Total Maximum Daily Loads of Nitrogen, Phosphorus and Biochemical Oxygen Demand for the Lower Wicomico River Wicomico County and Somerset County, Maryland

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List of Abbreviations

7Q10	7-Day consecutive lowest flow expected to occur once every 10 years
BMP	Best Management Practice
BOD	Biochemical Oxygen Demand
CBOD	Carbonaceous Biochemical Oxygen Demand
CEAM	Center for Exposure Assessment Modeling
CHL*a*	Active Chlorophyll
LWREM	Lower Wicomico River Eutrophication Model
CWA	Clean Water Act
DO	Dissolved Oxygen
EPA	Environmental Protection Agency
EUTRO5.1	Eutrophication Module of WASP5.1
FA	Future Allocation
LA	Load Allocation
MDA	Maryland Department of Agriculture
MDE	Maryland Department of the Environment
MOS	Margin of Safety
NH_3	Ammonia
NO_{23}	Nitrate + Nitrite
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source
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
WLA	Waste Load Allocation
WQLS	Water Quality Limited Segment
WWTP	Wastewater Treatment Plant

PREFACE

Section 303(d) of the federal Clean Water Act (the Act) directs States to identify and list waters, known as water quality limited segments (WQLSs), in which current required controls of a specified substance are inadequate to achieve water quality standards. For each WQLS, the State is to establish a Total Maximum Daily Load (TMDL) of the specified substance that the water body can receive without violating water quality standards.

The Lower Wicomico River was identified on the State's 1996 list of WQLSs as impaired by nutrients (nitrogen and phosphorus). Subsequent investigation determined that nitrogen, phosphorus, and biochemical oxygen demand are the dominant causes of high algal levels and low dissolved oxygen concentrations. This report proposes the establishment of TMDLs for the Lower Wicomico River: one for nitrogen, one for phosphorus, and one for biochemical oxygen demand (BOD).

Once the TMDLs are approved by the United States Environmental Protection Agency (EPA) they will be incorporated into the State's Continuing Planning Process, pursuant to Section 303(e) of the Act. In the future, the established TMDLs will support point and nonpoint source control measures needed to restore water quality in the Lower Wicomico River.

EXECUTIVE SUMMARY

This document proposes to establish Total Maximum Daily Loads (TMDLs) for the nutrients nitrogen and phosphorus and biochemical oxygen demand (BOD) in the Lower Wicomico River. The Lower Wicomico River ultimately drains to the Chesapeake Bay through the Tangier Sound, and is a part of the Lower Eastern Shore Tributary Strategy Basin. The watershed is contained within three counties, primarily in Wicomico County, MD, Somerset County, MD and Sussex County, DE. The river is impaired by the nutrients nitrogen and phosphorus, and BOD which cause excessive algal blooms and exceedance of the dissolved oxygen criterion.

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 Lower Wicomico River will be met. The TMDL was determined using the WASP5.1 water quality model. Loading caps for total nitrogen and total phosphorus entering the Lower Wicomico River are established for both low flow and average annual flow conditions. A total loading cap for BOD is established for low flow conditions. As part of the TMDL analysis, the model was used to investigate seasonal variations and to establish margins of safety that are environmentally conservative.

The low flow TMDL for nitrogen is 22,900 lb/month, the low flow TMDL for phosphorus is 5,764 lb/month, and the low flow TMDL for BOD is 80,114 lb/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 6,535 lb/month of total nitrogen, 152 lb/month of total phosphorus, and 10,818 lb/month of BOD. The point sources are allocated 16,038 lb/month of nitrogen, 5,604 lb/month of phosphorus, and 68,755 lb/month BOD. The explicit margins of safety make up the remainder of the nitrogen and phosphorus allocations.

The average annual TMDL for nitrogen is 1,266,530 lb/yr, and the average annual TMDL for phosphorus is 103,480 lb/yr. Allowable loads have been allocated to point and nonpoint sources considering an appropriate margin of safety. The nonpoint sources are allocated 832,460 lb/year of nitrogen, and 33,850 lb/year of phosphorus. The point sources are allocated 409,130 lb/year of nitrogen and 68,190 lb/year of phosphorus. The explicit margins of safety make up the remainder of the nitrogen and phosphorus allocations.

Four factors provide assurance that these TMDLs will be implemented. First, NPDES permits will play a major 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 and the applicable federal 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 Lower Wicomico River was first identified on the 1996 303(d) list submitted to EPA by the Maryland Department of the Environment (MDE). It was listed as being impaired by nutrients due to signs of eutrophication, expressed as low dissolved oxygen. Eutrophication is the over-enrichment of aquatic systems by excessive inputs of nutrients (nitrogen 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. This document reveals that the impairment is due to nitrogen, phosphorus, and biochemical oxygen demand (BOD) in the stream. For these reasons, this document proposes to establish TMDLs for the nutrients nitrogen, phosphorus and BOD in the Lower Wicomico River.

2.0 SETTING AND WATER QUALITY DESCRIPTION

2.1 General Setting and Source Assessment

The Wicomico River is located in Wicomico County, Maryland (Figure 1). The River is approximately 18.8 miles in length, from its confluence with the Ellis Bay and Monie Bay to the upper reaches of the headwaters. The Wicomico River watershed has an area of approximately 441 km^2 or 108,074 acres. The watershed land use consists of forest and other herbaceous (60,792 acres or 54.6%), mixed agriculture (23,819 acres or 21.4%), urban (23,464 acres or 21.1%), and water (3,260 acres or 2.9%), based on 1997 Maryland Office of Planning land cover data, and 1997 Farm Service Agency (FSA) data. Figure 2 shows the geographic distribution of the different land uses. Figure 3 shows the relative amounts of the different land uses.

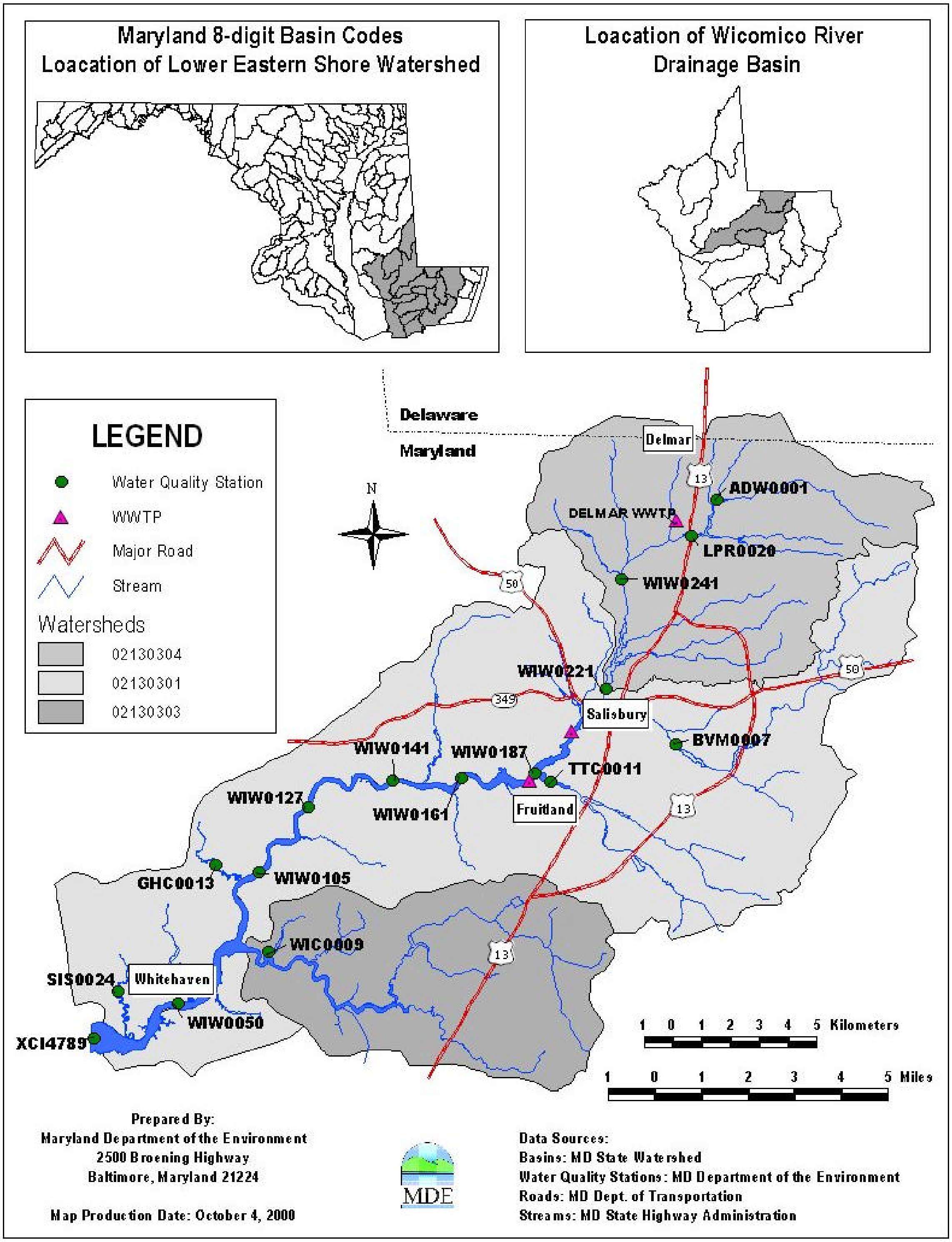

Figure 1: Location Map of the Lower Wicomico River Drainage Basin within Maryland

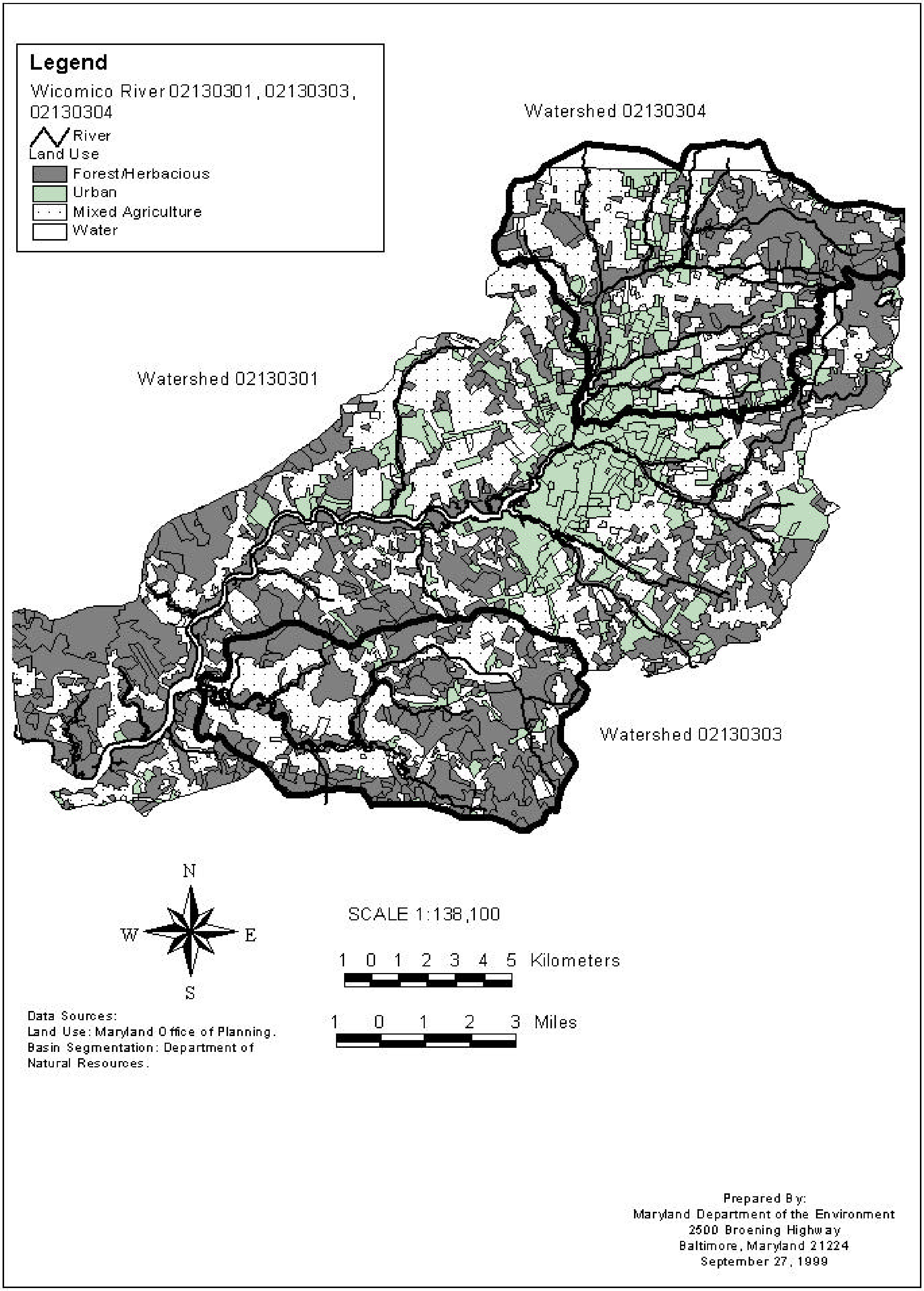

Figure 2: Predominant Land Use in the Lower Wicomico River Drainage Basin

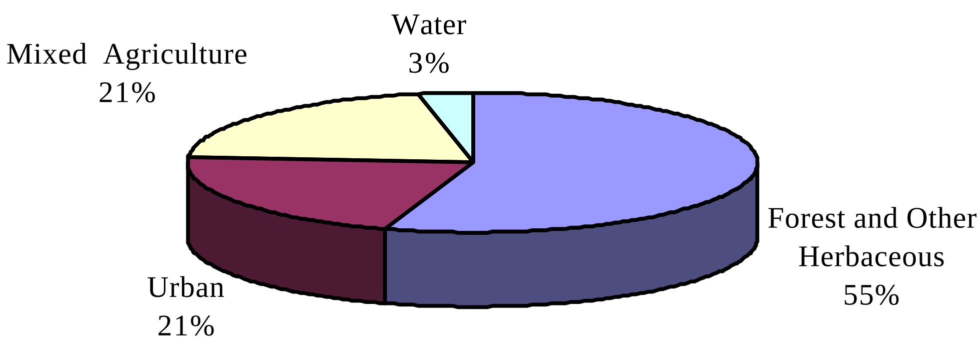

Figure 3: Proportions of Land Use in the Lower Wicomico River Drainage Basin

The mouth of Lower Wicomico River is bound by the Ellis Bay Wildlife Management Area on the North and by Monie Bay on the South. The depth of the river ranges from about 0.5 feet near the headwaters to greater than 30 feet at the confluence of the Lower Wicomico River with Ellis Bay and Monie Bay. Above Whitehaven there is virtually no salinity in the water column, and the water depths range between 20 and 30 feet. During summer there is only limited freshwater input to the Lower Wicomico, further reducing the already limited tidal transport within the system.

Land use between Whitehaven and the urbanized areas of Fruitland and Salisbury, well upstream of Whitehaven, has been in a period of accelerated transition for the past five years. Essentially, the urban areas are progressively expanding, with subdivisions replacing former cropland. Major regulated discharges are all located near the headwaters of the Lower Wicomico. These include the cities of Salisbury and Fruitland, which discharge directly to the tidal river.

In the Lower Wicomico River watershed, the estimated average annual total nitrogen load is 974,717 lb/yr, and the total phosphorus load is 53,639 lb/yr. This is the base-line load relative to which the average annual TMDL limits are compared. The nonpoint source component of this total nitrogen load accounts for 871,228 lb/yr, and the total nonpoint source phosphorus load is

47,770 lb/yr. Figure 4 shows the distribution of loads attributable to different land use categories. The average annual nonpoint source load was calculated by summing all of the individual land use areas and multiplying by the corresponding land use loading coefficients. The land use information was based on 1997 Maryland Office of Planning data, and adjusted using 1997 FSA crop acre data. The loading coefficients were based on the results of the Chesapeake Bay Watershed Model (U.S. EPA, 1996), a continuous simulation model. The Chesapeake Bay loading rates represent edge-of-stream loads, for the year 2000 assuming Best Management Practice (BMP) implementation at levels consistent with current progress, and account for atmospheric deposition, loads from septic tanks, and loads coming from urban development, agriculture, and forest land.

There are two significant point sources in the Lower Wicomico basin, the Salisbury Wastewater Treatment Plant and the Fruitland Wastewater Treatment Plant. In 1998, these two point sources were contributing about 103,489 lb/yr of nitrogen and 5,869 lb/yr of phosphorus to the Wicomico River. Several point sources that discharge above Johnson Pond are addressed indirectly by inclusion as part of the background load from the upstream model boundary at the dam release point. These upstream point sources are addressed explicitly in a TMDL under development for Johnson Pond.

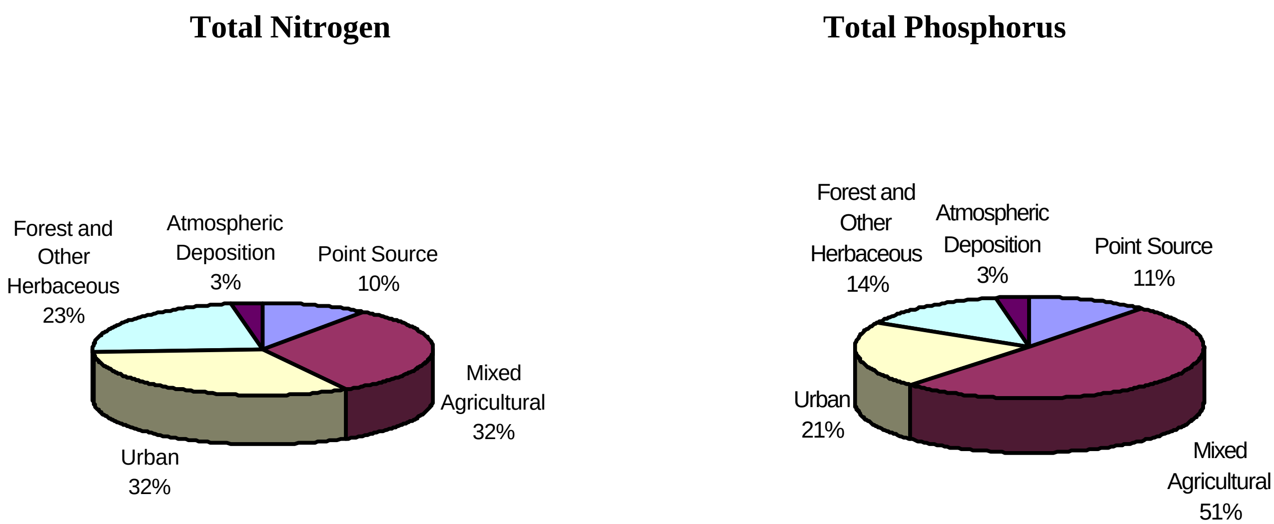

Figure 4: Average Annual Nitrogen and Phosphorus Loads

2.2 Water Quality Characterization

Five key water quality parameters, chlorophyll *a*, dissolved oxygen, dissolved inorganic nitrogen, dissolved inorganic phosphorus, and BOD are presented below. These data were collected by MDE during six water quality surveys conducted in the Lower Wicomico River during 1998. Three sets of samples were collected during seasonal low flow periods in summer (28-July-98, 24-Aug-98, 22-Sep-98), and three sets of samples during high flow periods in winter (18-Feb-98, 11-Mar-98, 4-Apr-98). 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, and September). During this season there is typically less stream flow available to flush the system, more sun light to grow aquatic plants, and warmer temperatures, which are favorable conditions for biological processes of both plant growth and decay of dead plant matter. Because problems associated with eutrophication are usually most acute during this season, the temperature, flow, sun light, and other parameters associated with this period represent critical conditions for the TMDL analysis. As discussed below, the TMDL analysis also considers other seasons, however the data collected during the high flow period (February, March, and April) does not show chlorophyll *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 Stations

Water Quality Station	Miles from Mouth of Wicomico River
Wicomico Mainstem	
XCI4789	0
WIW0050	2.12
WIW0105	6.00
WIW0127	8.66
WIW0141	10.60
WIW0161	13.10
Fruitland WWTP	15.60
WIW0187	16.20
Sailsbury WWTP	17.30
WIW0221	18.80
Shiles Creek	
SIS0024	4.03
Wicomico Creek	
WIC0009	5.58
Green Hill Creek	
GHC0013	7.75
Beaverdam Creek	
BVW0007	20.3

Figure 5 presents a longitudinal profile of chlorophyll *a* data sampled during summer 1998, the low flow period. The sampling region covers the entire tidal portion of the Lower Wicomico River from its confluence with Ellis Bay and Monie Bay (Station XCI4789) up to Johnson Pond (Station WIW0221). Figure 5 shows that ambient chlorophyll *a* concentrations in the summer for the first 6 miles from the river mouth are all below 50 µg/l. However, the levels are much greater above 6 miles, where mean values are about 80 µg/l, with a maximum concentration of 120 µg/l.

A similar longitudinal profile for dissolved oxygen (DO) concentrations is depicted in Figure 6. From the mouth up to a distance of about 6 miles, the DO levels occasionally fall below the water quality criteria of 5.0 mg/l, and are otherwise within the criteria.

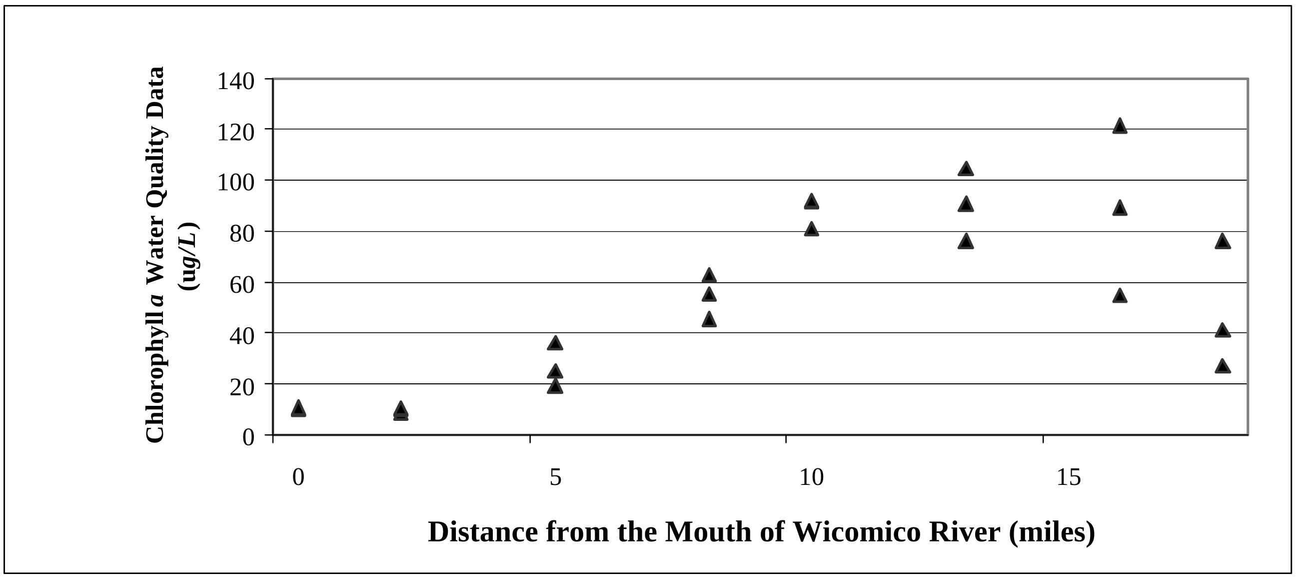

Figure 5: Longitudinal Profile of Chlorophyll *a* Data (Low flow)

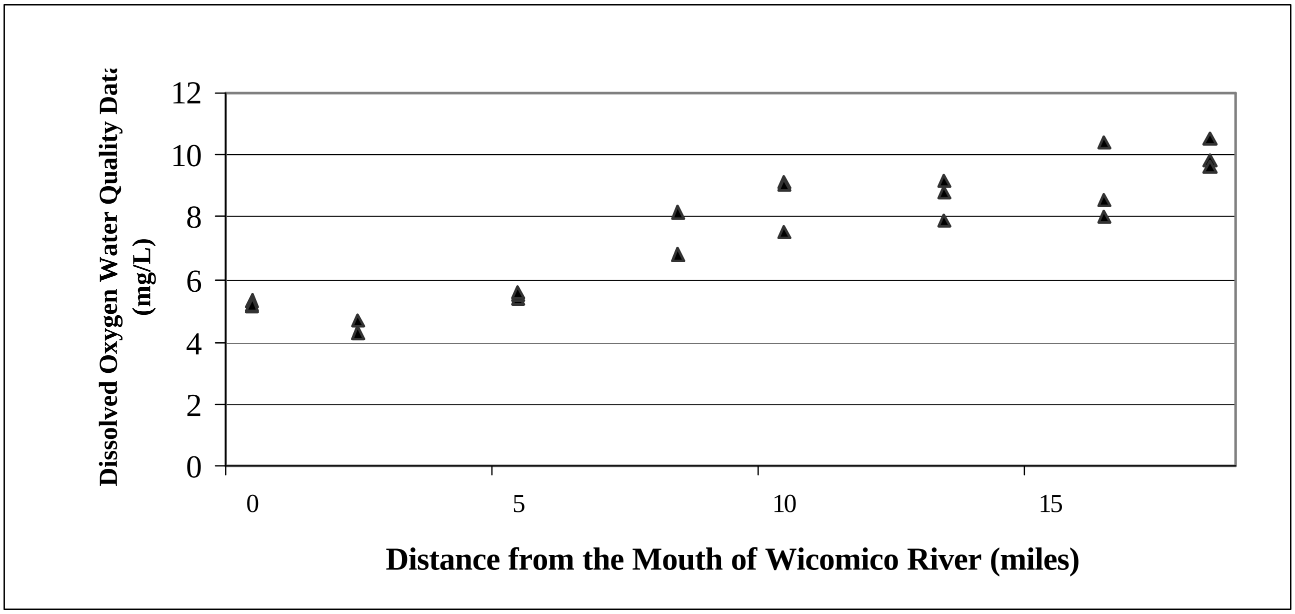

Figure 6: Longitudinal Profile of Dissolved Oxygen Data (Low flow)

Figure 7 presents a longitudinal profile of dissolved inorganic nitrogen levels measured in the samples collected in 1998, during low flow conditions. The levels are below 0.5 mg/l from the mouth up to about 8 miles. From above 8 miles upstream to Johnson Pond, the levels increase to 2.5 mg/l.

Figure 8 presents a longitudinal profile of dissolved inorganic phosphorus as indicated by dissolved ortho-phosphate levels measured in samples collected in 1998, during low flow conditions. All the values are in the range between 0.004 to 0.018 mg/l.

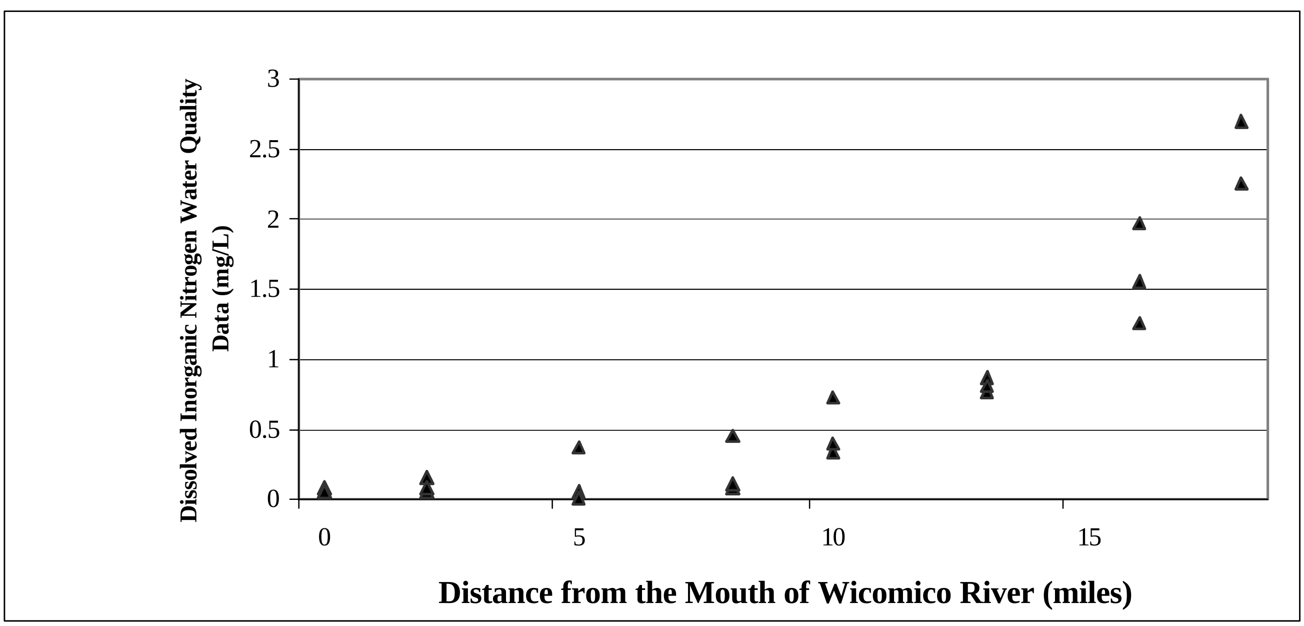

Figure 7: Longitudinal Profile of Dissolved Inorganic Nitrogen Data (Low flow)

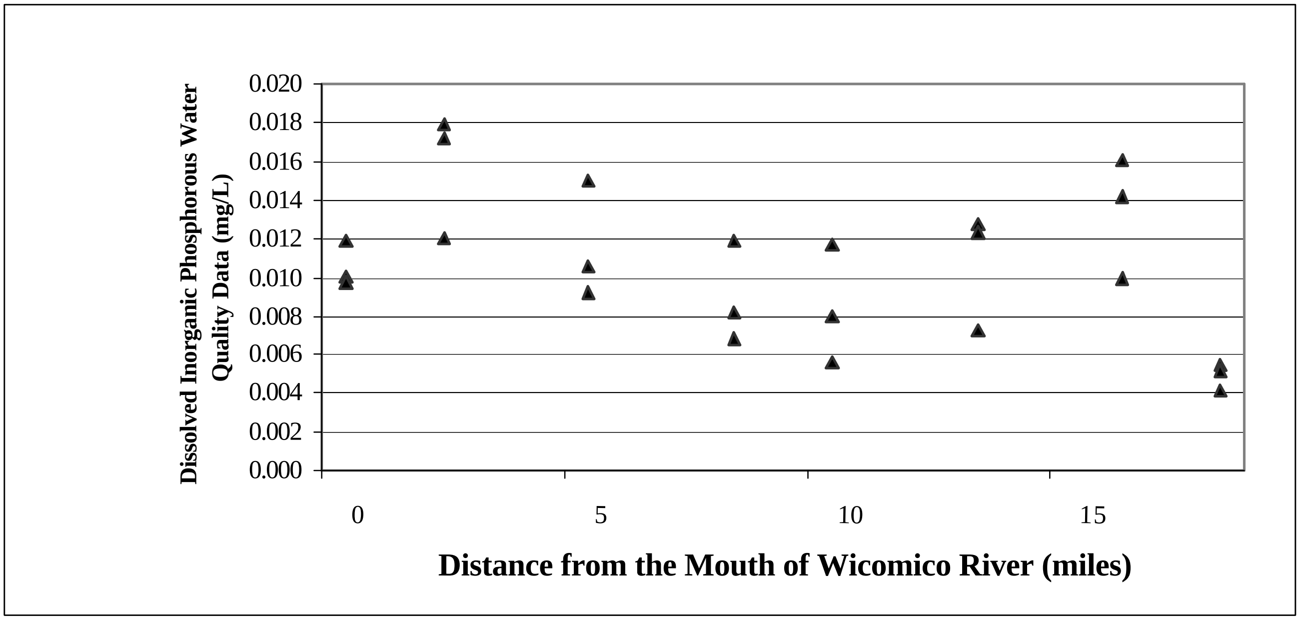

Figure 8: Longitudinal Profile of Dissolved Inorganic Phosphorus Data (Low flow)

Figure 9 presents a longitudinal profile of BOD concentrations measured in samples collected in 1998, during low flow conditions. All the values are in the range between 1.0 and 8.0 mg/l.

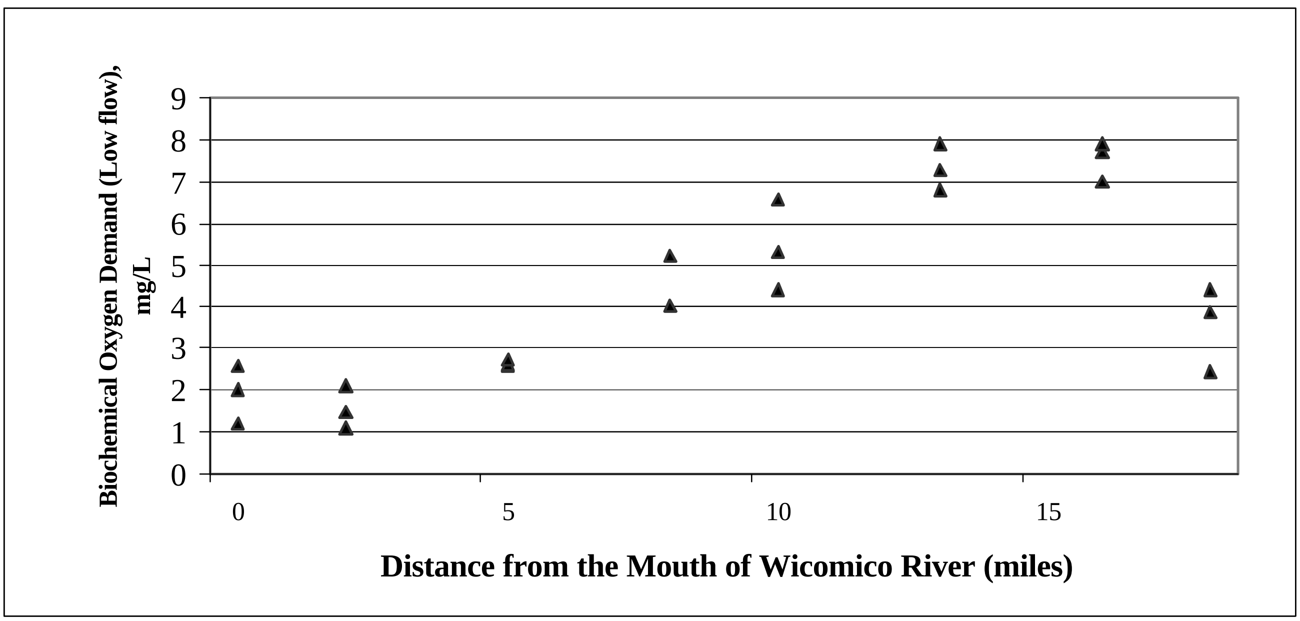

Figure 9: Longitudinal Profile of BOD Data (Low flow)

2.3 Water Quality Impairment

The water quality impairment of Lower Wicomico River addressed by these TMDLs consists of violations of the applicable numeric dissolved oxygen (DO) criterion and general water quality criteria.

The Lower Wicomico River above the ferry crossing at Whitehaven has been designated a Use I water body, pursuant to which it is protected for water contact recreation, fishing, aquatic life and wildlife. The Lower Wicomico River below Whitehaven is designated a Use II water body – Shellfish Harvesting. See Code of Maryland Regulations (COMAR) 26.08.02.07. Use I and II waters are subject to a DO criterion of not less than 5.0 mg/l at any time (COMAR 26.08.02.03-3A(2)) unless natural conditions result in lower levels of dissolved oxygen (COMAR 26.08.02.03A(2)). The dissolved oxygen concentrations in the Lower Wicomico River occasionally fall below the standard of 5.0 mg/l.

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 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 the Lower Wicomico River range between 50 and 120 µg/l. These levels have been associated with excessive eutrophication.

Violations of the dissolved oxygen and general water quality standards in the Lower Wicomico River are the result of over-enrichment by the nutrients nitrogen and phosphorus and by elevated BOD levels.

3.0 TARGETED WATER QUALITY GOAL

The objective of the nutrient and BOD TMDLs established in this document is to assure that the chlorophyll *a* levels support the Use I and Use II designation for the Lower Wicomico River. Specifically, the TMDLs for nitrogen and phosphorus for the Lower Wicomico River are intended to assure that a minimum dissolved oxygen level of 5.0 mg/l is maintained throughout the Lower Wicomico River system and to reduce peak chlorophyll a levela (a surrogate for algal blooms) to below 50 µg/l. The dissolved oxygen level is based on specific numeric criteria for Use I waters set forth in the Code of Maryland Regulations 28.08.02. The chlorophyll a water quality level is based on the designated use of the Lower Wicomico River and guidelines set forth by Thomann and Mueller (1987) and by the EPA *Technical Guidance Manual for Developing Total Maximum Daily Loads, Book 2, Part* (1997). These guidelines acknowledge it is acceptable to maintain chlorophyll a concentrations below a maximum of 100 µg/l, with a goal of less than 50 µg/l.

4.0 TOTAL MAXIMUM DAILY LOADS AND ALLOCATION

4.1 Overview

This section describes how the nutrient and BOD TMDLs and load allocations were developed for the Lower Wicomico River. The first section describes the modeling framework for simulating nutrient loads, hydrology, and water quality responses. The second and third 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 fourth and fifth sections present the modeling results in terms of TMDLs, and load allocations. The sixth section explains the rationale for the margin of safety. Finally, the pieces of the equation are combined in a summary accounting of the TMDLs for seasonal low flow conditions and for annual loads.

4.2 Analysis Framework

The computational framework chosen for the Lower Wicomico 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 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 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, described in more detail below.

The spatial domain of the Lower Wicomico River Eutrophication Model (LWREM) extends from the confluence of the Lower Wicomico River with Ellis Bay and Monie Bay for about 18.8 miles up the mainstem of the Lower Wicomico River to the discharge of Johnson Pond. The modeling domain is represented by 34 WASP5.1 model segments. A diagram of the WASP5.1 model segmentation is presented in Appendix A.

The nutrient TMDL analyses consist of two broad elements, an assessment of low flow loading conditions, and an assessment of average annual loading. Both the low flow and average annual loading analyses consider TMDLs that have been developed for several subwatersheds of the Wicomico River watershed (TMDLs for Phosphorus and Sediment in Johnson Pond (MDE, 2000) and Tony Tank Lake (MDE, 1999), and TMDLs for Nitrogen and Phosphorus in Wicomico Creek (MDE, 2000)). The low flow TMDL analysis investigates the critical conditions under which symptoms of eutrophication are typically most acute, that is, in late summer when flows are low, leading to poor flushing of the system, and when sun light and temperatures are most conductive 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. Calibration of the model for these two flow regimes establishes an analysis tool that may be used to assess a range of scenarios of differing flow and nutrient loading conditions. All nonpoint source loads estimated for the calibration of the model were based on observed water quality data collected during 1998, point source loads were based on 1998 plant operating data stored in MDE's discharge monitoring report (DMR) database. Further information on the calibration of the model can be found in Appendix A.

The estimation of stream flow used in the low flow analysis was based on 3 United States Geological Survey (USGS) gages near the Lower Wicomico River basin. A flow to area ratio was calculated by averaging 1998 summer low flow data from the 3 USGS gages and applied to the subwatersheds. The above ratio was not used to estimate the low flow coming from Johnson Pond, instead instantaneous data measurements taken during the July, August, and September 1998 field surveys were used as explained further in Appendix A. The annual average stream flow was estimated with a similar methodology based on the same 3 USGS gages by averaging 1984 to 1987 flow data. This time period was selected because the average load calculation was based on the Chesapeake Bay Program Watershed Model using the precipitation from the period of 1984 to 1987. The methods used to estimate stream flows are described further in Appendix A.

There are two municipal wastewater treatment plants (WWTP) in the Lower Wicomico River watershed. They are the Salisbury WWTP and the Fruitland WWTP. 1998 point source data from MDE's point source database was used to estimate point source loads for the calibration of the model. The methods of estimating nonpoint source (NPS) loadings are described in Section 4.3. In brief, low flow NPS loads were derived from concentrations observed during low flow sampling in 1998 multiplied by the estimated critical low flows. Because the loading estimations are based on observed data, they account for all human and natural sources. The average annual NPS loads were derived from existing data and results from previous watershed modeling conducted by the EPA Chesapeake Bay Program Office. These methods are elaborated upon in Section 4.3 and in Appendix A.

The concentrations of the nutrients (nitrogen and phosphorus) are modeled in their speciated forms. Nitrogen is simulated as ammonia (NH_3), nitrate and nitrite (NO23), and organic nitrogen (ON). Phosphorus is simulated as ortho-phosphate (PO_4) and organic phosphorus (OP). Ammonia, nitrate and nitrite, and ortho-phosphate 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 chlorophyll *a* levels and dissolved oxygen 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 Lower Wicomico River.

4.3 Scenario Descriptions

The WASP5.1 model was applied to investigate different nutrient and BOD loading scenarios under several stream flow conditions. These analyses allow a comparison of conditions under which 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 analysis accounts for seasonality, a necessary element of the TMDL development process.

The analyses are grouped according to *base-line conditions*, and *future conditions*. Both groups typically include low flow and average annual loading scenarios, for a total of four scenarios.

The base-line conditions are intended to provide a point of reference by which to compare the future scenarios that simulate the conditions of the TMDL. Defining this base-line for comparison with the TMDL outcome is preferred to trying to establish a "current condition". The base-line is defined in a consistent way among different TMDLs, and does not vary in time. Whereas, the alternative of using a "current condition" has the drawback that it changes over time, which creates confusion. It is "current" at one point in time for a given TMDL, but development and review often take several years; by the time the TMDL is done, the "current condition" is no longer current. Also, what constitutes "current" for one TMDL, is different for another TMDL developed at a later time. To avoid this confusion we use "base-line" scenario.

The base-line conditions for nonpoint source loads reflect an approximation of loads based on the 1998 water quality monitoring data. Base-line 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. As such, the base-line conditions often reflect a fixed potential future critical condition, which approximates a maximum future loading assuming no control actions. Specific base-line loading assumptions for the point sources are presented in the "Model Run Descriptions" section of Appendix A.

<u>First Scenario</u>: The first scenario represents the base-line conditions of the stream at a simulated 7Q10 low flow in the river. The 7Q10 flow is the 7-day consecutive lowest flow expected to occur once every 10 years. The method of estimating the 7Q10 flow is described in Appendix A. The scenario simulates a critical condition when the river system is poorly flushed, and sun light and warm water temperatures are most conducive to creating the water quality problems associated with excessive nutrient enrichment.

The nutrient and BOD concentrations for the first scenario were computed using observed data collected during the low flow period of July, August, and September of 1998. 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, and loads from septic tanks. For point source loads, these base-line conditions assume maximum allowable flow (based on maximum approved water and sewer plan flow) and appropriate parameter concentrations expected to occur at that flow (see "Point Source Loadings" of Appendix A for more detail). Several point sources that discharge above Johnson Pond are addressed indirectly by inclusion as part of the background load from the upstream model boundary at the dam release point. The point source loads discharging above Johnson Pond are captured in the 1998 water quality samples taken just below the dam, which are used to calculate the load from the upper watershed to the river.

Second Scenario: The second scenario provides an estimate of water quality conditions for average annual loads and flows, which serves as the base-line from which the average annual TMDL is computed (Fourth Scenario). The second scenario simulates a condition when the sun light and warm water temperatures are most conducive to algal growth, which can lead to water quality problems associated with excessive nutrient enrichment. Because higher stream flows, like the average flow, typically occur during cooler seasons, the assumptions of high water temperature and solar radiation used in the analysis are conservative with respect to environmental protection.

The total average annual nonpoint source loads were calculated using loading rates from the EPA Chesapeake Bay Program Phase IV watershed model (U.S. EPA, 1996). The loading rates represent edge-of-stream contributions assuming Best Management Practice (BMP) implementation at levels consistent with expected progress in year 2000. The land use, to which these loading rates were applied, was calculated using 1997 Maryland Office of Planning land cover data, and adjusted using 1997 FSA crop acre data. The nutrient loads account for both "natural" and human induced components and contributions from atmospheric deposition, septic tanks, cropland, pasture, feedlots, forest, and urban land. The total point source loads are the same as that used in the first scenario.

Third Scenario: The third scenario represents the future condition of maximum allowable loads during critical low stream flow. The stream flow is the same as that used in the first scenario. The scenario simulates a condition when the river system is poorly flushed due to low flows, and the sun light and warm water temperatures are most conducive to algal growth. These conditions are critical for causing water quality problems associated with excessive nutrient enrichment.

This scenario simulates an estimated 40% reduction in controllable nonpoint source loads of total nitrogen and total phosphorus from subwatersheds 1, 2, 3, and 5 (including the Johnson Pond basin and the Tony Tank Lake basin), and reduced loads from subwatershed 9, consistent with the draft Wicomico Creek TMDL (MDE, 2000). The reductions in subwatersheds 1, 2, 3, and 5 were made due to their proximity and influence on algal growth. And the reductions from subwatershed 9 are motivated by water quality goals for Wicomico Creek.

Consistency with the Wicomico Creek TMDL was achieved by utilizing the resulting nitrogen and phosphorus concentrations produced by the final low flow TMDL model scenario output as the input to the Lower Wicomico River. The TMDL analyses for the two impoundments (Johnson Pond and Tony Tank Lake) do not set explicit loading limits for low flow conditions. However, the nutrient control measures needed to meet the average annual phosphorus TMDLs for these impoundments are generally consistent with the low flow loading limits in the Lower Wicomico basin. Refinements of upstream loading limits can be made, if necessary, as part of the more detailed implementation planning process. More details on the nonpoint source loads for the third scenario are given in Appendix A. This scenario accounts for nitrogen, phosphorus, and BOD margins of safety computed as 5% of the total NPS load allocations.

The point source nitrogen, phosphorus and BOD loads were reduced to meet water quality standards. Details of the allowable point source loads are described further in the technical memorandum entitled "*Significant Nutrient and Biochemical Oxygen Demand Point and Nonpoint Sources in the Lower Wicomico River Watershed*." The point sources upstream of the dam are addressed explicitly in a TMDL under development for Johnson Pond (MDE, 2000). In this future condition scenario, reductions in sediment nutrient fluxes and sediment oxygen demand (SOD) were estimated based on the percentage reduction of organic matter available to settle to the bottom, which was computed as a function of the nutrient reduction. Further discussion 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 Scenario 2. The scenario simulates a condition when the sun light and warm water temperatures are most conducive to algal growth, which can lead to water quality problems associated with excessive nutrient enrichment. Because higher stream flows, like the average flow, typically occur during cooler seasons, the assumptions of high water temperature and solar radiation used in the analysis are conservative with respect to environmental protection. The nonpoint source loads for most subwatersheds were similar to scenario 2, but also included a 3% margin of safety. The phosphorus loads from the Johnson Pond watershed (MDE, 2000) and the Tony Tank Lake watershed (MDE, 1990) were reduced to equal the average annual TMDLs for those two watersheds. No explicit nitrogen TMDLs have been developed for these two basins. For the fourth scenario run no nonpoint source nitrogen reductions were assumed from these two basins, however, it is expected that the methods used to achieve phosphorus reductions will also decrease nitrogen loads. This creates another built-in margin of safety. The nitrogen and phosphorus loads from the Wicomico Creek watershed were reduced to equal their average annual TMDLs (MDE, 2000). The point source loads of nitrogen, phosphorus and BOD reflect maximum average annual loads which take into consideration the reduction to low flow loads. Details of point and nonpoint source loads are described further in the technical memorandum entitled "*Significant Nutrient and Biochemical Oxygen Demand Point and Nonpoint Sources in the Lower Wicomico River Watershed* ." 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 LWREM results for dissolved oxygen (DO) presented in this section are daily minimum concentrations. These DO concentrations account for diurnal fluctuations caused by photosynthesis and respiration of algae.

Base-line Loading Condition Scenarios:

1. *Low Flow:* Simulates critical low stream flow conditions during summer season. Nonpoint source water quality parameters (e.g., nutrient concentrations) are based on 1998 observed data. Point source loads assume maximum approved water and sewer plan flow and appropriate parameter concentrations expected to occur at that flow (10.2 mgd for Salisbury and 1.0 mgd for Fruitland).

2. *Average Annual Flow:* Simulates average annual stream flow conditions, with annual nonpoint source loads computed on the basis of 1997 land use and year 2000 loading rates. (See Appendix A). Point source loads assume maximum approved water and sewer plan flow and appropriate parameter concentrations expected to occur at that flow (10.2 mgd for Salisbury and 1.0 mgd for Fruitland).

Results for the first scenario, representing the base-line condition for summer low flow, are summarized in Figure 10. Under these conditions, the peak chlorophyll *a* level is well above the desired goal of 50 µg/l, reaching a peak value of about 250 µ*g*/l. DO concentrations are expected to fall below the minimum water quality criteria of 5.0 mg/l near stream-mile 17, and near the mouth of the river.

Results for the second scenario, representing the base-line condition for the average stream flow and average loads, are summarized in Figure 11. Under these conditions, the chlorophyll *a* concentrations are just bordering the desired goal of 50 µg/l and DO concentrations remain above 5.0 mg/l throughout the length of the river.

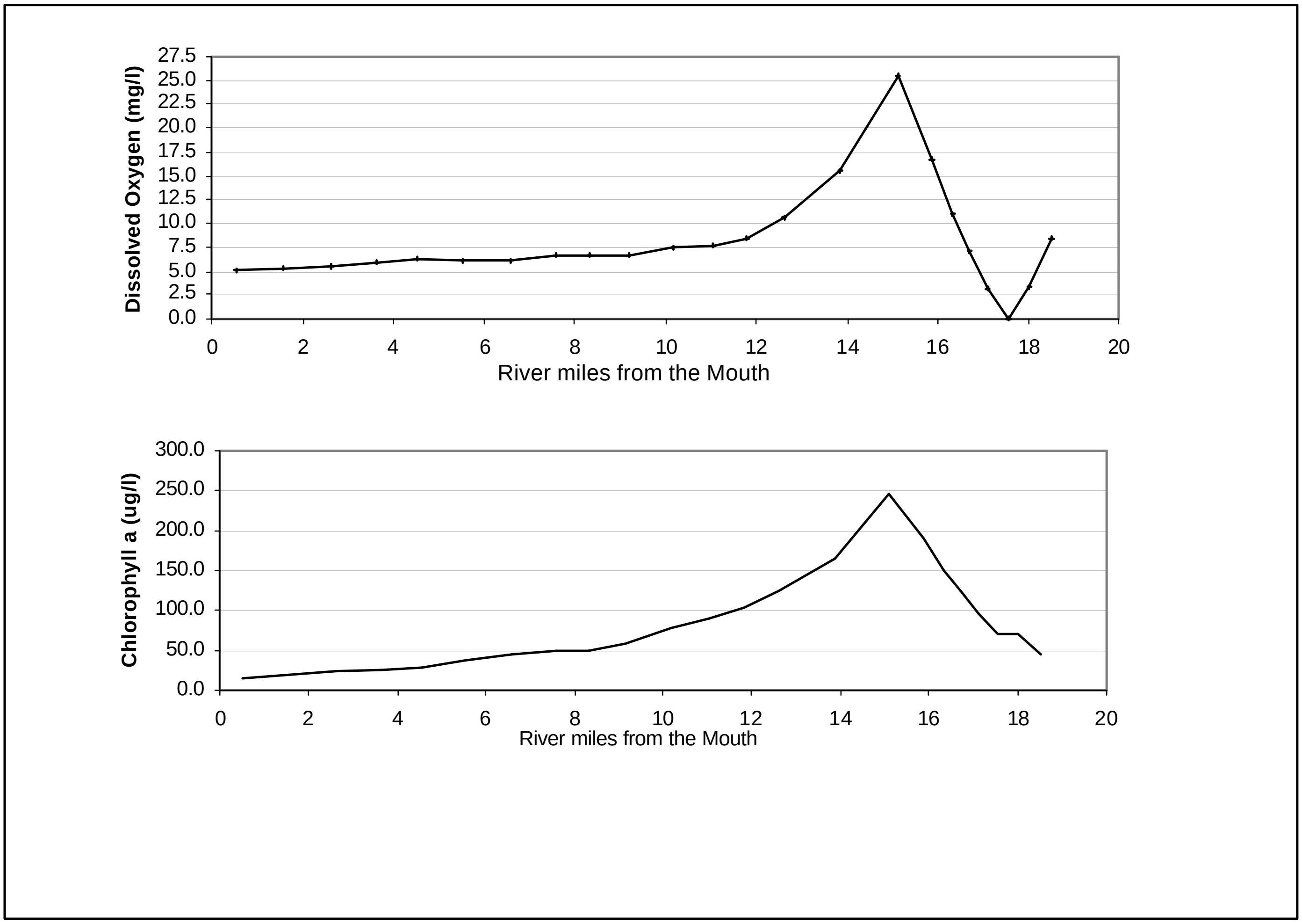

Figure 10: Model Results for the Low Flow Expected Condition Scenario for Chlorophyll *a* and Dissolved Oxygen (Scenario 1)

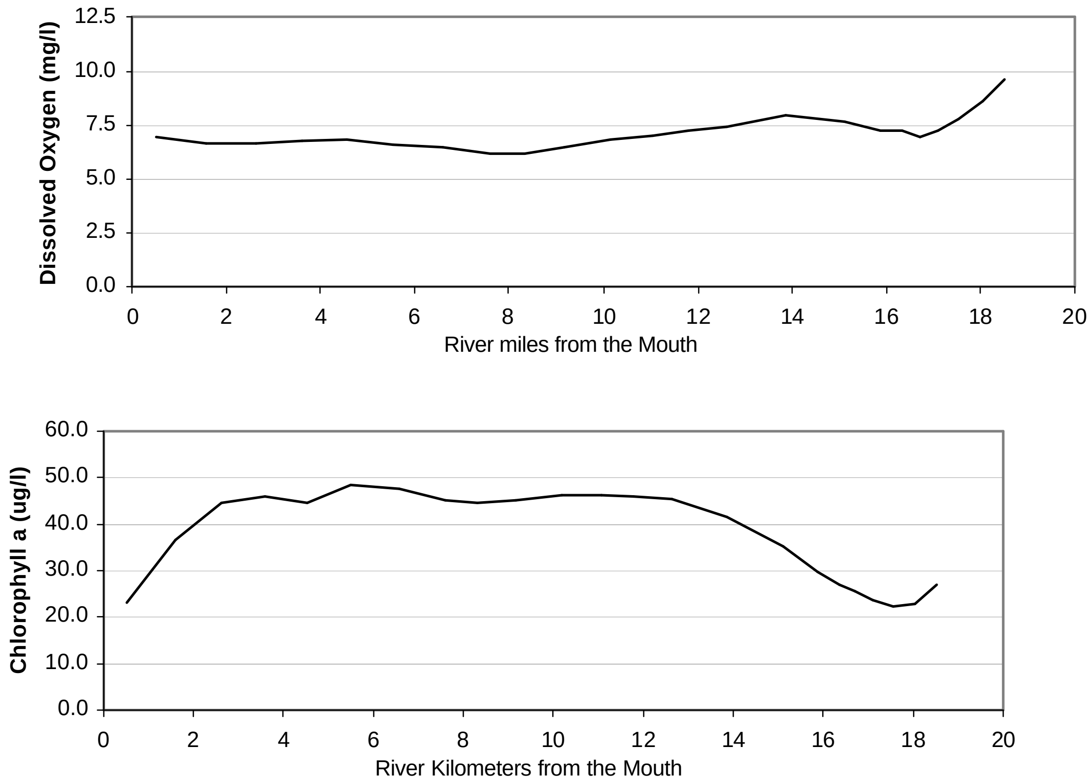

Figure 11: Model Results for the Average Flow Expected Condition Scenario for Chlorophyll *a* and Dissolved Oxygen (Scenario 2)

<u>Future Condition Scenarios:</u>

3. *Low Flow:* Simulates the future condition of maximum allowable loads for critical low stream flow conditions the during the summer season.

4. *Average Annual Flow:* Simulates the future condition of maximum allowable annual loads under average annual stream flow and loading conditions.

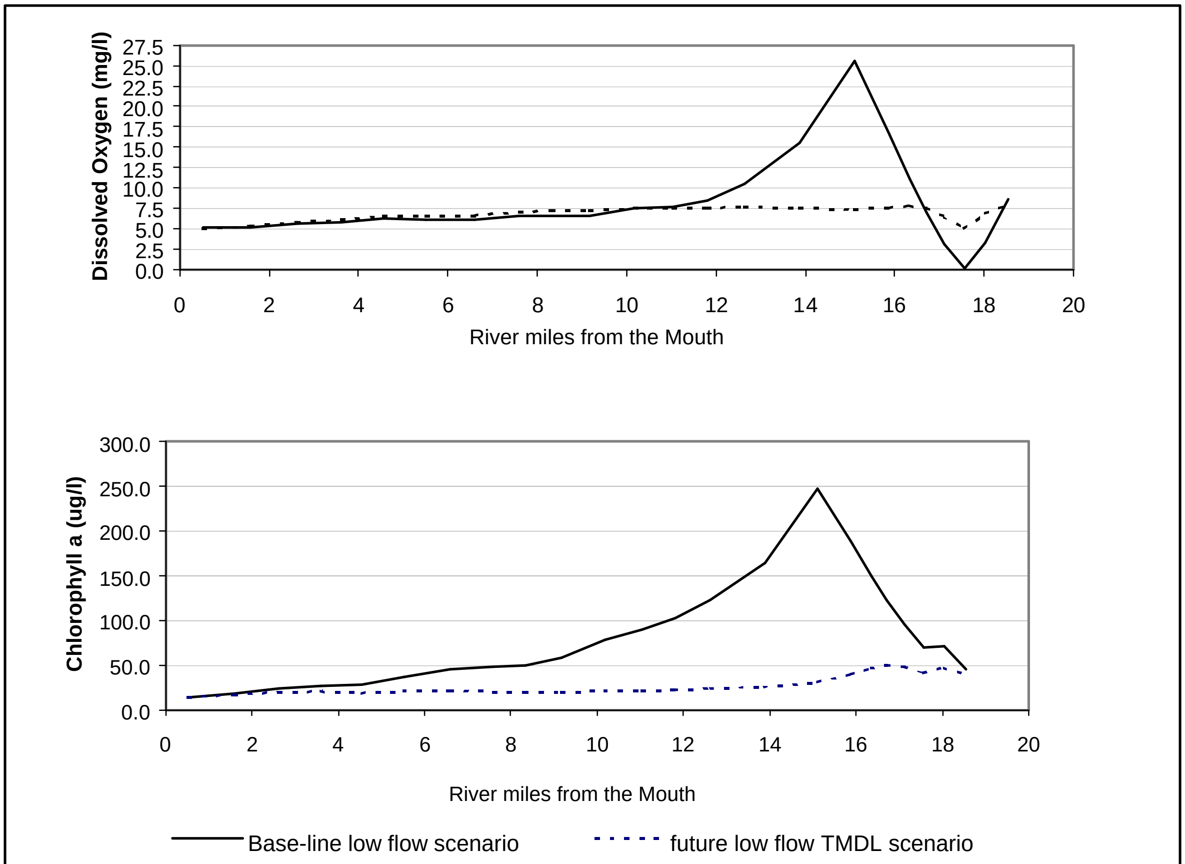

Figure 12: Model Results for the Low Flow Future Condition Scenario for Chlorophyll *a* and Dissolved Oxygen (Scenario 3)

Results for the third scenario (dotted line), representing the maximum allowable loads for summer-time critical low flow, are summarized in comparison to the appropriate base-line scenario (solid line) in Figure 12. Under the nutrient load reduction conditions described above for this scenario, the results show that chlorophyll *a* concentrations remain below 50 µg/L along the entire length of the Lower Wicomico River. For dissolved oxygen (DO), the comparison shows that the nutrient load reductions are projected to shift upwards, so that the minimum DO along the length of the river is just above the water quality criteria of 5.0 mg/L.

Results, for the fourth scenario, representing the maximum allowable loads for average annual flow, are relatively unchanged from the base-line scenario (scenario2), see Figure 11. The annual loads used in this scenario reflect year 2000 loads including nonpoint source nutrient reductions in the form of BMPs implemented at levels consistent with current progress, and a 3% margin of safety. Under the load conditions described above for this scenario, the results continue to show that chlorophyll *a* concentrations remain just below 50 μg/L, and minimum DO concentrations remain above the water quality criteria of 5.0 mg/L along the entire length of the Lower Wicomico River.

4.5 TMDL Loading Caps

This section presents total maximum daily loads (TMDLs) for nitrogen, phosphorus, and BOD. The outcomes are presented in terms of the critical low flow TMDLs, and average annual TMDLs. The critical season for excessive algal growth in the Lower Wicomico River is during the summer months, when the river system is poorly flushed. During this critical time, sun light 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 these critical conditions occur 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 loads (See Appendix A).

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

Low Flow TMDLs:

NITROGEN TMDL	**22,900 *lb/month***
PHOSPHORUS TMDL	**5,764 *lb/month***
BOD TMDL	**80,114 *lb/month***

The average annual TMDLs are being established for two purposes. First, they are designed to protect water quality in the Lower Wicomico River. Second, loading limits on average annual loads contribute to water quality problems observed in the low flow critical season.

The annual average TMDLs for nitrogen and phosphorus are:

Average Annual TMDLs:

NITROGEN TMDL	**1,266,530 *lb/year***
PHOSPHORUS TMDL	**103,480 *lb/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

There are two significant point source discharges of nutrients and BOD in the Lower Wicomico River basin[1]. The allocations described in this section demonstrate how the TMDLs can be implemented to achieve water quality standards in the Lower Wicomico River. Specifically, these allocations show that the sum of nutrient loadings to the Lower Wicomico River from existing point and nonpoint sources or anticipated land uses can be maintained safely within the TMDLs established here.

<u>Low Flow Allocations</u>:

The nonpoint source loads of nitrogen, phosphorus, and BOD simulated in the third scenario represent reductions from the base-line scenario (Scenario 1). Recall that the base-line scenario loads were based on nutrient concentrations observed in summer 1998 and an estimated critical low stream flow. These nonpoint source loads account for both "natural" and human-induced sources and cannot be separated into specific source categories, because they are based on observed in-stream concentrations.

Point source load allocations for the summer low flow future conditions made up the balance of the total allowable load. This point source load allocation was adopted from results of model Scenario 3. All significant point sources in the Lower Wicomico River basin are addressed by this allocation and are described further in the technical memorandum entitled "*Significant Nutrient and Biochemical Oxygen Demand Point and Nonpoint Sources in the Lower Wicomico River Watershed*." The nonpoint source and point source nitrogen, phosphorus, and BOD allocations for summer low flow conditions are shown in Table 2.

Table 2: Summer Low Flow Allocations

	Total Nitrogen ***(lb/month)***	**Total Phosphorus** ***(lb/month)***	**BOD** ***(lb/month)***
Nonpoint Source	6,535	152	10,818
Point Source	16,038	5,604	68,755

<u>Average Annual Allocations</u>:

The average annual nonpoint source nitrogen and phosphorus allocations are represented as estimated year 2000 loads, accounting for the TMDLs previously developed for Johnson Pond, Tony Tank Lake, and Wicomico Creek. The nonpoint source loads account for both "natural"

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1 Several point sources that discharge above the Johnson Pond are addressed indirectly as background of the upstream model boundary at the dam release point. These upstream point sources are addressed explicitly in a TMDL under development for Johnson Pond. The observed 1998 nutrient concentrations are used for this boundary, which is conservative given that future nutrient reductions are expected for Johnson Pond.

and human-induced components as was discussed in the "Scenario Descriptions" section of this document.

Point source load allocations for the annual flow conditions made up the balance of the total allowable load. This point source load allocation was adopted from results of model Scenario 4. All significant point sources are addressed by this allocation and are described further in the technical memorandum entitled "*Significant Nutrient and Biochemical Oxygen Demand Point and Nonpoint Sources in the Lower Wicomico River Watershed.*" Table 3 shows the load allocations to point and nonpoint sources respectively, for nitrogen and phosphorus for the average annual TMDL.

Table 3: Average Annual Allocations

	Total Nitrogen *(lb/yr)*	**Total Phosphorus *(lb/yr)***
Nonpoint Source	832,460	33,850
Point Source	409,130	68,190

4.7 Margins of Safety

A margin of safety (MOS) is required as part of a TMDL in recognition of the fact that there are many uncertainties in the understanding and simulation of water quality in natural systems. Specifically, 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 = WLA + LA + MOS). The second approach is to incorporate the MOS as conservative assumptions used in the TMDL analysis.

Maryland has adopted margins of safety that combine these two approaches. Following the first approach, the load allocated to the MOS was computed as 5% of the nonpoint source loads for nitrogen and phosphorus for the low flow TMDL. A 3% MOS was included in computing the average annual TMDLs. These explicit nitrogen and phosphorus margins of safety are summarized in Table 4.

In addition to these explicit set-aside MOSs, additional safety factors are built into the TMDL development process. For the fourth scenario run no nonpoint source nitrogen reductions were assumed from the Johnson Pond basin and the Tony Tank Lake basin; however, it is expected that the methods used to achieve phosphorus reductions needed to meet the TMDLs for these basins will also decrease nitrogen loads.

Further, the results of the model scenario for the critical low flow case indicate a chlorophyll *a* concentration that is around 50 µg/l. Further, the 50 µg/l chlorophyll *a* target is itself somewhat conservative. In the absence of other factors, a generally acceptable range of peak chlorophyll *a* concentrations is between 50 and 100 μg/l. For the present TMDLs, MDE has elected to use the more conservative peak concentrations of 50 μg/l. Table 4 presents the margins of safety incorporated in low flow and average flow TMDL.

Another MOS is that the fourth model scenario, for average flow, was run under the assumption of summer temperature and summer solar radiation. When the water is warmer and more sun light is present, there will be more algal growth and a higher potential for low dissolved oxygen concentrations. The model was also run under steady-state conditions, for 150 days, assuming continuous average flows and loads. It is unlikely that these flows and loads will actually be seen for such an extended period of time during the summer. The higher temperatures and solar radiation are conservative assumptions that represent significant margin of safety.

Table 4: Margins of Safety (MOS) for Low Flow and Average Annual TMDLs

	Total Nitrogen	**Total Phosphorus**	**BOD**
Low Flow (lb/month)	327	8	541
Average Annual (lb/yr)	24,940	1,440	N/A

4.8 Summary of Total Maximum Daily Loads

The critical low flow TMDLs, applicable from May 1 – Oct. 31 for the Lower Wicomico River, equated with illustrative allocations, are.

For Nitrogen (*lb/month*):

TMDL	**=**	**LA**	**+**	**WLA**	**+**	**MOS**
22,900	**=**	**6,535**	**+**	**16,038**	**+**	**327**

For Phosphorus (*lb/month*):

TMDL	**=**	**LA**	**+**	**WLA**	**+**	**MOS**
5,764	**=**	**152**	**+**	**5,604**	**+**	**8**

For BOD (*lb/month*):

TMDL	**=**	**LA**	**+**	**WLA**	**+**	**MOS**
80,114	**=**	**10,818**	**+**	**68,755**	**+**	**541**

The average annual TMDLs for the Wicomico River, equated with illustrative allocations, are:

For Nitrogen (*lb/year*):

TMDL	**=**	**LA**	**+**	**WLA**	**+**	**MOS**
1,266,530	**=**	**832,460**	**+**	**409,130**	**+**	**24,940**

For Phosphorus (*lb/year*):

TMDL	=	LA	+	WLA	+	MOS
103,480	**=**	**33,850**	**+**	**68,190**	**+**	**1,440**

Where:

TMDL = Total Maximum Daily Load
LA = Load Allocation
WLA = Waste Load Allocation
MOS = Margin of Safety

Average Daily Loads:

On average, the low flow TMDLs will result in loads of approximately 771 lb/day of nitrogen and 192 lb/day of phosphorus. And, on average the annual TMDLs will result in loads of approximately 3,470 lb/day of nitrogen and 284 lb/day of phosphorus.

5.0 ASSURANCE OF IMPLEMENTATION

This section provides the basis for reasonable assurances that the nitrogen, phosphorus and BOD TMDLs will be achieved and maintained. First, for the low flow TMDL, which is driven primarily by point source loads, NPDES permits will play a major role in assuring implementation. For both TMDLs, Maryland has several well-established programs that will be drawn upon: the Water Quality Improvement Act of 1998 (WQIA), and the EPA-sponsored Clean Water Action Plan of 1998 (CWAP), and the State's 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 WWTPs will require stricter limits. The NPDES permits in the Lower Wicomico River will have compliance provisions, which provide a reasonable assurance of implementation.

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 these nutrient management plans be developed and implemented by 2004. 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 1996 and 1998 approved by EPA. The State has given 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 Lower Eastern Shore Tributary Strategy Basin, which includes the Lower Wicomico 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.

Assurances that BOD reductions can be implemented are associated with the same plans that will be relied upon for nutrients. The nutrient management plans implemented through the WQIA will also help to control BOD. Best management practices such as conservation tillage, buffer strips, and treatment of highly erodible land will reduce the amount of BOD entering the stream. Animal waste accounts for large loads of BOD to the stream. Nutrient management plans also address the proper management, storage, and use of animal waste, which will assure a reduction of BOD loads to the stream.

It is reasonable to expect that non-point source 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 non-point source reductions of the magnitude identified by this TMDL allocation.

Finally, Maryland has recently adopted 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, within five years of establishing a TMDL, intensive follow-up monitoring will be performed. Thus, the watershed cycling strategy establishes a TMDL evaluation process that assures accountability.

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