail below. Limitations of this modeling framework are discussed in Appendix A.

The spatial domain of the Northeast River Eutrophication Model (NREM) extends from the confluence of the Chesapeake Bay and the Northeast River for about 6 miles along the mainstem to the head of the Northeast River. This modeling domain is represented by nine WASP model segments. A diagram of the WASP model segmentation is presented in Appendix A (Figure A7). Freshwater flows and NPS loadings from these subwatersheds are taken into consideration by dividing the drainage basin into 11 subwatersheds, also assuming the flows and loadings are direct inputs to the NREM.

The nutrient TMDL analysis consists of two broad elements: an assessment of low flow loading conditions and an assessment of average annual loading. The low flow TMDL analysis investigates the critical conditions under which symptoms of eutrophication are typically most acute (late summer when flows are low, system is poorly flushed and when sunlight and temperatures are most conducive to excessive algal production).

The water quality model was calibrated to reproduce observed water quality characteristics for both observed low flow and observed high flow conditions. The calibration of the model for these two flow regimes establishes an analysis tool that may be used to assess a range of scenarios with differing flow and nutrient loading conditions. Observed 1999 water quality data was used to support the calibration process, as explained further in the "Nonpoint Source Loadings" section of Appendix A.

Stream flow used in the low flow calibration was estimated based on the flows of one nearby U.S. Geological Survey (USGS) gage #01495000. An average flow for this USGS gage was calculated by obtaining an average value of the USGS data available for the month of August 1999. A ratio of flow to drainage area was calculated for that USGS gage. The flow for each subwatershed of the Northeast River was then determined by multiplying the flow to area ratio by its individual area. The 7Q10 flow (critical low flow) used for the low flow baseline scenario were also derived using the same method as described for the low flow calibration but using 7Q10 flow data from the same USGS station. The methods used to estimate stream flows are described further in Appendix A.

There are two significant point sources of nutrients in the Northeast River watershed: the Northeast River Municipal WWTP located just south of the Town of Charlestown and the Morning Cheer WWTP. The first treatment plant has a larger flow of up to 2.0 mgd or 0.088 m^3/s, and the flow from the second plant is smaller, only 0.055 mgd or 0.0024 m^3/s. (See Section 2.1, *General Setting and Source Assessment* for further discussion). These two treatment plants have been accounted for at the water quality model segments 5 and 4, respectively.

The methods of estimating NPS loadings are described in Section 4.3. In brief, low flow NPS loads were derived from concentrations observed during low flow sampling in 1999 multiplied by the estimated critical low flows. Because the low flow loading estimations are based on observed data, they account for all anthropogenic and natural sources. The average annual NPS loads were derived from an average of all data collected in 1999 for the purpose of average annual conditions. These methods are elaborated upon in Section 4.3 and in the "Nonpoint Source Loadings" section of Appendix A. It is important to note that the estimated NPS loads for baseline conditions (for low flow and average annual flow) solely serve as a rough basis from which to estimate the NPS reduction needed to reach the TMDL limit. The analysis used to estimate the maximum allowable load to the waterbody (TMDL) does not depend on the baseline estimate of the NPS loads. Thus, any uncertainty in the baseline NPS estimation does not affect the certainty of the estimated TMDL.

The concentrations of the nutrients (nitrogen and phosphorus) are modeled in their speciated forms. Nitrogen is simulated as ammonia (NH_3), nitrate and nitrite ($NO_{2\text{-}3}$), and organic nitrogen (ON). Phosphorus is simulated as ortho-phosphate (PO_4) and organic phosphorus (OP). NH_3, $NO_{2\text{-}3}$, and PO_4 represent the dissolved forms of nitrogen and phosphorus. The dissolved forms of nutrients are more readily available for biological processes such as algae growth, which affect Chl*a* levels and DO concentrations. The ratios of total nutrients to dissolved nutrients used in the model scenarios represent values that have been measured in the field. These ratios are not expected to vary within a particular flow regime. Thus, a total nutrient value obtained from these model scenarios, under a particular flow regime, is expected to be protective of the water quality criteria in the Northeast River.

4.3 Scenario Descriptions

The WASP model was applied to investigate different nutrient loading scenarios under various stream flow conditions. 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 both low flow and average annual loadings, 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 TMDL. Both groups include low flow and average annual loading scenarios for a total of four scenarios.

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, this mental picture has limitations. First, there is no such thing as a true "current" condition. Second, the baseline scenarios are typically simulations of unobserved conditions, as opposed to an observed "current" condition. Finally, the notion of "current" is confusing because there is no single reference point in time over the long process of TMDL analysis, review and approval.

The baseline conditions for NPS loads typically reflect an approximation of loads during the monitoring time frame, in this case, 1999. Baseline point source loads are typically estimated under the assumption of maximum approved water and sewer plan flows and either present permitted concentrations or estimates of expected concentrations at such flow. The baseline conditions often reflect a fixed potential future critical condition, approximating a maximum future loading with no control actions. Specific baseline loading assumptions for the point sources are presented in the "Point Source Loadings" section of Appendix A.

First Scenario: The first scenario represents the baseline conditions of the stream at a simulated critical low flow in the river. The method of estimating the critical low flow is described in Appendix A. The scenario simulates a critical condition 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 nutrient concentrations for the first scenario were computed using observed data collected during low flow conditions of August 1999. The low flow NPS loads were computed as the product of the observed concentrations and estimated critical low flow. These low flow NPS loads integrate all natural and human induced sources, including direct atmospheric deposition, loads from septic tanks, which are associated with river base flow during low flow conditions. For point sources loads, these baseline conditions assume maximum allowable flow (based on maximum approved water and sewer plan flow) and the corresponding parameter concentrations from the plants' National Pollutant Discharge Elimination System (NPDES) permits.

Second Scenario: The second scenario represents baseline conditions of the stream at average flow and average annual loading rate. Higher summer water temperatures and solar radiation values are used as conservative assumptions in this scenario. The total NPS loads were calculated using an average of all the observed 1999 data collected by MDE. The loads were computed as the product of the averaged observed 1999 concentrations and estimated average flow. The nutrient loads account for contributions from atmospheric deposition, septic tanks, cropland, pasture, feedlots, forest, and urban land. For point source loads, this scenario assumes maximum allowable WWTP flow and corresponding maximum parameter concentrations from the plants' NPDES permits (see "Point Source Loadings" of Appendix A for more details). A detailed description of this scenario can be found in Appendix A.

Third Scenario: The third scenario represents the future condition of maximum allowable loads during critical low stream flow. The stream flow is the same used in the first scenario. This scenario simulates an estimated overall 44% reduction and a 42% reduction from the TN and TP baseline conditions scenario NPS loads in the Northeast River watershed, respectively. This reduction in NPS loads includes a future allocation (FA) computed as 5% of the total NPS loads and a margin of safety (MOS) computed as 3% of the NPS load allocation (See section 4.7 for FA and MOS information). The point source loads were set at a level necessary to meet water quality standards. In this future condition scenario, reductions in nutrient sediment fluxes and sediment oxygen demand (SOD) were estimated based on the percentage reduction of organic matter settling on the bottom. Further discussion of this scenario is provided in Appendix A.

Fourth Scenario: The fourth scenario provides an estimate of future conditions of maximum allowable average annual loads. The scenario uses an average annual stream flow as in the second scenario. This scenario was conducted assuming high temperatures and sunlight to simulate conditions that are most conducive to algal growth. Because higher stream flows like the average annual flow, typically occur in cooler seasons, the assumptions of high water temperature and solar radiation used in the analysis are conservative with respect to environmental protection.

This scenario simulates an overall 52% reduction and a 49% reduction in NPS loads of nitrogen and phosphorus in all subwatersheds of the Northeast Creek watershed, respectively. A 5% of the total NPS load is included as FA and a 3% of the total NPS load is included as MOS for the NPS load allocations. The point source loads were set at a level necessary to meet water quality standards. Reductions in nutrient sediment fluxes were estimated based on the percent reduction of organic matter settling to the bottom, and computed as a function of the nutrient reduction. Further discussion of this scenario is provided in Appendix A.

4.4 Scenario Results

This section describes the results of the model scenarios described in the previous section. The NREM results presented in this section are daily minimum DO concentrations. These minimum DO concentrations account for diurnal fluctuations caused by photosynthesis and respiration of algae.

Baseline Condition Loading Scenario Results:

First Scenario (Low flow): Simulates critical low stream flow conditions during the summer season. Water quality parameters (e.g., NPS nutrient concentrations) are based on August 1999 observed data. Assumes maximum point source allowable flow and loads. Maximum allowable or maximum sampled concentrations were used in the baseline conditions scenario as a conservative assumption. Water temperature was estimated as the maximum temperature for the month of August from historical data (1984 to 1999).

Under these conditions, Chl*a* concentrations throughout parts of the length of the river exceed the maximum allowed goal of 50 µg/l, with values reaching up to 83.2 µg/l. Minimum DO concentrations remain above the minimum water quality criterion of 5.0 throughout the entire length of the river with a minimum value of 7.2 mg/l at the headwaters.

Results for the first scenario, representing the baseline conditions for summer critical low flow, are summarized in Figure 9.

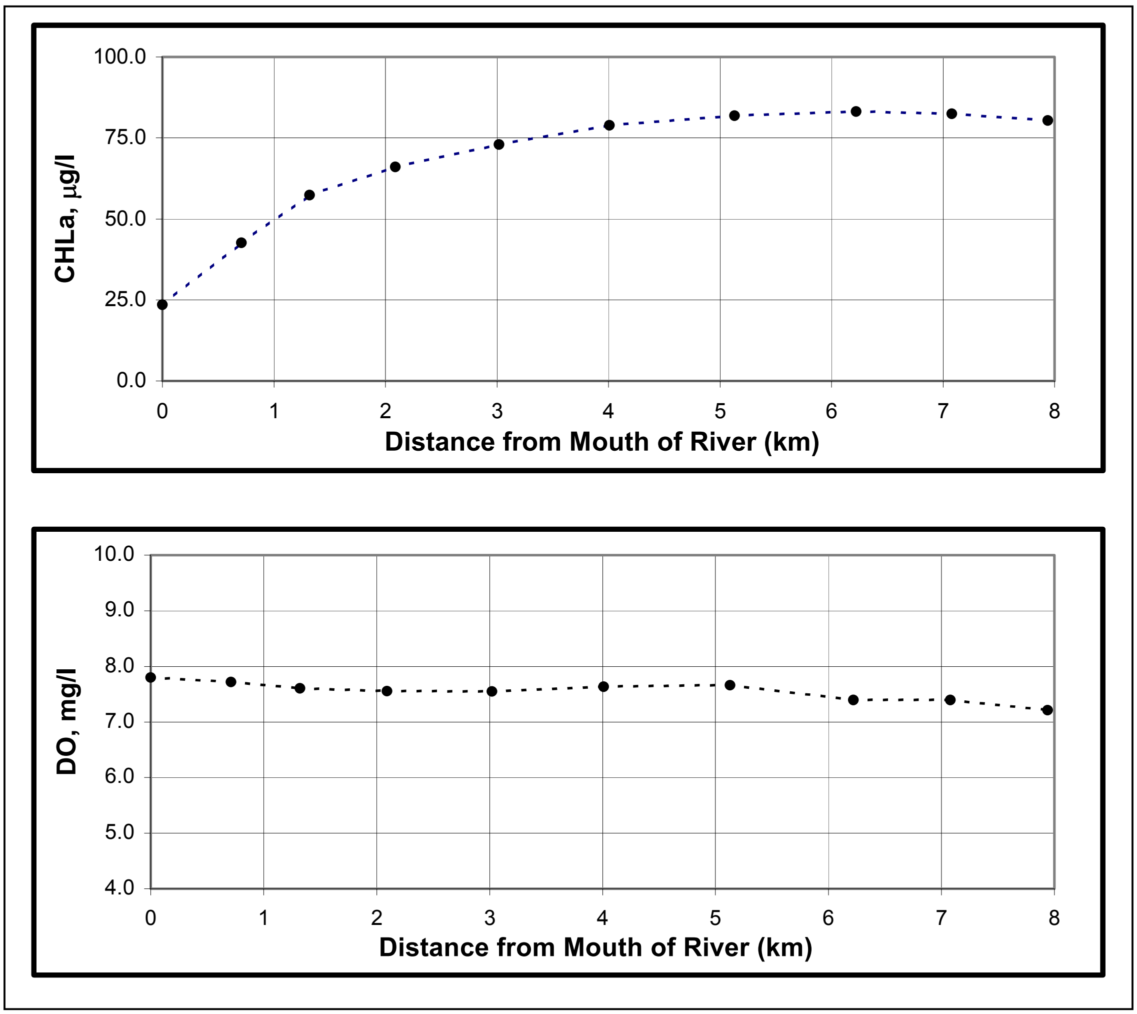

Figure 9: Model Results for the Baseline Low Flow Scenario for Chlorophyll *a* and Dissolved Oxygen (First Scenario)

<u>*Second Scenario (Average Annual Flow)*</u>*:* Simulates average annual 1999 stream flow condition under summer environmental conditions. Assumes baseline average annual nonpoint source

loads, and maximum point source design flow and load, and maximum mean temperature 28.9 ^{0}C for tidal and nontidal segments (see Appendix A).

Under these conditions, Chl*a* concentrations are higher than in the first scenario, almost reaching a value of 92.4 µg/l, and DO concentrations remain above 7.7 mg/l throughout the length of the river.

Results for the second scenario, representing the baseline conditions for the average annual stream flow and average loads, are summarized in Figure 10.

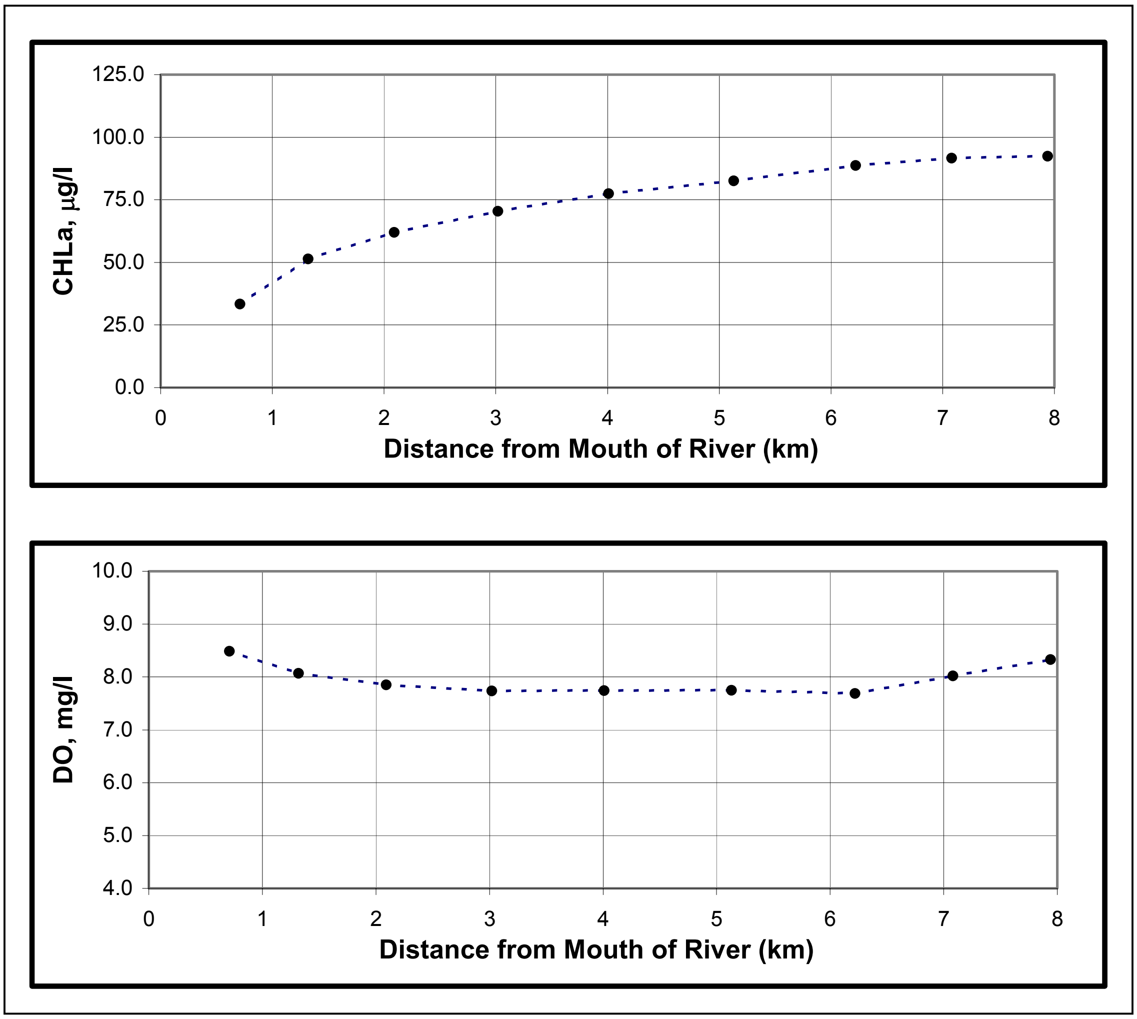

Figure 10: Model Results for the Baseline Average Annual Condition Scenario for Chlorophyll *a* and Dissolved Oxygen (Second Scenario)

Future Condition TMDL Scenarios Results:

Third Scenario (Low Flow): Simulates the future condition of maximum allowable loads for critical low stream flow conditions during the summer season (Figure 11). Results for the third scenario (bold line), representing the maximum allowable load for summer critical low flow, are summarized in comparison to the appropriate baseline conditions scenario (dotted line). Under the nutrient load reduction conditions described above for this scenario, the results show Chl*a* concentrations remain below 49.8 μg/l along the entire length of the Northeast River. For DO, the comparison shows that the nutrient load reductions result in little change, decreasing slightly the DO levels but maintaining the DO concentrations above 6.9 mg/l along the length of the river. Although the DO concentration model output reflects minimum DO, one of the major sources of DO in the water column is photosynthesis from chlorophyll *a* growth. If chlorophyll *a* growth decreases, the DO source will decrease slightly also. It can be noted the decrease in DO takes place as chlorophyll *a* decreases, and it is just a slight change.

NPS nutrient loads for this scenario were reduced by an overall 44% for nitrogen and 42% for phosphorus from the baseline NPS loads in order to reach the water quality goals.

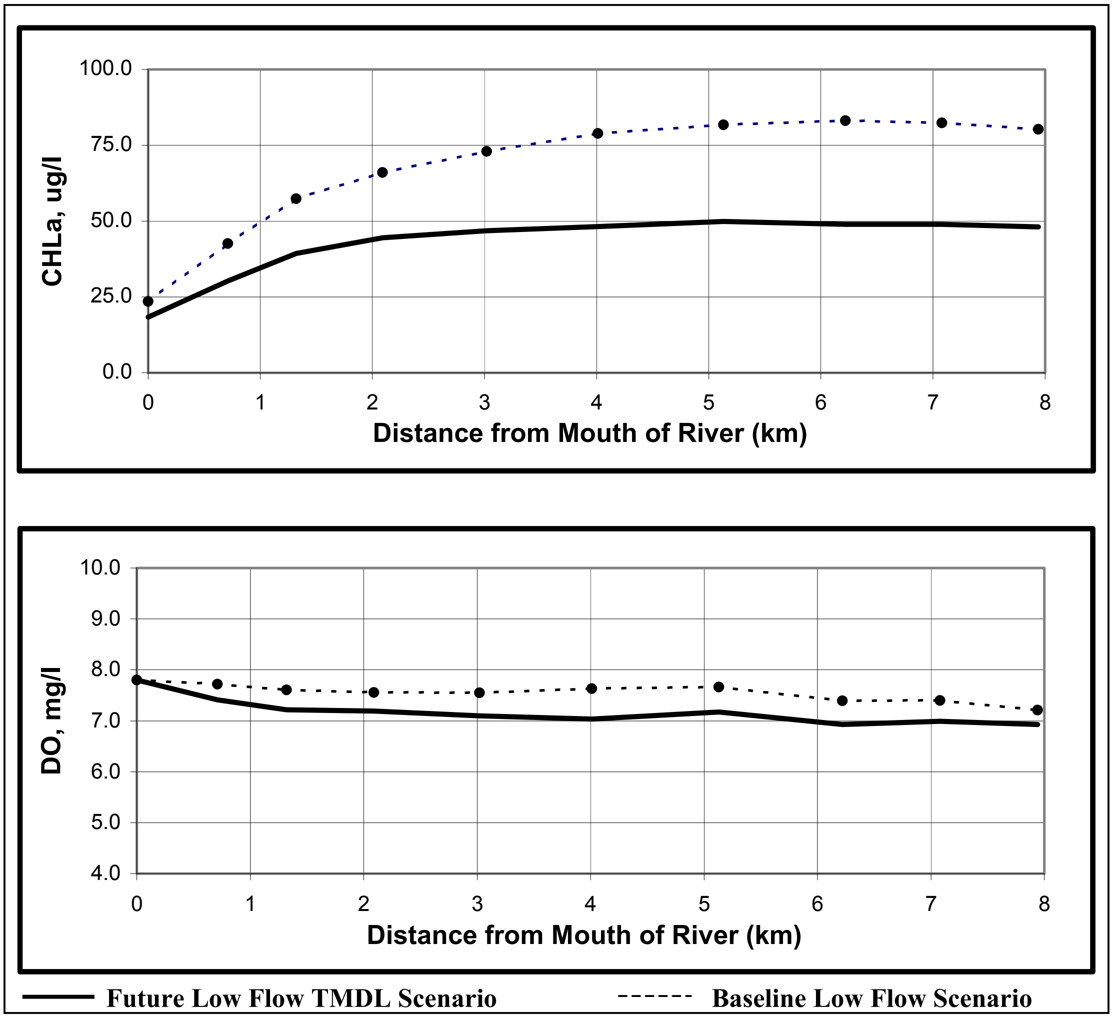

Figure 11: Model Results for the Low Flow Future Condition Scenario for Chlorophyll *a* and Dissolved Oxygen (Third Scenario)

Point source concentrations are set to new limits that were adjusted in order to reach the water quality goal concentrations of a maximum of 50 µg/l and a minimum DO of 5.0 mg/l. For the Northeast River WWTP, the total nitrogen concentration for this scenario is set to a maximum of 8 mg/l and the total phosphorus is set to a maximum limit of 1.0 mg/l, with a maximum allowable flow of 2 mgd. The Morning Cheer WWTP is considered a "minor" plant with a maximum allowable flow equal to 0.055 mgd, therefore no load reductions were assumed for this WWTP, and it is assumed that the concentrations are the same as the current plant concentrations with no additional treatment.

Fourth Scenario (Average Annual Flow): Simulates the future condition of maximum allowable annual loads under average annual stream flow and loading conditions.

Results for the fourth scenario (bold line), representing the maximum allowable loads for average annual flow, are summarized in comparison to the appropriate baseline scenario (dotted line) in Figure 12.

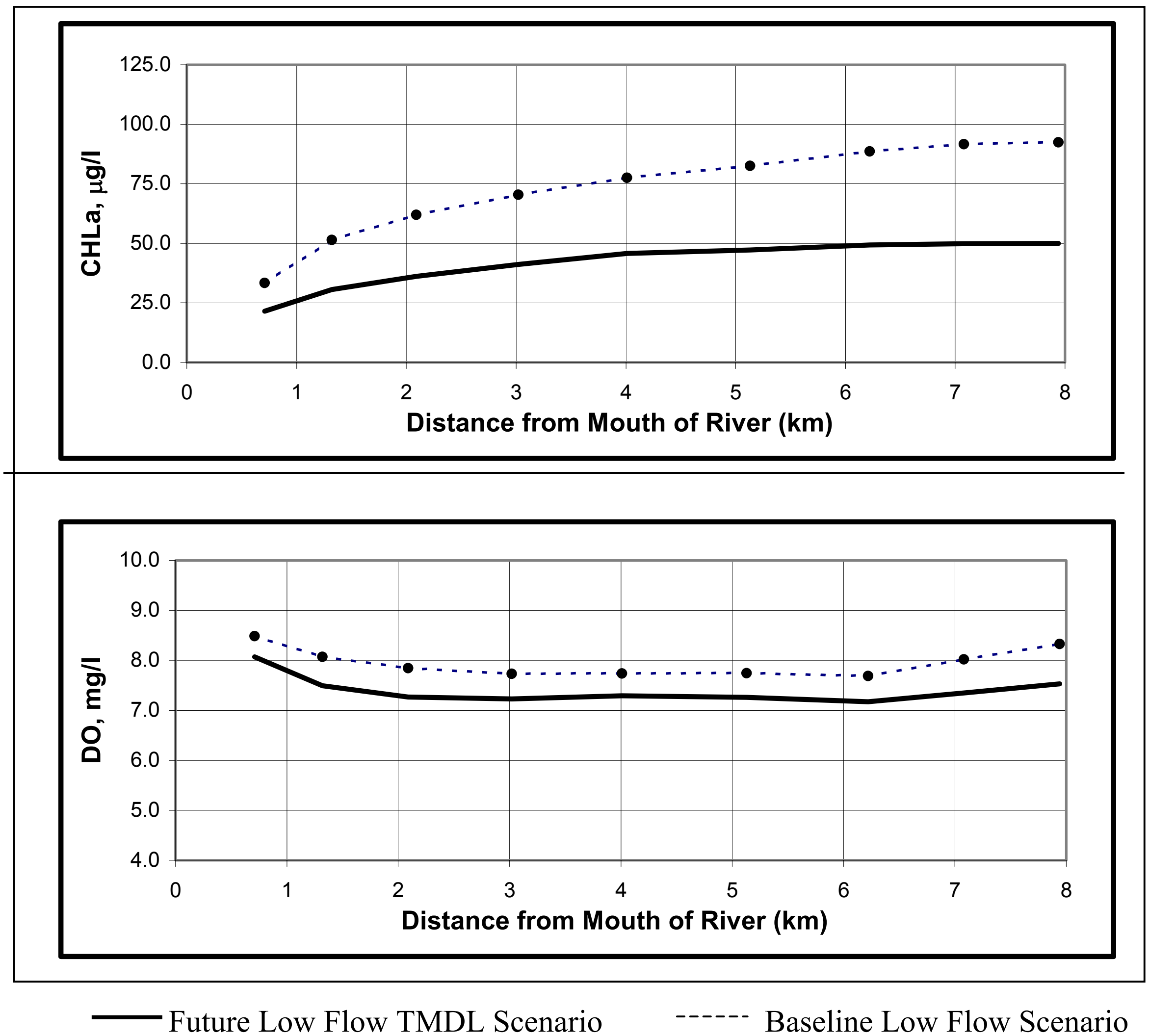

Figure 12: Model Results for the Average Annual Flow Future Condition Scenario for Chlorophyll *a* and Dissolved Oxygen (Fourth Scenario)

Under the load reduction conditions described above for this scenario, the results show that Chl*a* concentrations remain below 50 µg/l along the entire length of the Northeast River. For DO, the comparison shows that the DO along the length of the river remains above 7.2 mg/l for both scenarios. NPS nutrient loads for this scenario were estimated to be reduced by an overall 52% for nitrogen and 49% for phosphorus from the average baseline NPS loads in order to reach the target concentrations. Point sources concentrations are the same as set in the third scenario (low flow TMDL).

4.5 TMDL Loading Caps

This section presents TMDLs for nitrogen and phosphorus. The outcomes are presented in terms of the low flow TMDL and average annual flow TMDL. The critical season for excessive algal growth in Northeast River is during the summer months when the river is poorly flushed. During this critical time, sunlight and warm water temperatures are most conducive to creating the water quality problems associated with excessive nutrient enrichment. The low flow TMDLs are stated in monthly terms because this critical condition occurs for a limited period of time. It should be noted that limits placed on average annual loads are accounted for indirectly by adjusting bottom sediment nutrient fluxes and SOD to be consistent with reductions in average annual conditions scenario.

For the summer months, May 1 through October 31, the following TMDLs apply:

Low Flow TMDLs:

NITROGEN TMDL **6,365** ***lbs/month***

PHOSPHORUS TMDL **673** ***lbs/month***

The average annual TMDLs for nitrogen and phosphorus are:

Average Annual TMDLs:

NITROGEN TMDL **168,344** ***lbs/year***

PHOSPHORUS TMDL **12,110** ***lbs/year***

Because the TMDLs set limits on nitrogen, and because of the way the model simulates nitrogen, it is not necessary to include an explicit TMDL for nitrogenous biochemical oxygen demand (NBOD).

4.6 Load Allocations Between Point Sources and Nonpoint Sources

The watersheds draining to the Northeast River have two permitted point sources that discharge nutrients directly to the river. The allocations described in this section demonstrate how the TMDLs can be implemented to achieve water quality standards in the Northeast River. Specifically, these allocations show that the sum of nitrogen and phosphorus nutrient loadings to the Northeast River from existing point and nonpoint sources can be maintained safely within the TMDLs established here. The State reserves the right to adjust future allocations provided that such adjustments are consistent with achieving water quality standards.

Low Flow TMDL Allocations:

The NPS loads of nitrogen and phosphorus simulated in the third scenario represent an overall 44% TN reduction (between 44.2% and 50% reduction from controllable NPS –urban and agricultural- and no reductions from non-controllable NPS – forest and atmospheric deposition) and an overall TP reduction of 42% (between 41.6% and 43.4% reduction from the controllable NPS and no reductions from controllable NPS) from the low flow baseline scenario. Recall that the baseline scenario loads were based on nutrient concentrations observed in summer 1999. These NPS loads, based on observed concentrations, account for both "natural" and human-induced components and cannot be separated into specific source categories.

Point source waste load allocations for the summer low flow TMDLs plus a 5% FA and a 3% MOS, estimated as explained in the next section, make up the balance of the total allowable load. The point source waste load allocations were adopted from results of model Scenario 3. The point source waste load allocation represents the maximum load associated with approved water and sewer plan flows, for the Northeast River WWTP, concentrations were set to achieve water quality goals to a maximum of total nitrogen of 8 mg/l and total phosphorus of 1 mg/l. For the Morning Cheer WWTP, with flow less than 0.055 mgd, it is assumed that the concentrations are the same as the current plant concentrations with no additional treatment. All significant point sources are addressed by this allocation and are described further in the technical memorandum entitled "*Significant Nutrient Point Sources in the Northeast River Watershed*" and Appendix A. The nitrogen and phosphorus allocations for summer low flow conditions are presented in Table 2.

Table 2: Summer Low Flow Allocations

	Total Nitrogen *(lbs/month)*	**Total Phosphorus *(lbs/month)***
Nonpoint Source	1,886	113
Point Source	4,316	550
FA	102	6
MOS	61	4

<u>Average Annual TMDL Allocations</u>:

The average annual NPS nitrogen and phosphorus allocations are represented as the average annual 1999 loads estimated from MDE observed data with an overall 48% reduction in nitrogen and phosphorus NPS loads in all subwatershed loads (52% reduction from controllable NPS nitrogen loads and 49% reduction from controllable NPS phosphorus loads). The NPS loads assumed in the model account for both "natural" and human-induced components.

Point sources load allocations plus a 5% FA and 3% MOS for the average annual flow conditions make up the balance of the total allowable load. To address future developments in the watershed, including construction activities, a 10% of the estimated urban stormwater loads is reserved for future growth. This 10% is based on the average growth rate estimated by the 2000 Census in Cecil County. The Census data showed a 20.5% growth in 10 years, which translates to an approximate growth of 2.05% per year. In the same way, the growth projection in the urban areas of Cecil County as estimated by the Maryland Department of Planning (DOP) is 29.5 % in 20 years, which represents a growth of 1.5% per year. A 2% growth/year was used to be conservative. This estimated growth rate equals 10% in 5 years. The FA allocation set aside as 5% of the total NPS load includes the 10% increase in the urban load as described above.

Point sources concentrations are the same as set for the low flow TMDLs allocations. 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 is described further in the technical memorandum entitled *"Significant Nitrogen and Phosphorus Nonpoint Sources and Point Sources in the Northeast River Watershed.*" The NPS and point source nitrogen and phosphorus allocations for average annual 1999 loads conditions are shown in Table 3.

Table 3: Average Annual Allocations

	Total Nitrogen *(lbs/yr)*	**Total Phosphorus *(lbs/yr)***
Nonpoint Source	74,749	3,763
Point Source	84,268	7,906
FA	5,829	276
MOS	3,498	165
Total	168,344	12,110

4.7 Future Allocations and Margins of Safety

Future allocations represent assimilative surplus loading capacity that is either currently available, or projected to become available due to planned implementation of environmental controls or other changes. MDE has elected to reserve loads equal to 5% of the current NPS loads to address the future regional development. For comparison, the current future nitrogen allocation reserved for urban stormwater is 5,829 lbs/yr, which is approximately18 % of the annual allocation for urban stormwater (32,515 lbs/yr). Compared with the 1.5 % estimated annual growth based on the projection from MDP for this region (29.5% in 20 years), the loads reserved in the future allocation should be sufficient for future regional development within the timeframe in which the TMDL allocations could be adjusted. To further ensure that the future allocation is sufficient, the following methodology was used to check whether the future allocation given in the TMDL is sufficient to address the future development activities. Land use data from the available 1994 and 2000 MDP land use acreages for the Northeast River watershed were used to estimate loads for these years in the same way that the baseline average annual loads were estimated (see detail description in Appendix A). The changes in land use and loads for urban, forest and agricultural land uses between 1994 and 2000 were then calculated. By substracting the nutrient load loss from the disappearance of forest and agriculture land use from the gain of load through urban land increase, it was assumed that the result is the load increase due to urban growth activity. This final load was averaged over the six-year period used (1994-2000) to obtain a gross estimation for annual growth and development activities. For the Northeast River watershed the average TN and TP loads gained through land use change are 1,530 lbs/yr (approximately 26% of annual FA) and 34 lbs/yr (approximately 12% of annual FA) respectively. After comparing these loads with the annual future allocations, it is concluded that the future allocation will be adequate.

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 MOS for these TMDLs using both above-mentioned approaches. Following the first approach, the reserved load allocated to the MOS was computed as 5% of the NPS loads for nitrogen and phosphorus minus the FA. For the low flow TMDL, this MOS represents a 3% of the total NPS loads. Similarly, a 5% of the total NPS loads and a 3% of the total NPS loads represent the FA and the MOS in the average annual TMDL. These explicit nitrogen and phosphorus margins of safety are summarized in Table 4.

For the second approach, in addition to the explicit set-aside MOS, additional safety factors are built into the TMDL development process. For example, the fourth model scenario (average annual flow) was run under the assumption of summer temperature and summer solar radiation. When the water is warmer and more sunlight is present, there will be more algal growth and a higher potential for low DO concentrations. The higher temperatures and solar radiation are conservative assumptions that represent a significant MOS. In addition, a reserved portion of the loading capacity is used as a MOS. For instance, the average monthly flow from the Northeast River WWTP is approximately 0.5 mgd, which accounts for only a 25% of the design flow of the plant (2.0 mgd) utilized in the baseline scenarios simulations.

Table 4: Summer Expected Low Flow and Annual Future Allocations (FA) and Margins of Safety (MOS)

	Total Nitrogen	Total Phosphorus
FA Low Flow	102 lbs/month	6 lbs/month
MOS Low Flow	61 lbs/month	4 lbs/month
FA Average Flow	5,829 lbs/yr	276 lbs/yr
MOS Average Flow	3,498 lbs/yr	165 lbs/yr

4.8 Summary of Total Maximum Daily Loads

The critical low flow TMDLs, applicable from May 1 – Oct. 31 for the Northeast River follow:

For Nitrogen (*lbs/month*):

TMDL	=	LA	+	WLA	+	FA	+	MOS
6,365	=	**1,886**	+	**4,316**	+	**102**	+	**61**

For Phosphorus (*lbs/month*):

TMDL	=	LA	+	WLA	+	FA	+	MOS
673	=	**113**	+	**550**	+	**6**	+	**4**

The average annual flow TMDLs for the Northeast River follow:

For Nitrogen (*lbs/year*):

TMDL	=	LA	+	WLA	+	FA	+	MOS
168,344	=	**74,749**	+	**84,268**	+	**5,829**	+	**3,498**

For Phosphorus (*lbs/year*):

TMDL	=	LA	+	WLA	+	FA	+	MOS
12,110	=	**3,763**	+	**7,906**	+	**276**	+	**165**

Where:

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

Average Daily Loads:

On average, the low flow TMDLs will result in loads of approximately 212 lbs/day of nitrogen and 22 lbs/day of phosphorus. Similarly, the average flow TMDLs will result in loads of approximately 461 lbs/day of nitrogen and 33 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 the use of NPDES permits. The NPDES permits for the Northeast River and Morning Cheer WWTPs will have compliance provisions, 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 that will support the implementation of nonpoint source controls in the Upper Eastern Shore Tributary Strategy Basin, which includes the Northeast River watershed. Maryland is in the forefront of implementing quantifiable nonpoint source controls through the Tributary Strategy efforts. This will help to assure that nutrient control activities are targeted to areas in which nutrient TMDLs have been established.

It is reasonable to expect that NPS loads can be reduced during low flow conditions. While the low flow loads cannot be partitioned specifically into contributing sources, the sources themselves can be identified. These sources 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 NPS reductions of the magnitude identified by this TMDL allocation.

The potential influence of high flow events from the Susquehanna River was noted in the General Setting and Source Assessment section of this report. The effects of the Susquehanna River and Chesapeake Bay in the circulation pattern of the Northeast River are poorly understood and could be very complex. The implications for nutrient loadings could range from very little (if the fresh water flushing does not result in a net increase in load) to very significant. The implications for implementation are similarly uncertain. The Susquehanna River and the Chesapeake Bay could be a significant nutrient source, implying that a lower proportion of the load is from nonpoint sources in the Northeast River basin. In such case, load reductions from the Susquehanna, as part of the Chesapeake Bay Agreement, could have a significant positive effect on the Northeast River water quality. Regardless of the uncertainty, nonpoint source reductions associated with the programs outlined above should be pursued aggressively to address the extensive enrichment of the Bay and Northeast River and to off-set the increasing population pressure.

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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APPENDIX A