Total Maximum Daily Loads of Phosphorus for the Sassafras River, Cecil and Kent Counties, Maryland

FINAL

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List of Abbreviations

BMP	Best Management Practice
BOD	Biochemical Oxygen Demand
CAFO	Confined Animal Feeding Operations
CBOD	Carbonaceous Biochemical Oxygen Demand
CEAM	Center for Exposure Assessment Modeling
Chla	Chlorophyll *a*
CBP	Chesapeake Bay Program
cfs	Cubic feet per second
COMAR	Code of Maryland Regulations
DIN	Dissolved Inorganic Nitrogen
DIP	Dissolved Inorganic Phosphorus
DO	Dissolved Oxygen
EUTRO5.1	Eutrophication Module of WASP5.1
LA	Load Allocation
LILAC	Low Income Loans for Agricultural Conservation
MACS	Maryland's Agricultural Cost Share Program
MDA	Maryland Department of Agriculture
MDE	Maryland Department of the Environment
mgd	Million gallons per day
MOS	Margin of Safety
NBOD	Nitrogenous Biochemical Oxygen Demand
NH_4	Ammonia
NO_{2-3}	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
SREM	Sassafras River Eutrophication Model
The Act	Clean Water Act
TMDL	Total Maximum Daily Load
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WASP5.1	Water Quality Analysis Simulation Program Version 5.1
WLA	Waste Load Allocation
WQLS	Water Quality Limited Segment
WWTP	Waste Water Treatment Plant

EXECUTIVE SUMMARY

This document proposes a Total Maximum Daily Load (TMDL) for phosphorus in the Sassafras River. The Sassafras River drains to the Chesapeake Bay and is part of the Upper Eastern Shore Tributary Strategy Basin. The Sassafras River was identified on the State's 1996 list of Water Quality Limited Segments (WQLSs) as impaired by nutrients and suspended sediments. The suspended sediment impairment will be addressed at a later date. Limits are established for phosphorus because phosphorus is the nutrient that limits algal growth. The water quality goal of this TMDL is to reduce high chlorophyll *a* concentrations (a surrogate for algal blooms) and to maintain the dissolved oxygen criterion at a level where the designated uses for the Sassafras River will be met.

The TMDL was determined using the WASP5.1 water quality model. The modeling work investigated seasonal variations indicating that phosphorus causes excessive algal growth during low flow and average flow conditions. Therefore, a loading cap on phosphorus entering the Sassafras River is established for low-flow and average annual flow conditions. This will ensure that loads during the higher flow seasons do not contribute to impairments observed during the low flow seasons.

The low flow TMDL for phosphorus is 747 lb/month, which applies during the period May 1 through October 31. The allowable loads have been allocated between point and nonpoint sources. The nonpoint sources are allocated as 169 lb/month. The point sources are allocated as 569 lb/month. A future allocation and explicit margin of safety make up the balance of the allocation.

The average annual TMDL for phosphorus is 13,875 lb/yr. Baseline average annual nonpoint source loads, from which reductions are computed, are based on data collected by MDE in 1999. The allowable loads have been allocated between point and nonpoint sources. The nonpoint sources are allocated as 6,839 lb/yr. The point sources are allocated as 6,824 lb/yr. A future allocation and explicit margin of safety make up the balance of the allocation.

Four factors provide assurance that this TMDL will be implemented. First, NPDES permits will assure implementation for point sources. Second, Maryland has several well-established programs to draw upon, including Maryland's Tributary Strategies for Nutrient Reductions developed in accordance with the Chesapeake Bay 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 adopted a watershed cycling strategy, assuring that future monitoring and TMDL evaluations of the Sassafras River 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 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. Water quality standards are 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 can be either narrative statements or numeric values designed to protect the designated uses. Criteria may differ among waters with different designated uses.

The Sassafras River was first identified on the 1996 303(d) list submitted to U.S Environmental Protection Agency (EPA) by the Maryland Department of the Environment (MDE). It was listed as being impaired by nutrients due to signs of eutrophication and suspended sediments (suspended sediments impairment will be addressed at a later date). This document addresses the nutrient impairment only. Eutrophication is the over-enrichment of aquatic systems by excessive inputs of nutrients, especially nitrogen and phosphorus. Nutrients act as fertilizer leading to excessive growth of aquatic plants. Algae eventually die and decompose leading to bacterial consumption of dissolved oxygen. Analyses indicate that algae growth is limited by the availability of phosphorus. For this reason, it is possible to eliminate the impairment by limiting the amount of phosphorus entering the waterbody, without regard to the loadings of other nutrients.

Although the Sassafras River was initially listed for nutrients in general, the TMDL analysis indicates that phosphorus is the nutrient that limits algal growth. (See Calibration and Sensitivity Analysis in Appendix A). Accordingly, the MDE proposes to establish a TMDL for phosphorus in the Sassafras River.

2.0 SETTING AND WATER QUALITY DESCRIPTION

2.1 General Setting and Source Assessment

Sassafras River is located within Cecil and Kent Counties, Maryland with its headwaters in New Castle County, Delaware (Figure 1). It drains directly into Chesapeake Bay. The River is approximately 20.6 miles (33 kilometers) in length, from its confluence with Chesapeake Bay to the non-tidal upper reaches of its headwaters. The Sassafras River watershed has an area of approximately 62,059 acres (251 km^2). As seen in Figure 2, the land use in the watershed consists of mixed agriculture (31,793 acres or 51%), forest and other herbaceous cover (11,932 acres or 19%), urban (9,740 acres or 16%), and water (8,594 acres or 14%). The land use is

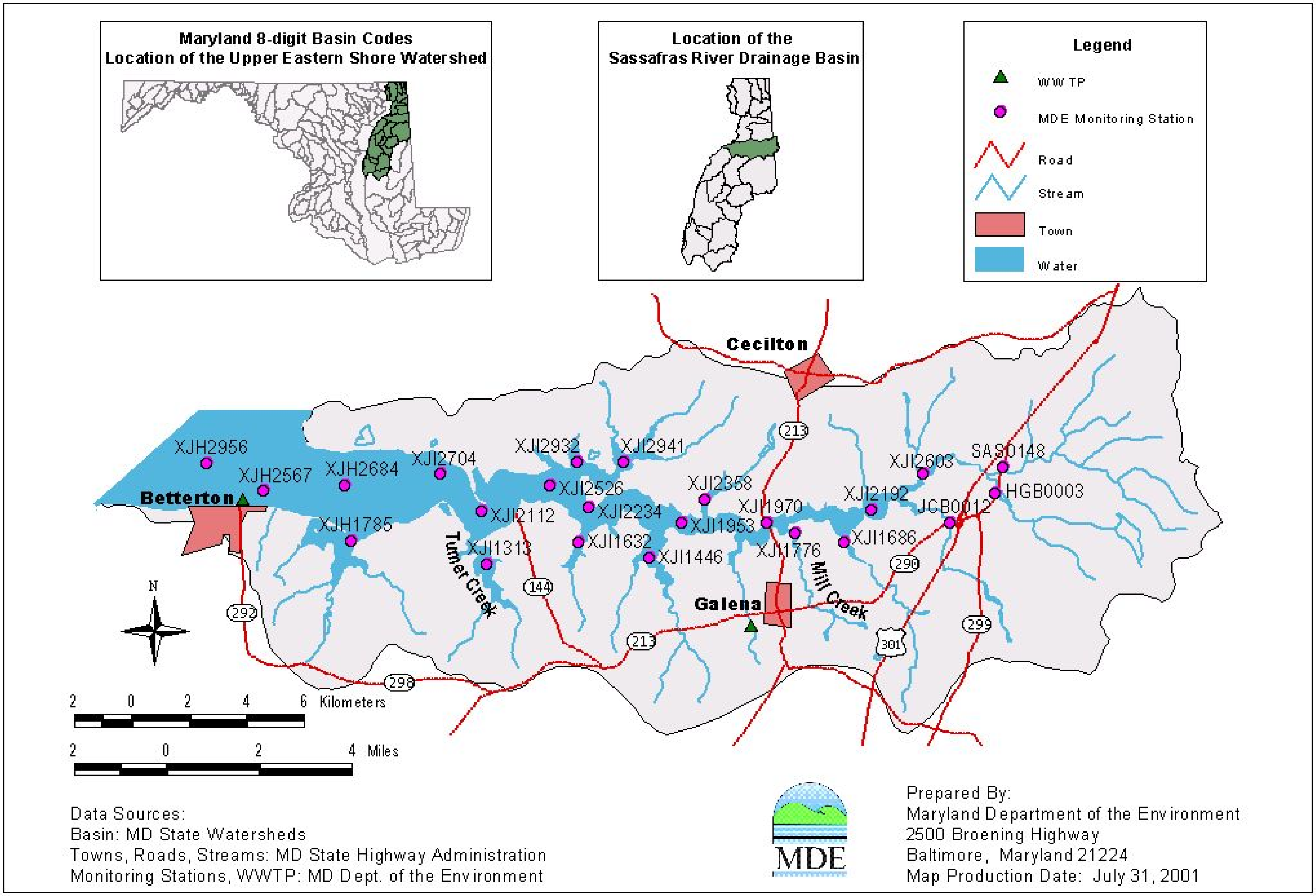


Figure 1: Location Map of the Sassafras River Drainage Basin within Maryland and Delaware

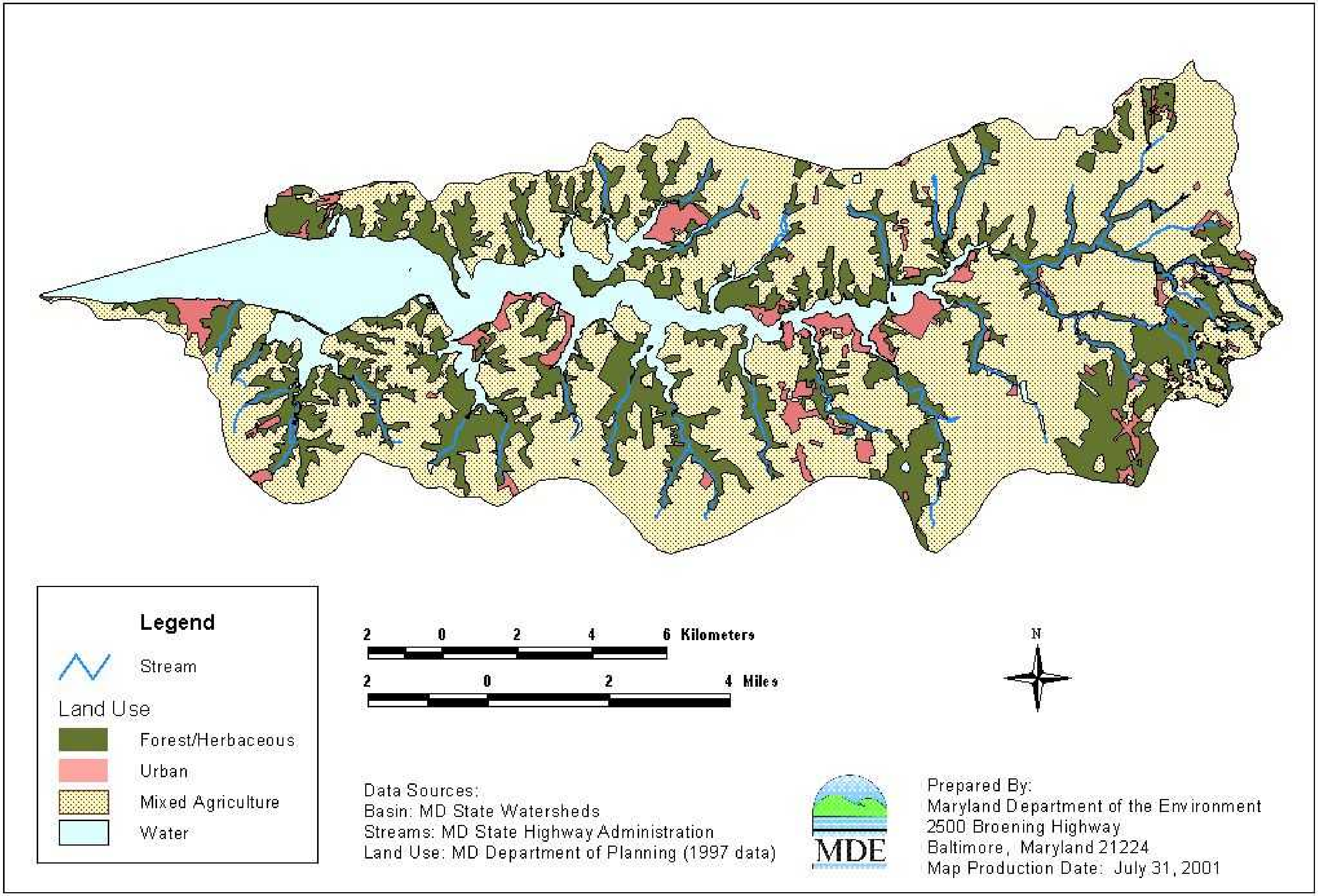


Figure 2: Land Use in the Sassafras River Drainage Basin

based on 1997 Maryland Office of Planning land cover data, 1997 Delaware Office of State Planning land cover data, and 1997 Farm Service Agency information. Figure 3 shows the relative amounts of the different land uses.

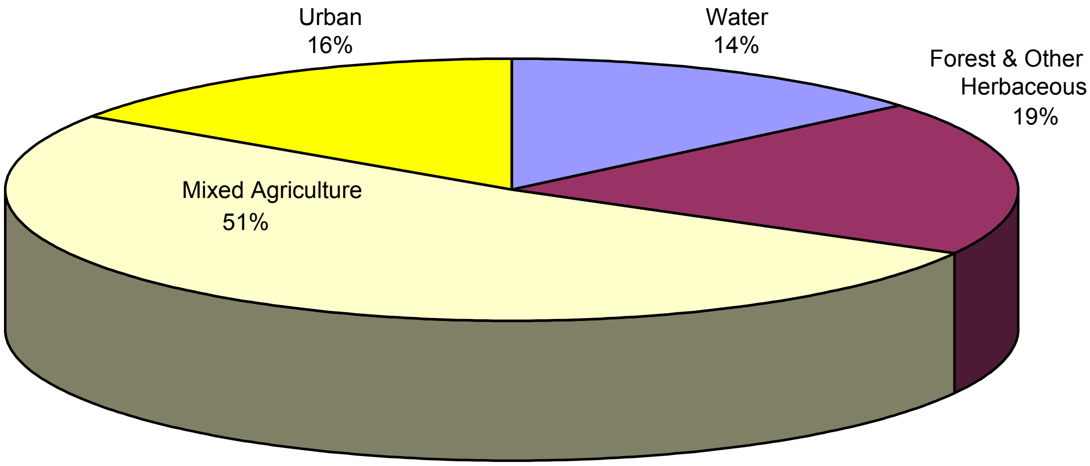


Figure 3: Proportions of Land Use in the Sassafras River Drainage Basin

The Sassafras River is tidal throughout its navigable reach, extending from the confluence with Chesapeake Bay to approximately 20.6 miles (33 kilometers). The head of tide is located near the intersection of the river with Route 301. The tidal section headwater zones of the Sassafras River are characterized by weak current activity, rendering the overall region quite stagnant. This atypical tidal exchange produces unusual salinity distributions within the Sassafras River as well as other related hydrologic anomalies.

This particular characteristic of the Sassafras River is partially responsible for elevated chlorophyll *a* concentrations observed in the upper sections of the River. This is indicated by a broad depositional headwater zone, partially relating to the area's distance from the origin of the tidal dependency. This limited tidal flushing causes higher rates of sediment deposition that elevates bottom sediments in the creek, decreasing its volume capacity. The depths of the river range from about 0.5 ft (0.15 meters) near the headwaters to greater than 35 ft (11 meters) in the middle of the river. Widths can vary from 400 ft (122 meters) at the headwaters to 6,560 ft (2000 meters) at the mouth.

The watershed topography consists of well-drained soils with mild or minimal slopes. The land is predominantly agriculture and the edges of the river are buffered with mature riparian forest. The agriculture in the area is primarily row crops like corn and soybeans mixed with extensive hay land management, small grains (i.e. wheat, rye, barley) and the use of cover crops. Agricultural practices in this area include the active use of physical and agronomic best management practices to assure water quality and minimize soil loss. Animal operations include poultry, dairy and beef cattle with a planned increase in the animal unit numbers. Commercial fertilizer and animal waste are used in the region. No confined animal feeding operations (CAFOs) are found in the Sassafras River watershed. An extensive marina community is also in the watershed.

In the Sassafras River watershed, the estimated average annual total nitrogen load is 193,430 lb/yr (87,739 kg/yr), and the total phosphorus load is 20,318 lb/yr (9,217 kg/yr). The nonpoint source (NPS) component of this total nitrogen load accounts for 176,553 lb/yr (80,084 kg/yr), and the NPS phosphorus load is 13,494 lb/yr (6,121 kg/yr). These average phosphorus and nitrogen loads were estimated from MDE observed data collected in 1999. These NPS load estimations are about one-half of what is estimated by the Chesapeake Bay Program Watershed Model for this area. Both estimations are uncertain; the MDE estimation is based on limited observed data, while the Bay Program estimation is based on a model that is not calibrated in this watershed. 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. Thus, any uncertainty in the baseline NPS estimation does not affect the certainty of the estimated TMDL. Figure 4 shows the relative amounts of nitrogen and phosphorus point source and NPS loadings.

The NPS loads distribution in Figure 4 were determined using land use loading coefficients. The land use information was based on 1997 Maryland Office of Planning data, with refinements to cropland acres, based on 1997 Farm Service Agency data. The total nonpoint source load was calculated by summing all of the individual land use areas and multiplying by the corresponding land use loading coefficient. The Chesapeake Bay Program loading coefficients account for atmospheric deposition, loads from septic tanks and loads coming from urban development, agriculture and forestland. These percentages were used only for nutrient sources based on land use and were used to calculate the percentage of loads that could be controlled. These data were not used for TMDL calculation purposes.

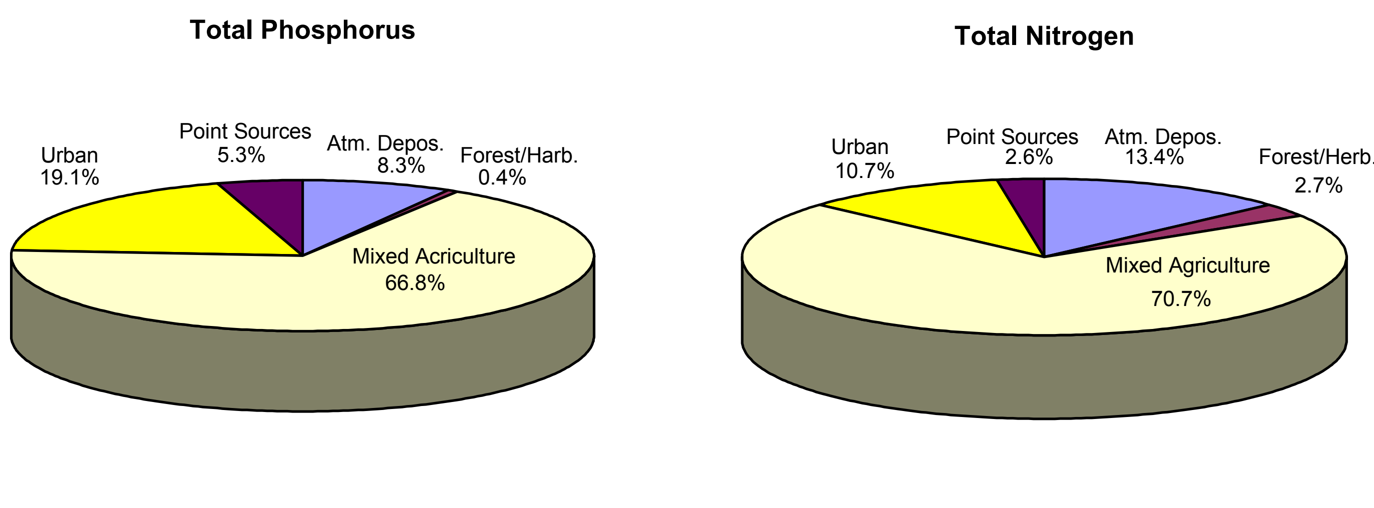


Figure 4: Estimated Average Annual Nitrogen and Phosphorus Point and Nonpoint Source Loads

MDE considered two current point sources that discharge within the Sassafras River watershed. These two point sources are: Betterton WWTP and Galena WWTP. Information was reviewed from discharge monitoring reports stored in MDE's point source database.

During 1999, the time period used to calibrate the simulation model, loads from Betterton and Galena WWTPs were estimated to contribute 16,876 lb/yr (7,655 kg/yr) of nitrogen and 6,824 lb/yr (3,095 kg/yr) of phosphorus. As part of the source assessment, we have considered that nutrient loads from the Chesapeake Bay might affect the Sassafras River. It is possible, during high flow events from the Susquehanna River, freshwater intrusions cause algal growth or nutrient-laden sedimentation, having secondary effects at later times (e.g., during low flow conditions). The freshwater 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 on future control strategies are acknowledged in the section entitled "Assurance of Implementation."

2.2 Water Quality Characterization

Four water quality parameters associated with the observed impairment of Sassafras River - chlorophyll *a* (Chla), dissolved oxygen (DO), dissolved inorganic nitrogen (DIN), and dissolved inorganic phosphorus (DIP) - are presented in Figures 5 through 8 below. These data were collected by MDE at twenty water quality stations in the Sassafras River and its branches during 1999. Three sets of samples were collected during seasonal low flow periods in summer (26-July-99, 23-Aug-99, 27-Sept-99) and three high flow periods in winter (1-Apr-99, 19-Apr-99, 17-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 of the river.

Table 1: Location of Water Quality Monitoring Stations along the Sassafras River

Water Quality Station	Distance from the Mouth (km)
Sassafras Mainstem	
XJH2956	0.0
XJH2567	1.2
XJH2684	3.0
XJI2704	5.9
XJI2112	7.4
XJI2526	9.9
XJI2234	11.2
XJI1953	14.4
XJI1970	17.3
XJI2192	20.5
XJI2603	22.5
Lloyd Creek	
XJH1785	5.0
Tumer Creek	
XJI1313	8.9
Freeman Creek	
XJI1632	12.1

Table 1 (cont'd)

Water Quality Station	Distance from the Mouth (km)
Woodland Creek	
XJI1446	14.8
Mill Creek	
XJI1776	18.1
Swantown Creek	
XJI1686	20.0
Back Creek	
XJI2932	11.4
XJI2941	12.6
Hall Creek	
XJI2358	15.8

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 - favorable conditions for biological processes of both plant growth and dead plant matter decay. Because problems associated with eutrophication are usually most acute during the summer season, temperature, flow, sunlight 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 (April, May) does not show chlorophyll *a* or DO problems. The following graphs present data from the low flow period. Additional data, including these for the high flow periods, are presented in Appendix A.

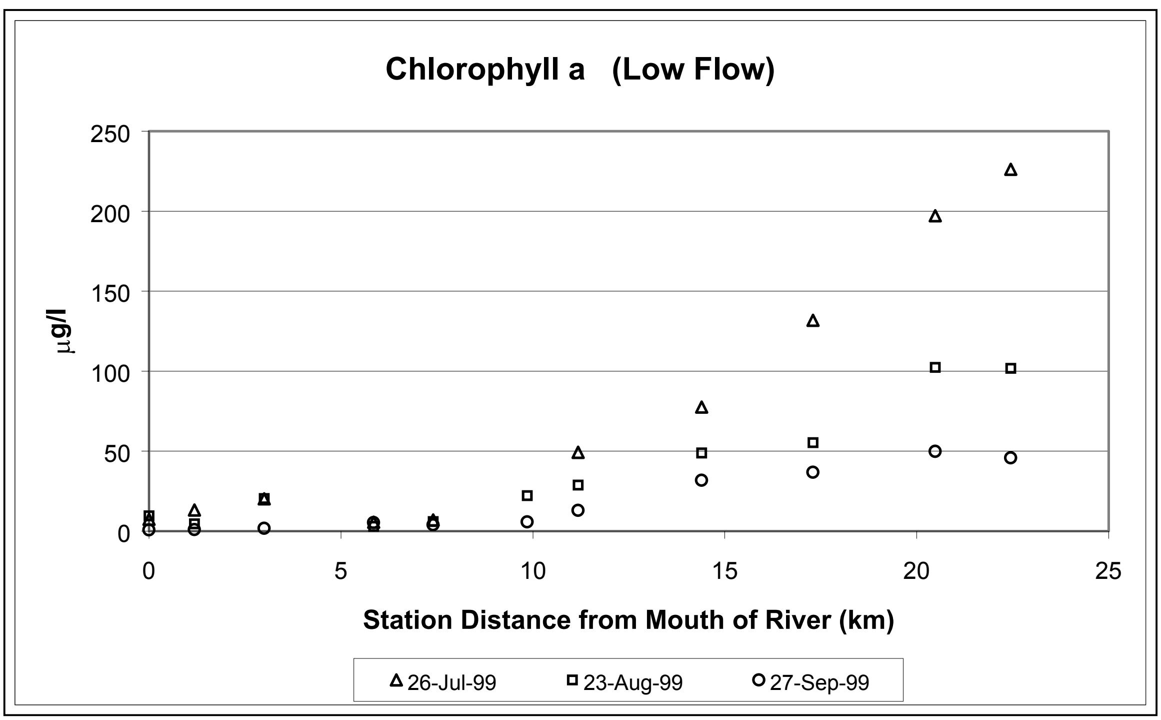


Figure 5: Longitudinal Profile of Chlorophyll *a* Data (Low Flow)

Figure 5 presents a longitudinal profile of chlorophyll *a* data collected during summer 1999, the low flow period. The sampling region, shown in the figure, covers the entire tidal portion of the Sassafras River, from its confluence with Chesapeake Bay (Station XJH2956, 11.2 km) upstream approximately 20 km (Station XJI2192). Ambient chlorophyll *a* concentrations are below 50 µg/L downstream of station XJI2234. Upstream from this station, values of chlorophyll *a* reach an observed maximum of 226 µg/L (Station XJI2603, approximately 14 miles from the mouth, on July-26-99).

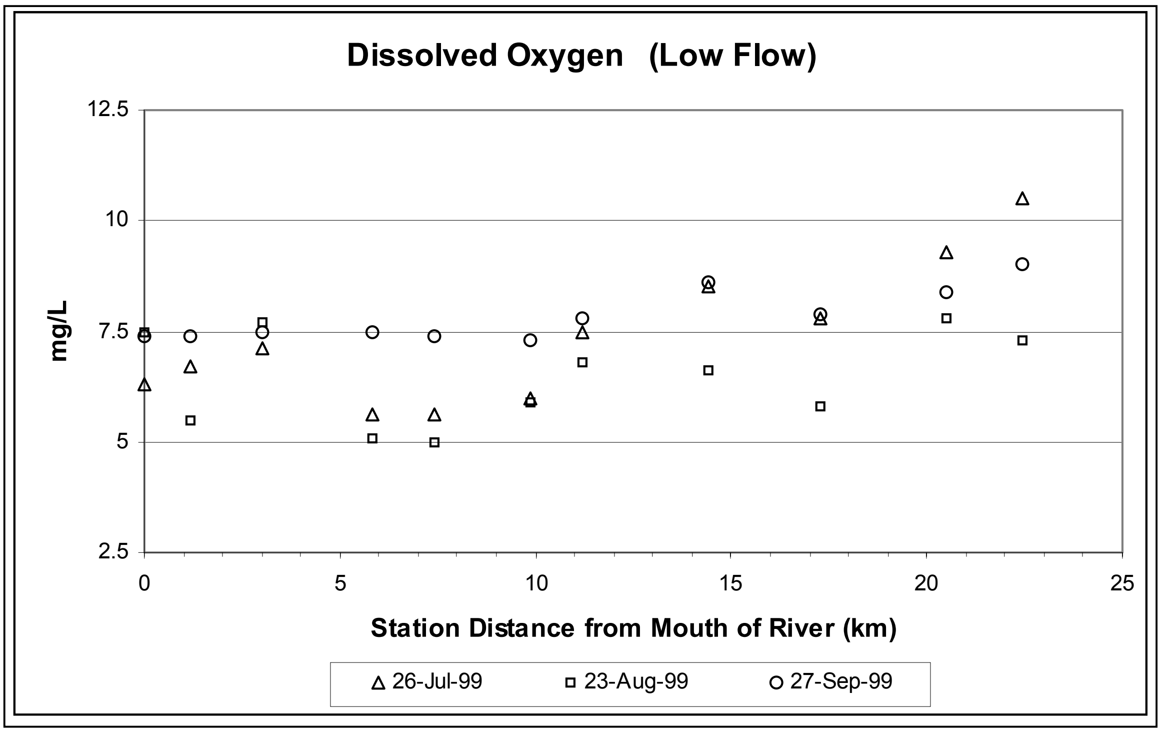


Figure 6: Longitudinal Profile of Dissolved Oxygen Data (Low Flow)

Figure 6 shows a similar longitudinal profile for DO concentrations. As the data indicate, during low flow, most of the stations show DO levels above the State's water quality standard. The higher values between the headwaters (25 km) and the 15-km mark correspond with high chlorophyll *a* values, suggesting elevation due to the effects of photosynthetic activity and the potential for diurnal DO depletion. But at two stations downstream (XJI2704 and XJI2112) the DO levels are fairly close to the water quality standard of 5.0 mg/L. Note that during the day, the chlorophyll *a* photosynthesis activity releases enough oxygen to mask low concentrations of DO that can be detected if the sampling takes place during night hours. For that reason, except for the calibration of the model, all scenario runs will simulate diurnal DO values. The DO figures presented in the sections ahead represent the minimum DO concentrations in the stream.

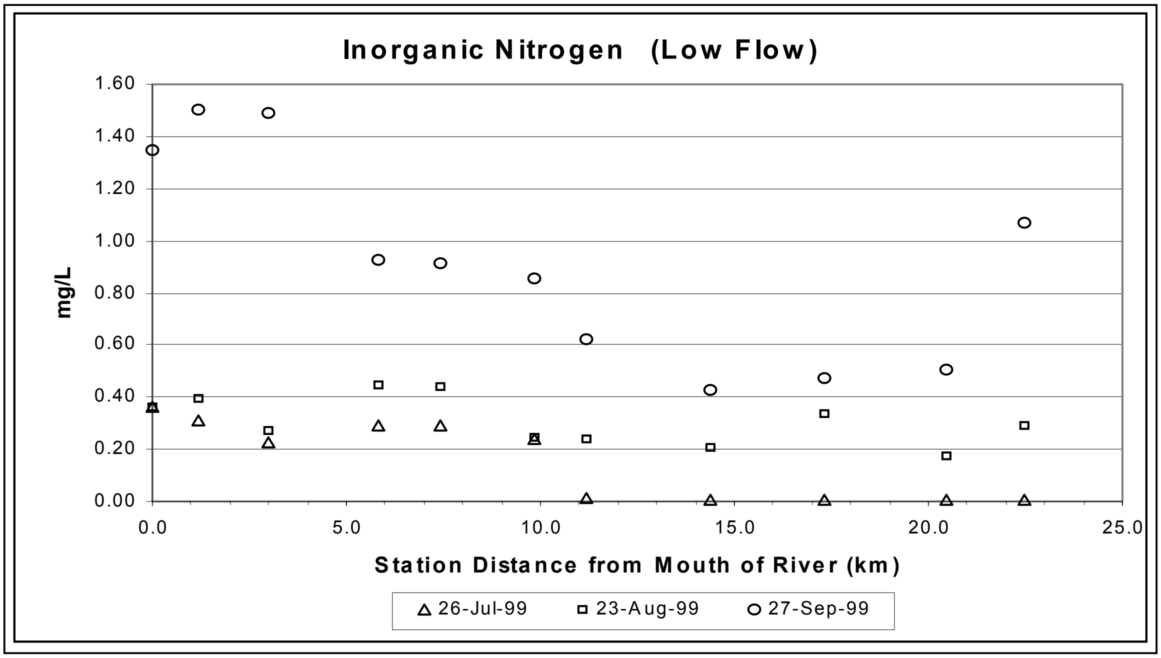


Figure 7: Longitudinal Profile of Dissolved Inorganic Nitrogen Data (Low Flow)

Figure 7 presents a longitudinal profile of DIN measured as ammonia plus nitrate plus nitrite levels in the samples collected in 1999 - low flow conditions. The concentration of inorganic nitrogen varies greatly throughout the length of the creek with values ranging between detection limits and 1.5 mg/L. These lower values indicate possible consumption of nutrients due to temperature increase and chlorophyll *a* growth. The highest values are located near the mouth of the river where the concentrations of chlorophyll *a* are low.

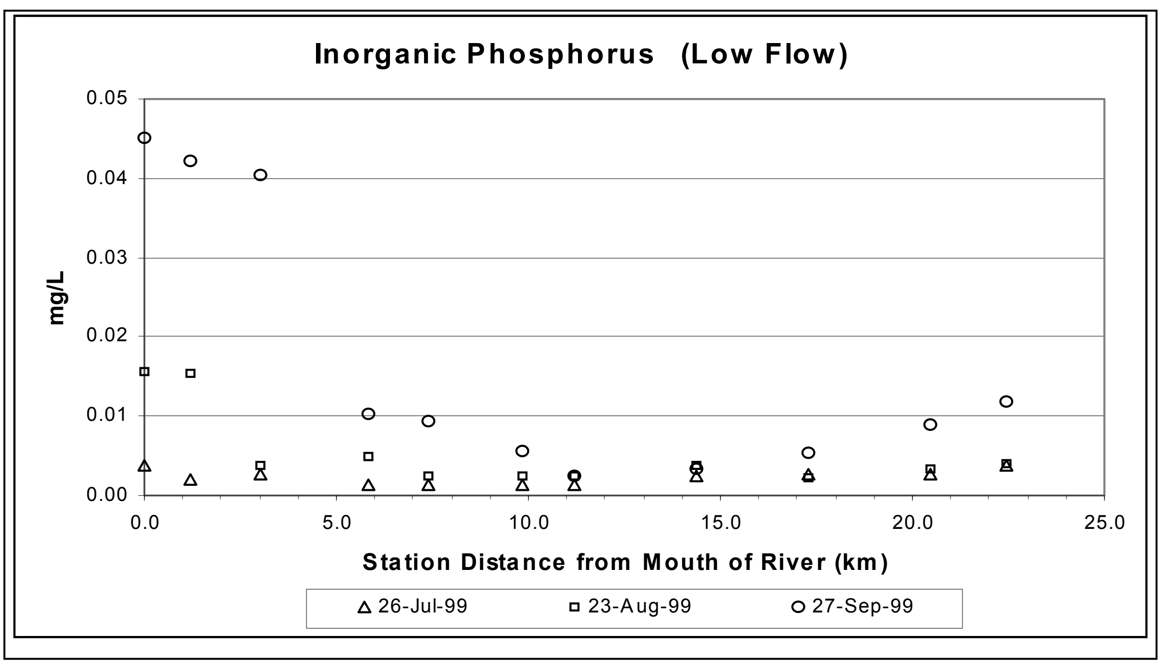


Figure 8: Longitudinal Profile of Dissolved Inorganic Phosphorus Data (Low Flow)

Figure 8 presents a longitudinal profile of DIP as indicated by dissolved ortho-phosphate levels measured in samples collected from summer 1999 surveys - low flow conditions. All the inorganic phosphorus values are low throughout the length of the river suggesting the phosphorus-limiting conditions of the system during low flow. All values are in the range between 0.0013 to 0.042 mg/L.

2.3 Water Quality Impairment

The Maryland Water Quality Standards Surface Water Use Designation (COMAR 26.08.022.07) for the Sassafras River is Use I – *water contact recreation, fishing, and protection of aquatic life and wildlife*. The water quality impairment of the Sassafras River system being addressed by this TMDL analysis consists of an over-enrichment of nutrients. Nutrient loadings from both point and nonpoint sources have resulted in higher than acceptable chlorophyll *a* concentrations. Although observed DO concentrations are not below the minimum criteria of 5.0 mg/L in any of the samples taken during the 1999 surveys, high concentrations of chlorophyll *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 a nuisance or interfere directly or indirectly with designated uses. See Code of Maryland Regulations (COMAR) 26.08.02.03B(2). Excessive eutrophication, indicated by elevated levels of chlorophyll *a*, can produce nuisance levels of algae and interfere with designated uses such as fishing and swimming. The chlorophyll *a* concentration in the upper reaches of the Sassafras River can reach up to 226 µg/L. These levels have been associated with excess eutrophication.

3.0 TARGETED WATER QUALITY GOALS

The objective of the phosphorus TMDL established in this document is to assure that the dissolved oxygen criteria support the Use I designation for Sassafras River and to control nuisance algal blooms. Specifically, the TMDL for phosphorus for the Sassafras River is intended to assure that a minimum dissolved oxygen level of 5.0 mg/L is maintained throughout the Sassafras River System and reduce peak chlorophyll *a* levels (a surrogate for algal blooms) to below 50 µg/L. The chlorophyll *a* water quality level is based on the designated uses of the Sassafras River, guidelines set forth by Thomann and Mueller (1987) and by the EPA Technical Guidance Manual for Developing TMDLs, Book 2, Part 1 (1997). These guidelines acknowledge it is acceptable to maintain chlorophyll *a* concentrations below a maximum of 100 µg/L, with a target threshold of less than 50 µg/L.

4.0 TOTAL MAXIMUM DAILY LOADS AND ALLOCATIONS

4.1 Overview

This section describes how the nutrient TMDL and load allocations for point sources and nonpoint sources were developed for the Sassafras 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 equation are combined in a summary accounting of the TMDL for seasonal low flow conditions and for average annual loads.

4.2 Analysis Framework

The computational framework chosen for the Sassafras River TMDL 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, 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, Georgia (Ambrose *et al.,* 1993). EUTRO 5.1 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 waterbody volume over the tidal cycle. The tidal mixing is accounted for using dispersion coefficients, quantifying the exchange of conservative substances between WASP5.1 model segments. The model simulates an equilibrium state of the waterbody, which in this case - considered low flow and average annual flow conditions, described in more detail below. Limitations of this modeling framework are discussed in Appendix A.

The spatial domain of the Sassafras River Eutrophication Model (SREM) extends from the confluence of the Sassafras River for about 25 km up the mainstem. The modeling domain is represented by 27 WASP model segments. A diagram of the WASP model segmentation is presented in Appendix A. Freshwater flows and NPS loadings from these subwatersheds are taken into consideration by dividing the drainage basin into 22 subwatersheds; also assuming the flows and loadings are direct inputs to the SREM.

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, poor flushing of the system 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 collected was used to support the calibration process, as explained further in the "Nonpoint Source Loadings" section of Appendix A.

The estimation of stream flow, used in the critical low flow analyses, was based on a regression analysis, making use of 30 years of data from United States Geological Survey (USGS) flow gages (Station # 1493000, Station # 1493112 and Station # 1493500) located between the Sassafras and Chester Rivers, Kent County. The estimation of the average annual flow in the Sassafras River builds upon an analysis of flow data from the same USGS stations in 1999. This time period is consistent with that used in the average annual flow scenario. The methods used to estimate stream flows are described further in the "Freshwater Flows" section of Appendix A.

Two point sources of nutrients were in the Sassafras River watershed when the 1999 data was collected. These are the municipal wastewater treatment plants in Betterton and Galena. MDE point source discharge data was used to estimate the point source loads for the 1999 calibration. (See Section 2.1, *General Setting and Source Assessment* for further discussion).

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 human and natural sources. The average annual NPS loads were derived from the same data, averaging together the concentrations observed throughout 1999. 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 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 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 (NO2-3), 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 Sassafras 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, where 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 annual average 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* 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, to compare the future scenarios that simulate the conditions of the TMDL. Defining this baseline, for comparison with the TMDL outcome, is preferred to trying to establish a "current condition." The baseline is defined in a consistent way among different TMDLs and does not vary in time. The alternative of using a "current condition" has the drawback of changing over time, which creates confusion. It is "current" at one point in time for a given TMDL, but TMDL 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 "baseline" scenario.

The baseline conditions for nonpoint source loads typically reflect an approximation of loads during the calibration 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.

<u>First Scenario</u>: The first scenario represents baseline conditions of the stream at simulated low flow in the creek and low flow loading rates. The method of estimating the critical low flow is described in the "Freshwater Flows" section of Appendix A. The scenario simulates a critical condition when the creek system is poorly flushed, where sunlight and warm water temperatures are most conducive to creating the water quality problems associated with excessive nutrient enrichment.

The nonpoint source nutrient concentrations for the first scenario were computed using the observed data collected during the low flow conditions of July and August of 1999 – the same used in the calibration of the model. The low flow nonpoint source loads were computed as the product of the observed concentrations and estimated critical low flow. These low flow nonpoint source loads integrate natural and human induced sources - including direct atmospheric deposition and loads from septic tanks, which are associated with river base-flow during low flow conditions. For point sources loads, these baseline conditions assume maximum future flow and appropriate parameter concentrations expected to occur at that flow with no control actions (see "Point Source Loadings" of Appendix A for more details).

Second Scenario: The second scenario represents baseline conditions of the stream at average flow and average annual loading rate. Higher summer water temperatures and higher solar radiation values are used as conservative assumptions in this scenario. The total nonpoint source loads were calculated using an average of all the observed 1999 data collected by MDE. The loads were computed as the product of the observed 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 future flow and appropriate parameter concentrations expected to occur at that flow with no control actions (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 a reduction from the baseline conditions scenario of controllable nonpoint source loads in the Sassafras River watershed. This reduction in nonpoint source loads includes a margin of safety computed as 5% of the NPS load allocation. The point source loads were left unchanged because the flows from those point sources were small (0.2 and 0.08 mgd) and also because of their location -one at the mouth of the river, and the other discharging in a distant segment of a tributary of the Sassafras- they have little influence on the water quality of the system. In this future condition scenario, reductions in nutrient 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 modeled with high temperatures and sunlight to simulate conditions that are most conducive to algal growth, leading to water quality problems associated with excessive nutrient enrichment. Because higher stream flows, like the average flow typically occurring 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 a reduction in controllable NPS loads of phosphorus in all subwatersheds of the Sassafras River watershed. A 3% margin of safety was also included for the nonpoint source load calculation. Reductions in nutrient sediment fluxes and sediment oxygen demand (SOD) were estimated based on the percent reduction of organic matter settling to the bottom, 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 SREM results presented in this section are daily minimum DO concentrations. These minimum DO concentrations account for diurnal fluctuations caused by photosynthesis and algal respiration.

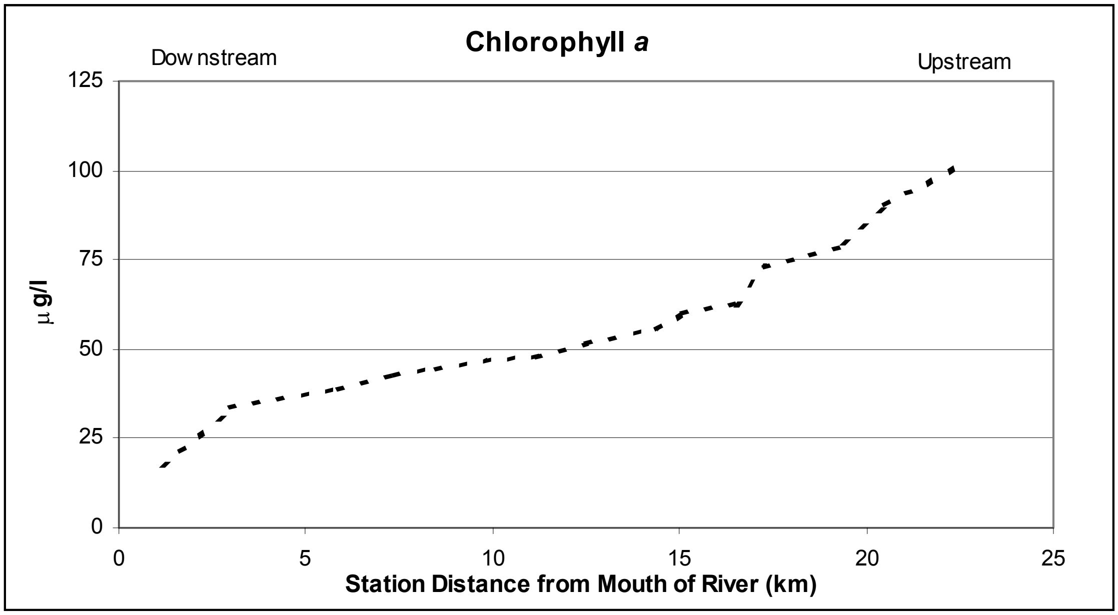
Baseline Conditions Loading Scenarios:

First Scenario (Low flow): Simulates critical low stream flow conditions during the summer season. Water quality parameters (e.g., nutrient concentrations) are based on 1999 observed data.

Results for the first scenario, representing the baseline conditions for summer critical low flow, are summarized in Figure 9. Under these conditions, chlorophyll *a* concentrations at the middle of the river and its upper headwater reaches exceed the maximum allowed goal of 50 µg/L with values reaching 101 µg/L value. At the same time, DO concentrations do not fall below the minimum water quality criterion of 5.0 mg/L throughout the length of the river, although it is close to the limit (5.3 mg/L) at the lower part of the river near its junction with Tumer Creek.

Second Scenario (Average annual flow): Simulates 1999 average annual stream flow condition, with baseline annual nonpoint source loads computed on the basis of 1999 MDE observed data (see Appendix A).

Results for the second scenario, representing the baseline conditions for the average annual stream flow and average loads, are summarized in Figure 10. Under these conditions, chlorophyll *a* concentrations are higher than in the previous (first) scenario, almost reaching a value of 150 µg/L. There are two point sources of nutrients in the Sassafras River watershed, but due to their location and concentrations they have insignificant influence on the water quality of the river.



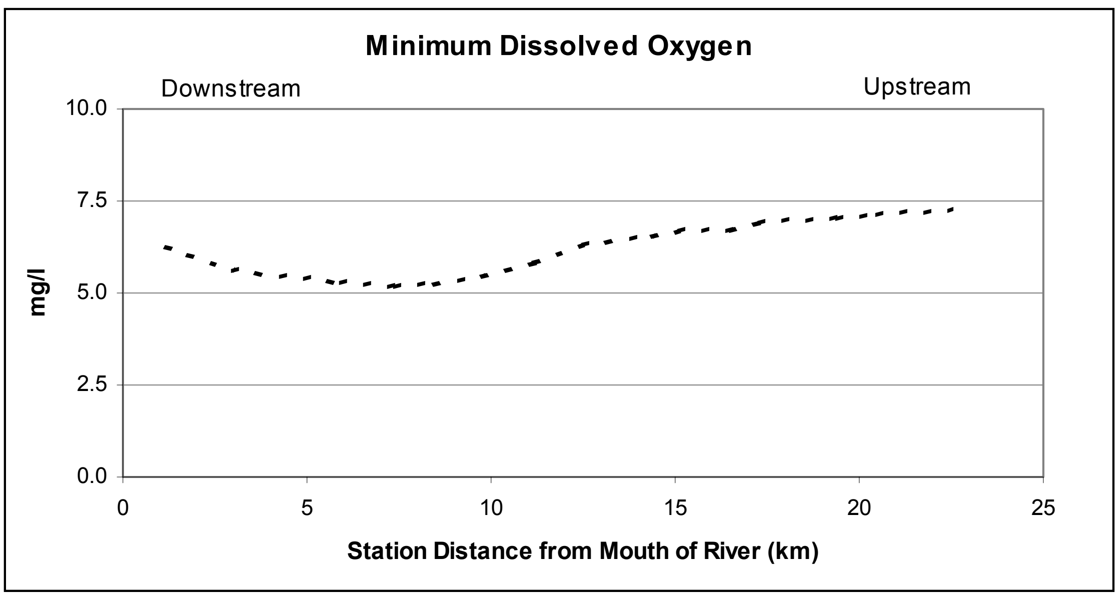


Figure 9: Model Results for the Low Flow Baseline Condition Scenario for Chlorophyll *a* and Dissolved Oxygen (First Scenario)

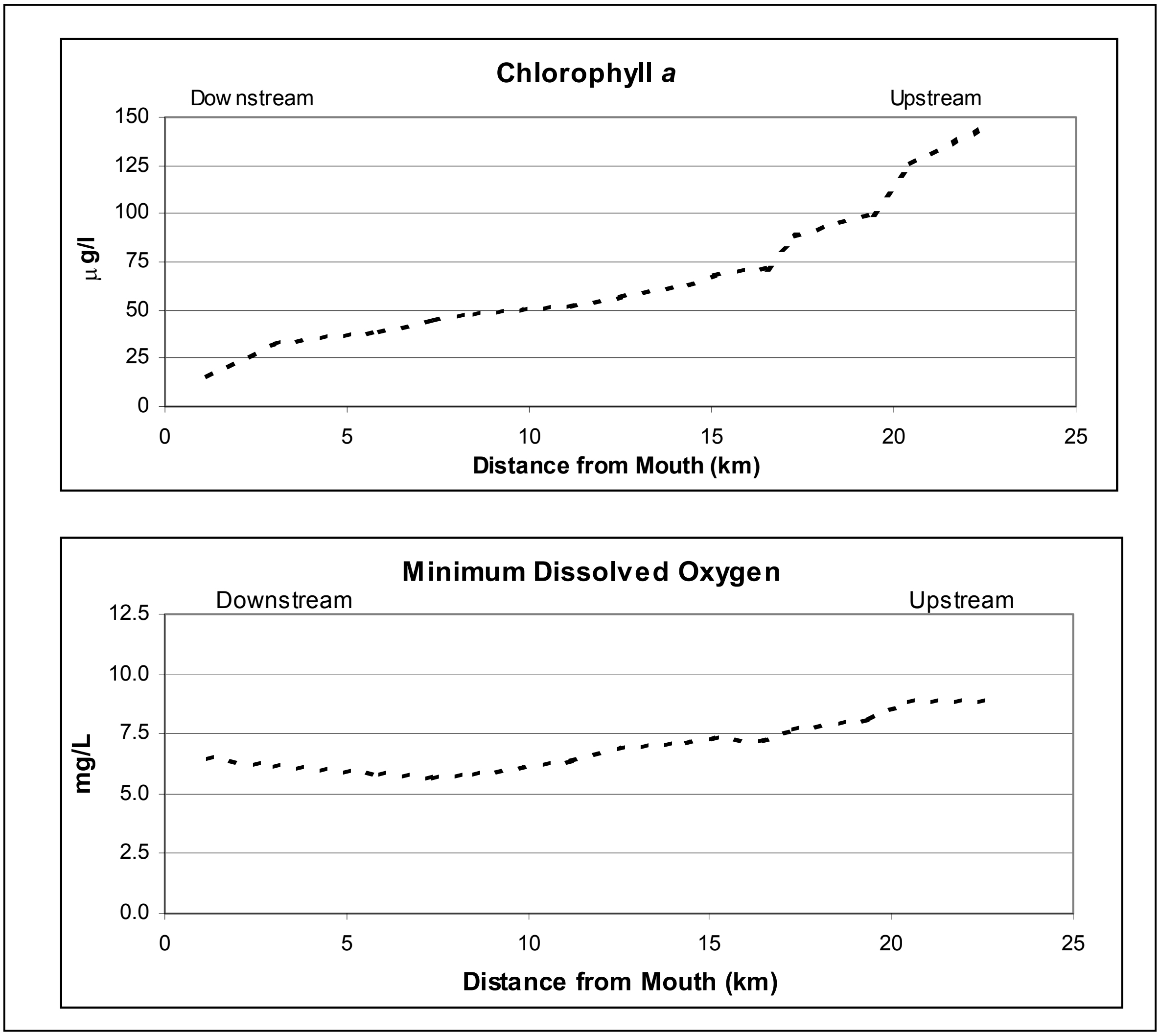


Figure 10: Model Results for the Average Annual Flow Baseline Condition Scenario for Chlorophyll *a* and Dissolved Oxygen (Second Scenario)

<u>Future Condition TMDL Scenario:</u>

<u>Third Scenario (Low Flow)</u>: Simulates the future condition of maximum allowable loads for critical low stream flow conditions during the summer season.

Results for the third scenario (solid line), representing the maximum allowable load for summer-time critical low flow, are summarized in comparison to the appropriate baseline conditions scenario (dotted line) in Figure 11. Under the nutrient load reduction conditions described above for this scenario, the results show chlorophyll *a* concentrations remain below 50 µg/L along the entire length of the Sassafras River. For dissolved oxygen (DO), the comparison shows that the nutrient load reductions result in little change, maintaining the DO concentrations above the water quality criterion of 5.0 mg/L along the length of the river.

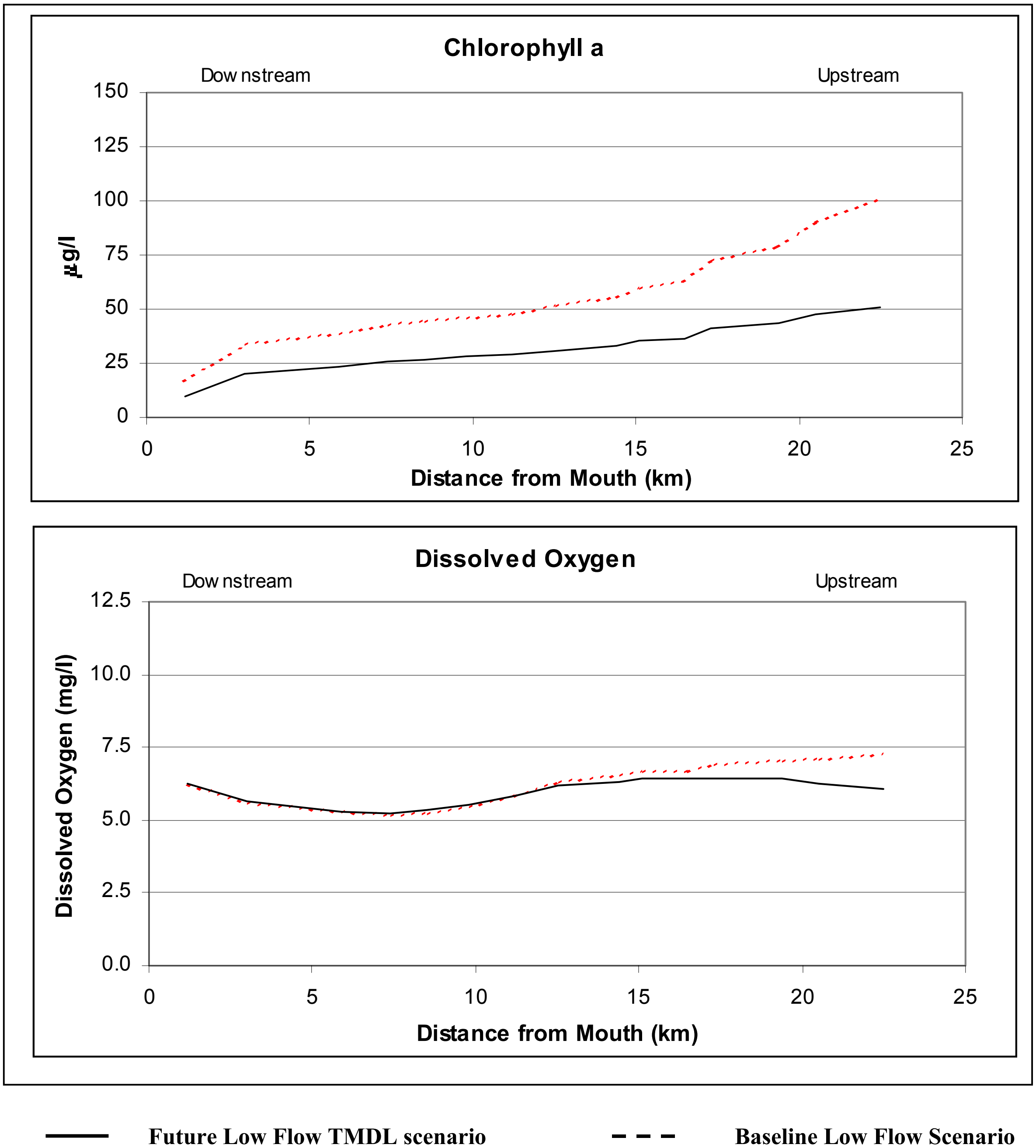
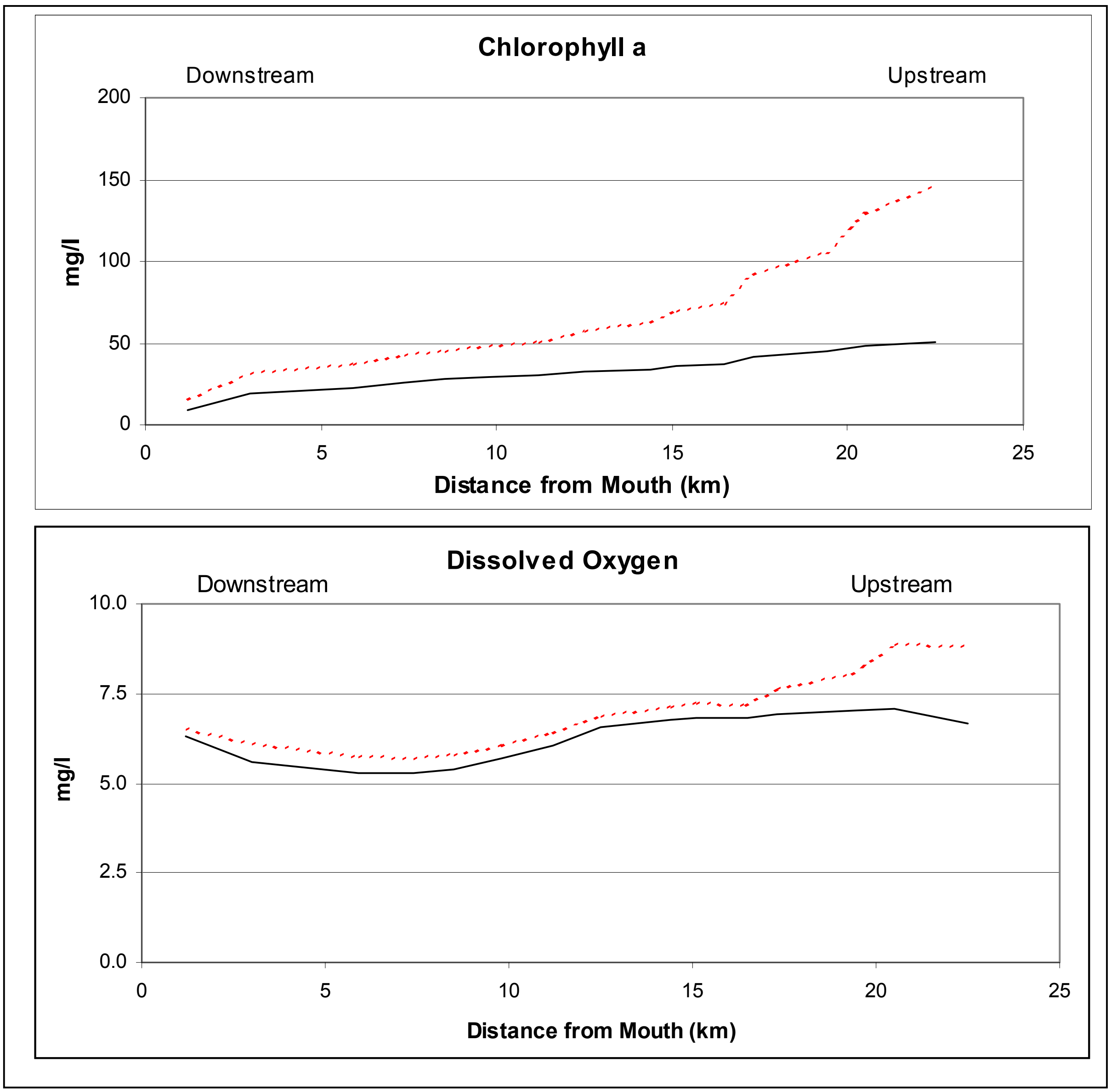


Figure 11: Model Results for the Low Flow Future Condition Scenario for Chlorophyll *a* and Dissolved Oxygen (Third Scenario)

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 (solid line), representing the maximum allowable loads for average annual flow, are summarized in comparison to the appropriate baseline scenario (dotted line) in Figure 12. Under the 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 Sassafras River. For dissolved oxygen (DO), the comparison shows that the DO along the length of the river remains above the water quality criterion of 5.0 mg/L for both scenarios.



Future Low Flow TMDL Scenario **Baseline Low Flow Scenario**

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

4.5 TMDL Loading Caps

This section presents the Total Maximum Daily Load (TMDL) for phosphorus. The outcomes are presented in terms of the critical low flow TMDL and average annual TMDL. The critical season for excessive algal growth in the Sassafras River is during the summer months, when the river system 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 TMDL is stated in monthly terms because these critical conditions occur for limited periods 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 TMDL applies:

Low Flow TMDL:

PHOSPHORUS TMDL **747** ***lb/month***

The average annual TMDL is being established for two purposes. First, it is designed to protect water quality in the Sassafras River. Second, average annual loads contribute to water quality problems observed in the low flow critical season.

The annual average TMDL for phosphorus is:

Average Annual TMDL:

PHOSPHORUS TMDL **13,875** ***lb/year***

4.6 Load Allocations Between Point Sources and Nonpoint Sources

The watershed that drains to the Sassafras River has two permitted point source discharges of nutrients. The allocations described in this section demonstrate how the TMDL can be implemented to achieve water quality standards in the Sassafras River. Specifically, these allocations show the sum of phosphorus loadings to the Sassafras River from existing point and nonpoint sources can be maintained safely within the TMDL established here. These allocations demonstrate how this TMDL could be implemented to acheive water quality standards; however, the State reserves the right to revise these allocations provided the allocations are consistant with the acheivement of the water quality standard.

Low Flow Allocations:

The NPS loads of phosphorus simulated in the third scenario represent a reduction from the baseline scenario. Recall that the low flow 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 baseline conditions make up the balance of the total allowable load. This point source waste load allocation was adopted from results of model Scenario 3. All significant point sources are addressed by this allocation and are described further in the technical memorandum entitled *"Significant Phosphorus Point Sources in the Sassafras River Watershed.*" The NPS and point source phosphorus allocations for summer critical low flow conditions are shown in Table 2.

Table 2: Summer Low Flow Allocations

	Total Phosphorus *(lb/month)*
Nonpoint Source	169
Point Source	569

Average Annual Allocations:

The average annual nonpoint source phosphorus allocations are represented as the average of the 1999 data, with a reduction in controllable phosphorus NPS loads in all subwatersheds of the Sassafras River watershed. The nonpoint source loads assumed in the model, account for both "natural" and human-induced components. As discussed in the "Scenario Descriptions" section of this document, the loads were based on year 1999 MDE observed data.

Point source load allocations for the average annual flow baseline conditions make up the balance of the total allowable load. This point source waste load allocation was adopted from results of the fourth model scenario. All significant point sources are addressed by this allocation and are described further in the technical memorandum entitled *"Significant Phosphorus Point Sources in the Sassafras River Watershed.*" The NPS and point source phosphorus allocations for summer critical low flow conditions are shown in Table 3.

Table 3: Average Annual Flow Allocations

	Total Phosphorus *(lb/yr)*
Nonpoint Source	6,839
Point Source	6,824

4.7 Margins of Safety

A margin of safety (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 = LA + WLA + 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 NPS load (9 lb/month) for phosphorus for the low flow TMDL. Similarly, a 3% MOS was included in computing the average annual TMDL. These explicit phosphorus margins of safety are summarized in Table 4.

Table 4: Expected Summer Low Flow and Annual Average Flow Margins of Safety (MOS)

	Phosphorus MOS
MOS Low Flow	9 lb/month
MOS Average Flow	212 lb/yr

In addition to these explicit set-aside MOSs, additional safety factors are built into the TMDL development process. Note that the results of the model scenario for the critical low flow case indicate a chlorophyll *a* concentration that is around 50 µg/l. 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 TMDL, MDE has elected to use the more conservative peak concentrations of 50 µg/l.

The fourth model scenario, for average annual flow, was run under the assumption of summer temperature and summer solar radiation - another MOS. When the water is warmer and more sunlight 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 200 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 a significant margin of safety.

4.8 Summary of Total Maximum Daily Loads

The critical low flow TMDL for Sassafras River, applicable from May 1 – Oct. 31 follows:

For Phosphorus (*lb/month*):

TMDL	=	LA	+	WLA	+	MOS
747	=	**169**	+	**569**	+	**9**

Where:

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

Low Flow Average Daily Loads:

On average, the low flow TMDL will result in loads of approximately 24 lb/day of phosphorus.

The average annual TMDL for the Sassafras River is as follows:

For Phosphorus (*lb/yr*):

TMDL	=	LA	+	WLA	+	MOS
13,875	=	**6,839**	+	**6,824**	+	**212**

Where:

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

Average Annual Flow Daily Loads:

The average annual flow TMDL will result in loads of approximately 38 lb/day of phosphorus.

5.0 ASSURANCE OF IMPLEMENTATION

This section provides the basis for reasonable assurances that the phosphorus TMDL will be achieved and maintained. Maryland has several well-established programs to draw upon: the Water Quality Improvement Act of 1998 (WQIA), the Clean Water Action Plan (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 two point sources located in the Sassafras River watershed, Betterton and Galena WWTPs, have flows below 0.5 million gallons per day (actual total flow of 280,000 gallons per day). As noted in section 4.4 (second scenario description), they have a negligible effect in the water quality of the river because of the location and concentrations of these point sources of nutrients. Thus, tighter restrictions in effluent limits for the plants are not required.

Maryland's Water Quality Improvement Act, of 1998, requires that comprehensive and enforceable nutrient management plans be developed, approved and implemented for all agricultural lands throughout Maryland. This act specifically requires that phosphorus management plans be developed by December 2001 and be implemented by December 2002 if chemical fertilizer is used, and by 2004-5 for those who use manure or organic sources (Title 15 Maryland Department of Agriculture Subtitle 20 Soil and Water Conservation: 15.20.07.04). In addition to nutrient management plans, Maryland’s Agricultural Cost Share Program (MACS) has been developed to address potential pollution problems from agriculture and is available to fund Best Management Practices (BMPs) in this watershed; and Low Income Loans for Agricultural Conservation (LILAC) program provides loans for projects.

Maryland’s CWAP has been developed in a coordinated manner with the State's 303(d) process. All CWAP Category I watersheds identified in Maryland's Unified Watershed Assessment process are totally coincident with the impaired waters list approved by EPA for 1996 and 1998. 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 implementation plans to achieve these nutrient reduction goals. Maryland’s resultant Tributary Strategies for Nutrient Reduction provide a framework that will support the implementation of NPS controls in the Lower Eastern Shore Tributary Strategy Basin, including the Sassafras River watershed. These Tributary Strategies are soon to be updated as part of the Chesapeake 2000 initiative under the Chesapeake Bay Agreement. Maryland is in the forefront of implementing quantifiable NPS controls through the Tributary Strategy efforts. This will help to assure that nutrient control activities are targeted to areas where nutrient TMDLs have been established.

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 and deposition of nutrients and organic matter to the streambed 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.

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/Bay 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/Bay could be a significant nutrient source, implying that a lower proportion of the load is from nonpoint sources in the Sassafras River basin. In such a case, load reductions from the Susquehanna, as part of the Chesapeake Bay Agreement, could have a significant positive effect on the Sassafras River 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 Sassafras River also off-setting 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 National Pollutant Discharge Elimination System (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