Total Maximum Daily Loads of Nitrogen and Phosphorus for the Worton Creek Kent County, Maryland

FINAL

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List of Abbreviations

BMP	Best Management Practice
BOD	Biochemical Oxygen Demand
CBOD	Carbonaceous Biochemical Oxygen Demand
CEAM	Center for Exposure Assessment Modeling
CHL*a*	Active Chlorophyll
WCEM	Worton Creek Eutrophication Model
CWA	Clean Water Act
DO	Dissolved Oxygen
EPA	Environmental Protection Agency
EUTRO5.1	Eutrophication Module of WASP5.1
LA	Load Allocation
MDA	Maryland Department of Agriculture
MDE	Maryland Department of the Environment
MOS	Margin of Safety
NH_4	Ammonia
NO_{23}	Nitrate + Nitrite
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

EXECUTIVE SUMMARY

This document proposes to establish Total Maximum Daily Loads (TMDLs) for nitrogen and phosphorus in Worton Creek. Worton Creek drains directly into the Chesapeake Bay and is part of the Upper Eastern Shore Tributary Strategy Basin. The creek is impaired by the nutrients nitrogen and phosphorus, which are causing excessive algal blooms that could violate 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 Worton Creek will be met. The TMDLs were determined using the WASP5.1 water quality model. Maximum loads for total nitrogen and total phosphorus entering Worton Creek are established for both low flow and average annual flow conditions. As part of the TMDLs' 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 351 lbs/month, and the low flow TMDL for phosphorus is 22 lbs/month. These TMDLs apply during the period May 1 through October 31. The low flow nonpoint source loads for the TMDLs were computed by multiplying the observed base flow concentrations by the estimated critical low flow. Allowable low flow regime loads have been allocated to nonpoint sources only, considering an appropriate margin of safety, because the watershed contains no permitted point sources to which allocations can be made.

The average annual TMDL for nitrogen is 18,016 lbs/yr, and the average annual TMDL for phosphorus is 1,382 lbs/yr. Baseline average annual nonpoint source loads, from which reductions are computed, are based on data collected by MDE in 1999. Again, because the watershed contains no permitted point sources to which allocations can be made, allowable average annual loads have been allocated to nonpoint sources only considering an appropriate margin of safety.

Three factors provide assurance that these TMDLs will be implemented. First, 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. Second, 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 maximum 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.

Worton Creek, as part of the Still Pond/Fairlee Creek watershed, was first identified on the 1996 303(d) list submitted to the 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, expressed as high chlorophyll *a* concentrations. 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 growth of aquatic plants, which eventually die and decompose, leading to bacterial consumption of dissolved oxygen and dissolved oxygen concentrations below what is necessary to support the designated use. For these reasons, this document proposes to establish TMDLs for the nutrients nitrogen and phosphorus in Worton Creek.

2.0 SETTING AND WATER QUALITY DESCRIPTION

2.1 General Setting and Source Assessment

Worton Creek is located within Kent County, Maryland and is part of the Upper Eastern Shore Tributary Basin (Figure 1). Its headwaters originate near the intersection of Maryland's routes 297 and 298 (Worton Park). Two smaller tributaries, Mill Creek and Tims Creek, feed Worton Creek, which itself finally drains to the Chesapeake Bay. The Worton-Mill Creek is approximately 6.5 miles (10.5 km) in length. Worton Creek alone is only 2.5 miles (4 km). The Worton Creek watershed has an area of approximately 11,656 acres (18.2 sq. miles). The land uses in the watershed consist of forest and other herbaceous (2,958 acres or 25.4 %), mixed agriculture (6,957 acres or 59.7 %), water (800 acres or 6.9 %), and urban (941 acres or 8 %), based on 1997 Maryland Department of Planning land use/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.

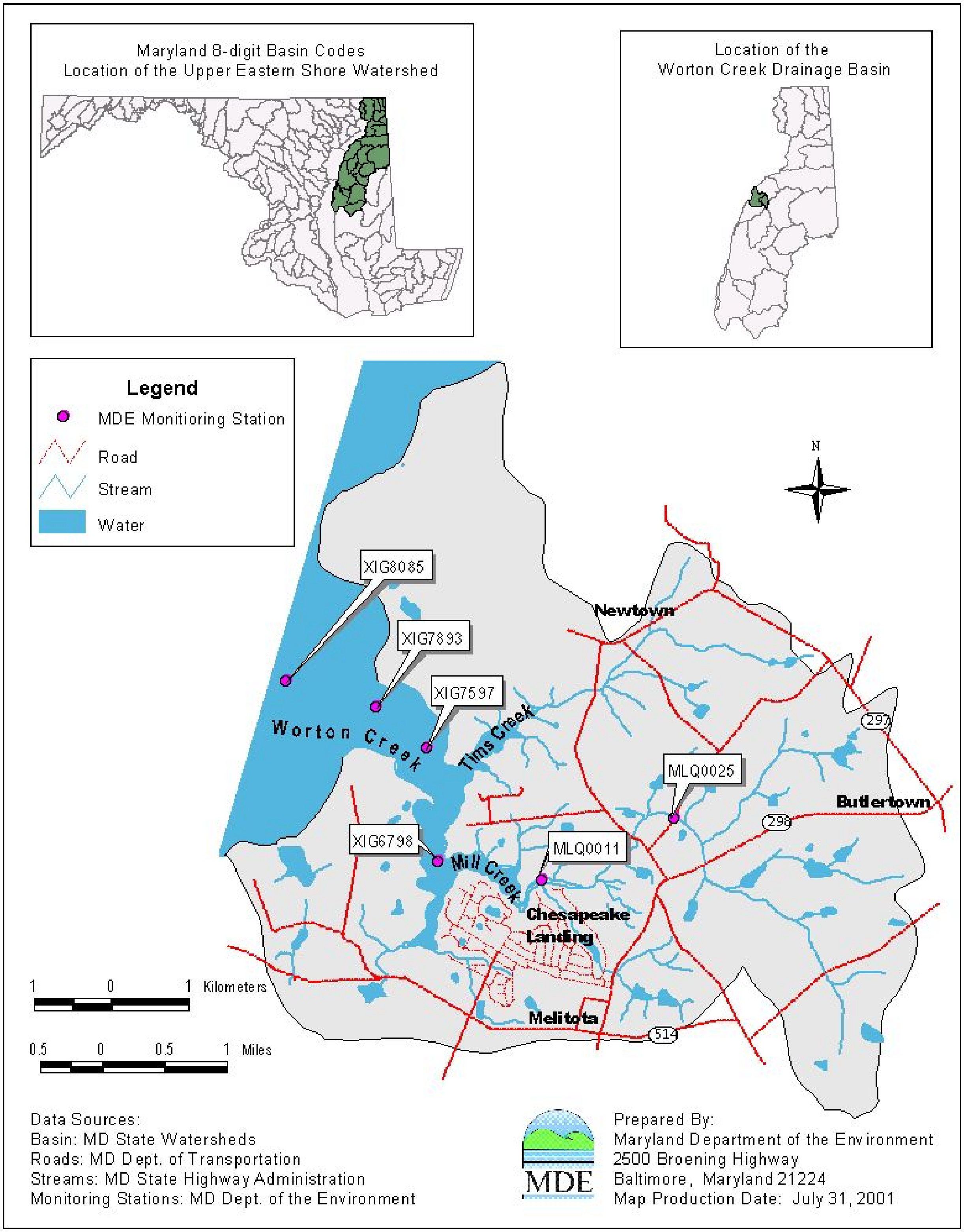

Figure 1: Location Map of the Worton Creek Drainage Basin within Maryland

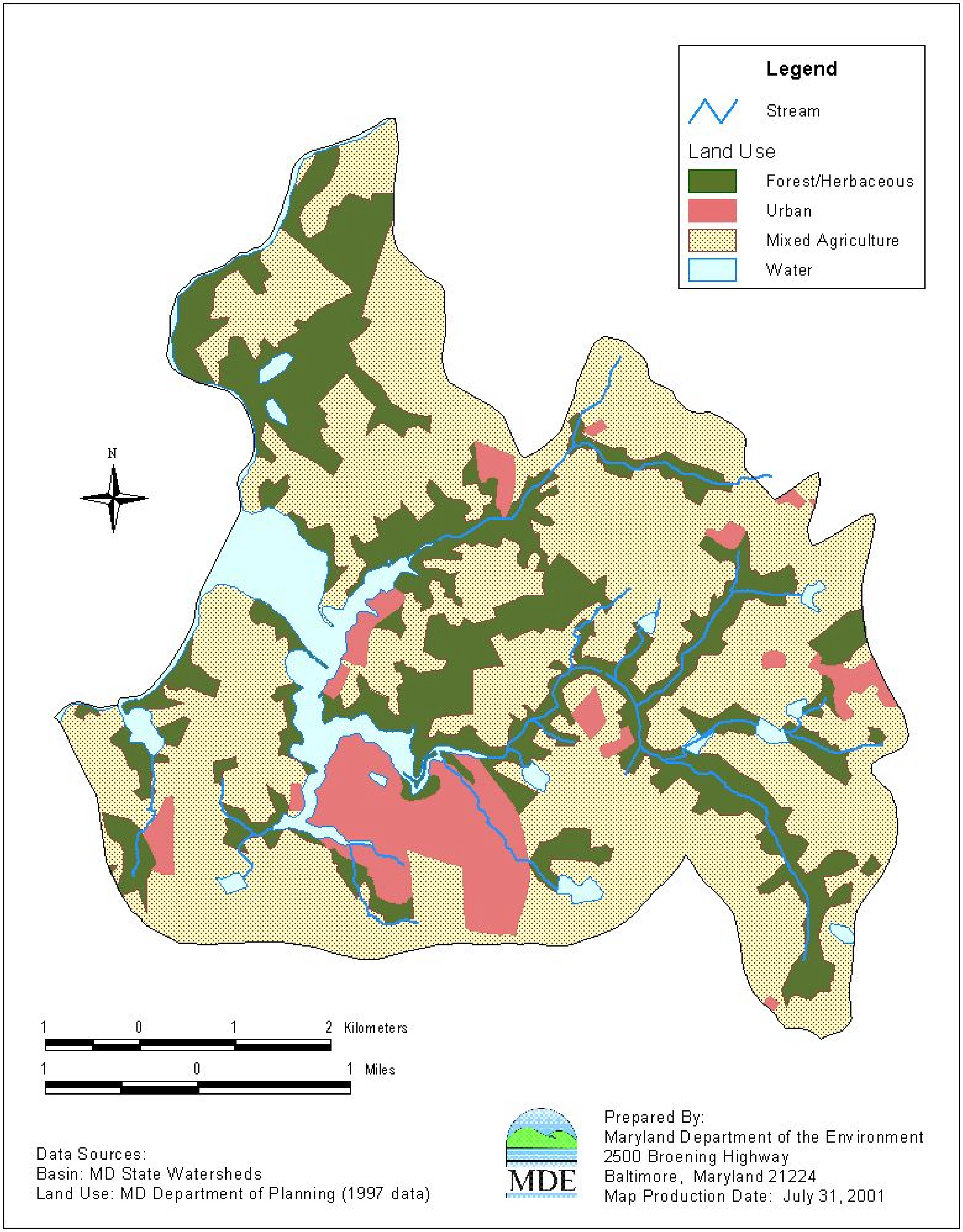

Figure 2: Land Uses in the Worton Creek Drainage Basin

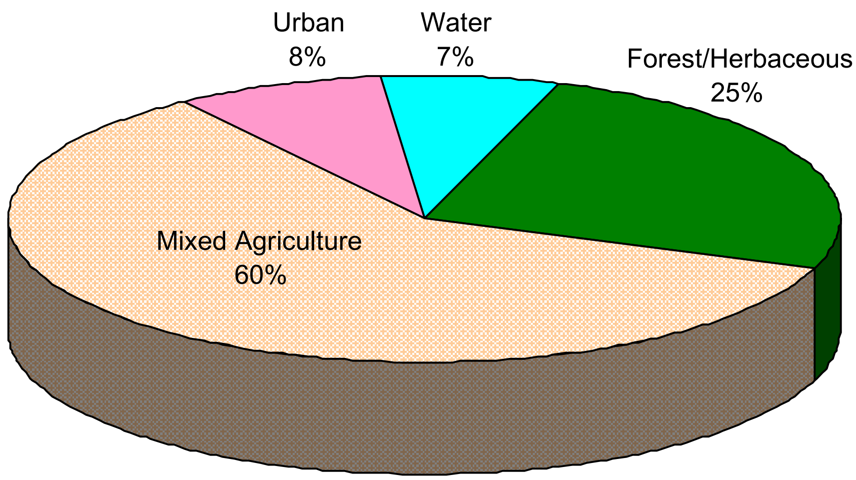

Figure 3: Proportions of Land Use in the Worton Creek Drainage Basin

Worton Creek is tidal throughout its navigable reach, which extends from the confluence with the Chesapeake Bay approximately 1.6 miles upstream to the confluence with Mill Creek, which has a length of approximately 5 miles. The head of tide is located in Mill Creek approximately 1.5 miles upstream of the Worton-Mill Creek confluence. Worton creek presents a narrow constriction at its confluence zone, which results in very limited tidal exchange with the adjacent waters of the Chesapeake. This atypical tidal exchange produces unusual salinity distributions within Worton and Mill Creeks as well as other related hydrologic anomalies.

This particular characteristic of Worton Creek is at least partially responsible for elevated chlorophyll *a* concentrations observed in the upper sections of the Mill Creek. This headwater zone of the tidal section of the Worton-Mill Creek system are also characterized by resultant weak current activity, rendering the overall region quite stagnant. Weak currents and stagnation are indicated by the broad depositional headwater zone, which at least partially relates 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 and decreases its volume. The depth of the creek ranges from about 1.4 feet (0.4 m) at the headwaters to approximately 10 feet (3 m) at the mouth of the creek.

The watershed topography consists of well-drained soils with mild or minimal slopes, extensive agriculture with riparian forest along the edges of the river, and a rather extensive marina community. Land use is predominantly agriculture, and nearly exclusively row crop in character. Soybeans and corn are the predominant crops. Chemical fertilizer predominates in this region, primarily anhydrous ammonia. No confined animal feeding operations (CAFOs) are found in the Worton Creek watershed. However, a large seasonal migratory waterfowl population is present.

In the Worton Creek watershed, the estimated total nitrogen load is 24,876 lbs/yr, and the estimated total phosphorus load is 1,907 lbs/yr. The percentages of the various land uses contributing to these loads are shown in Figure 4. These figures represent loads from nonpoint sources only. There are no permitted point sources in the watershed that discharge nutrients. 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 flow) solely serve as a rough basis by which to compare the NPS reduction needed to reach the TMDL limit, but are not used in the TMDL calculation itself.

MDE's estimate of annual loads is the best estimate available that is based on observed data. The data was collected in 1999, a fairly average year, in which the annual rainfall of 43.9 inches was slightly above the 10 year average of 37.5 inches over 1990-2000. The range of annual rainfall for this period was 30 inches to 58 inches. The Bay Program's loads, by contrast, are based on a coarse scale watershed model that is not calibrated for this particular watershed. MDE's estimate is further supported by the results of water quality modeling, which indicated that loads higher than what was estimated on the basis of observed data would result in unrealistically elevated nutrients and algal levels in the creek. Therefore, MDE's estimate of nonpoint source loads will be considered reasonable and will be used for the analysis. 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.

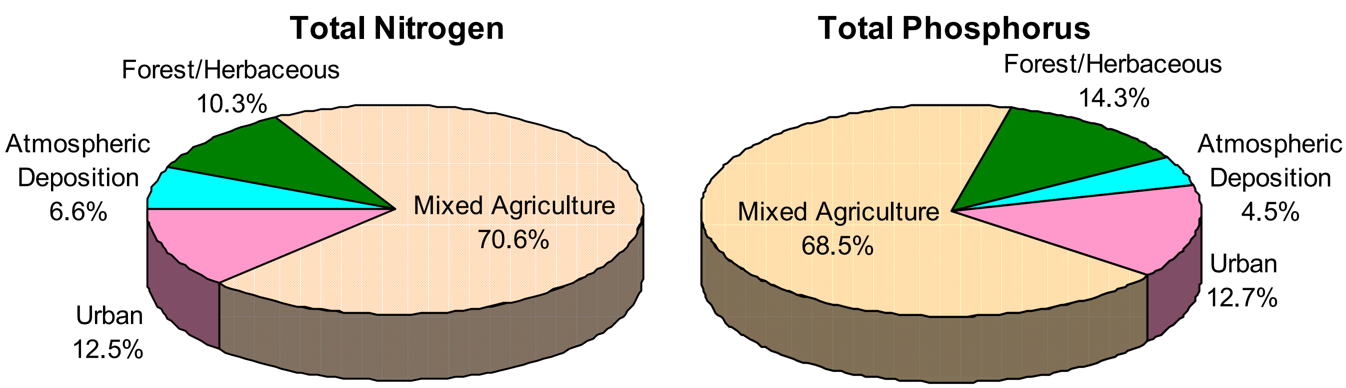

Figure 4: Percentages of Average Annual Nitrogen and Phosphorus Nonpoint Source Loads

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

The nonpoint source loads shown in Figure 4 were determined using land use loading coefficients. The land use information was based on 1997 Maryland Department of Planning data, with refinements of 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 coefficients. 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 account for atmospheric deposition, and loads from septic tanks, urban development, agriculture, and forestland. This data was used only for an estimate of current nonpoint source loadings and to calculate the percentages of the loads that could be controlled. It was not used in the development of the model used to calculate the TMDLs.

2.2 Water Quality Characterization

Four key water quality parameters, chlorophyll *a*, dissolved oxygen, dissolved inorganic nitrogen, and dissolved inorganic phosphorus are presented below. These data were collected by MDE during six water quality surveys conducted in Worton Creek during 1999. Three sets of samples were collected during seasonal low flow periods in summer (19-July-99, 16-Aug-99, 13-Sep-99), and three high flow periods in winter and spring (18-Mar-99, 12-April-99, 10-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.

Table 1: Location of Water Quality Stations

Water Quality Station	Miles from the Mouth of the Worton Creek
XIG8085	-0.67 (Bay)
XIG7893	0.07
XIG7597	0.61
XIG6798	1.56
MLQ0011	2.65
MLQ0025*	4.2

*Non-tidal (free flowing) sampling station

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 sunlight to grow aquatic plants, and warmer temperatures, which are favorable conditions for biological processes of both plant growth and decay of dead plant matter. Because problems associated with eutrophication are usually most acute during this season, the 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 (March, April and May 1999) 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 period, are presented in Appendix A.

As mentioned above in Section 2.1, the hydrologic characteristics of the Worton Creek make the system susceptible to algal blooms. This is more prevalent at the upper reaches of the creek where the tidal dispersion is so poor that the water is stagnant and any nutrients entering the stream from the watershed including the marinas, or from the Chesapeake Bay, accumulate, and produce excessive chlorophyll *a* levels. This chlorophyll *a* eventually dies, settles and is expected to cause higher sediment nutrient fluxes, and sediment oxygen demand, than is commonly seen in other systems.

Figure 5 presents a longitudinal profile of chlorophyll *a* data sampled during summer 1999. Note that during this low flow period, higher chlorophyll *a* values occur in the upper section of the creek, near the head of tide. The sampling region covers the entire tidal portion of Worton Creek from the station XIG8085 located approximately 0.67 miles below the mouth of the river, up to its confluence with Mill Creek located 0.6 miles below the head of tide (station MLQ0011). There is also one sampling station in the free flowing section of the Mill Creek, located approximately one mile upstream of the head of tide. Figure 5 shows that ambient chlorophyll *a* concentrations in the summer increase just below the head of tide. Concentrations reach their maximum at the 2.65 miles mark, and then taper off towards the mouth of the creek. At this point, concentrations exceed the 50 μg/l criterion, with a maximum concentration of about 160 μg/l.

A similar longitudinal profile for dissolved oxygen (DO) concentrations is depicted in Figure 6. With the exception of one low value just below the head of tide, at the same location where the high chlorophyll *a* values are observed, the data show a range between 5 and 10 mg/l throughout the length of the creek. One value exceeds 10 mg/l near the mouth of the river. Note that during the day, the chlorophyll *a* photosynthesis activity releases oxygen enough to mask low concentrations of DO and that can only be detected if the sampling takes place during night time. For this reason, except for the calibration of the model, where the simulation results are being compared to actual data, all scenario runs will simulate minimum DO values. The DO figures presented in the sections ahead represent the minimum DO concentrations in the stream.

Figure 7 presents a longitudinal profile of dissolved inorganic nitrogen (DIN) levels measured in the samples collected in 1999 during low flow conditions. The levels are generally below 0.60 mg/l throughout the stream system with several observations below 0.05 mg/l. The higher values are seen at the last station or "free flowing" station where chlorophyll *a* concentrations are very low. The "U shape" of the profile is consistent with the slightly "mound-shaped" chlorophyll *a* profile, suggesting that the consumption of DIN supports the growth of algae.

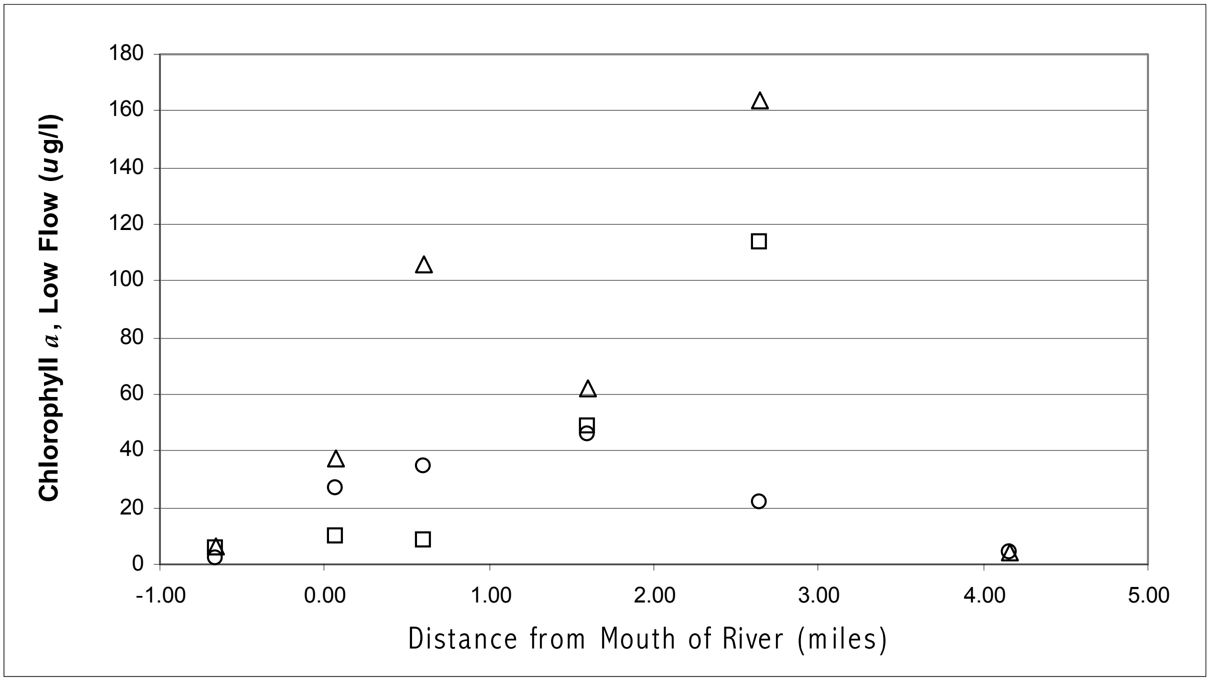

Figure 5: Longitudinal Profile of Chlorophyll *a* Data (Low Flow)

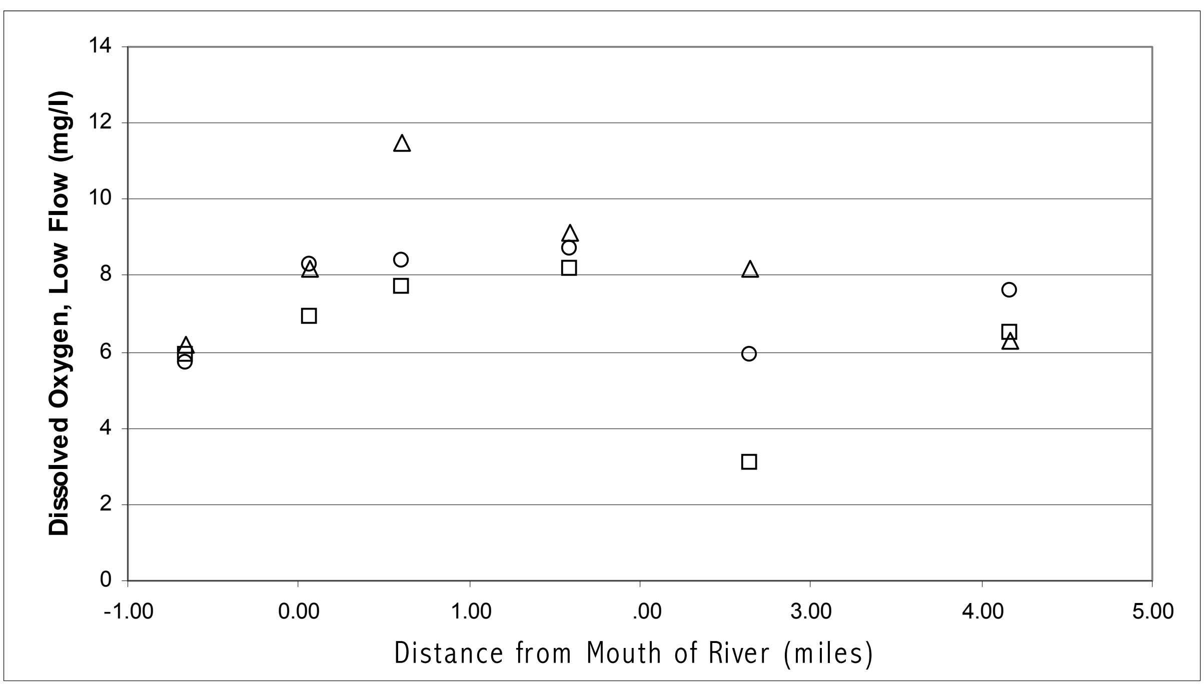

Figure 6: Longitudinal Profile of Dissolved Oxygen Data (Low Flow)

△**July 1999** □ **August 1999** ○ **September 1999**

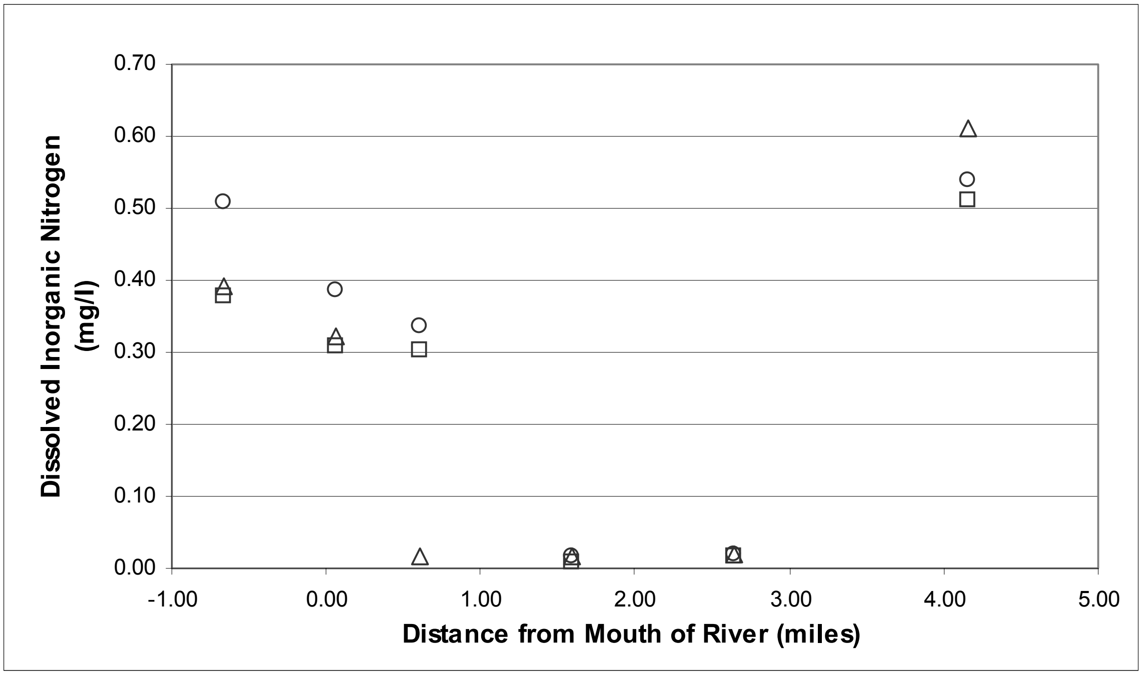

Figure 7: Longitudinal Profile of Dissolved Inorganic Nitrogen Data (Low Flow)

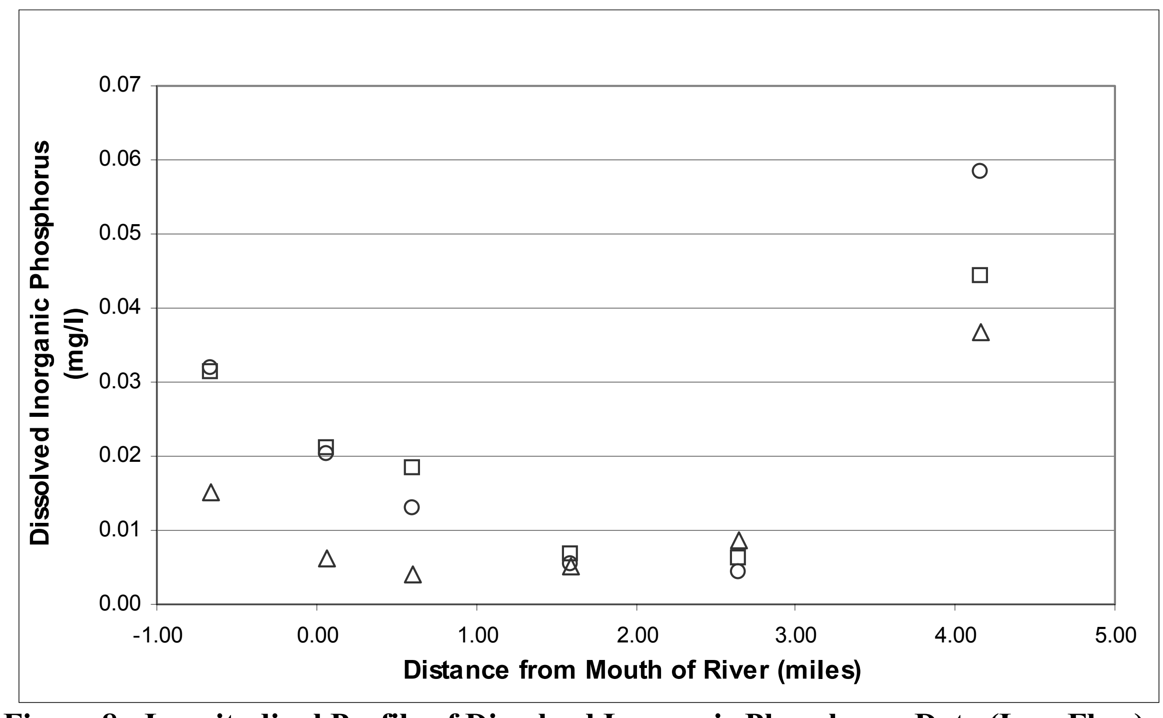

Figure 8: Longitudinal Profile of Dissolved Inorganic Phosphorus Data (Low Flow)

△ **July 1999** □ **August 1999** ○ **September 1999**

Figure 8 presents a longitudinal profile of dissolved inorganic phosphorus (DIP) as indicated by ortho-phosphate levels measured in samples collected in 1999, during low flow conditions. All values fall in the range between 0.004 to 0.03 mg/l except for the "free flowing" station value, which reaches almost 0.06 mg/l. Again, as in the DIN profile, the concentrations of dissolved phosphorus decrease upstream as we approach the head of tide. Notice that the last station near the 4.5 mile is the "free flowing' station where the concentrations of chlorophyll *a* are almost negligible. The profile is consistent with the slightly "mound-shaped" chlorophyll *a* profile, suggesting that the consumption of DIP supports the growth of algae.

2.3 Water Quality Impairment

The water quality impairment of Worton Creek addressed by these TMDLs consists of exceedances of MDE's chlorophyll *a* concentration goal of 50 µg/l. These violations are the result of over-enrichment by the nutrients nitrogen and phosphorus.

Worton Creek, as part of the Upper Eastern Shore, has been designated as a Use I water body, pursuant to which it is protected for water contact recreation, fishing, aquatic life and wildlife. See COMAR 26.08.02.07. Use I waters are subject to a DO criterion of not less than 5.0 mg/l at any time (COMAR 26.08.02.03A(2)).

The data collected in 1999 showed only one value of dissolved oxygen concentration in the upper reaches of Worton Creek below the criterion of 5.0 mg/l. However, chlorophyll *a* concentrations exceeded MDE's goal of 50 µg/l several times at different locations throughout the stream. 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 Worton Creek has been observed to reach levels of 160 µg/l. These levels have been associated with excessive eutrophication.

3.0 TARGETED WATER QUALITY GOAL

The objective of the nitrogen and phosphorus TMDLs established in this document is to assure that the dissolved oxygen levels support the Use I designation for Worton Creek and to control nuisance algal blooms. 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 Worton Creek 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 that it is acceptable to maintain chlorophyll *a* levels 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 TMDLs and load allocations were developed for Worton Creek. 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 Worton Creek 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 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, 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 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 Worton Creek Eutrophication Model (WCEM) extends from the confluence of Worton Creek with the Chesapeake Bay for about 3 miles up to the head of tide. Twenty-one WASP5.1 model segments represent this modeling domain. Fifteen segments are located in the Worton-Mill Creek length. The remaining six segments are located in the upper reaches of the Worton Creek and in a small tributary called Tim's Creek. Concentrations of relevant water quality parameters, observed in 1999 in the "free flowing" station of the river, serve as the model's upstream boundary. A diagram of the WASP5.1 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 11 subwatersheds and assuming that flows and loadings are direct inputs to the WCEM.

The nutrient TMDL analysis consists of two broad elements, an assessment of low flow loading conditions, and an assessment of annual average loading. 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 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 water quality data collected during 1999 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, which made use of the 1999 low flow months (August and September) data from the USGS flow gage station #01493000, Unicorn Branch located near Millington, MD; the station #01493112, Chesterville Branch near Crumpton, MD; and the station #01493500, Morgan Creek near Kennedyville, MD. The estimation of the annual average flow in the Worton Creek builds upon an analysis of historical flow data from the same USGS stations using the data from the entire 1999. This time period used to calculate the flows corresponds to the same time period used to calculate the boundary conditions for the model. The methods used to estimate stream flows are described further in the "Freshwater Flows" section of Appendix A.

The methods of estimating NPS loadings are described in Section 4.3. In brief, low flow NPS loads were derived from concentrations observed during low flow sampling in 1999 multiplied by the estimated critical low flows. Because the low flow loading estimations are based on observed data, they account for all human and natural sources. The annual average NPS loads were calculated using the same method but using all the data available for the year 1999. These methods are elaborated upon in Section 4.3 and in the "Nonpoint Source Loadings" section of 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 (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 Worton Creek.

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, 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 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 TMDLs. Both groups include low flow and average annual loading scenarios, for a total of four scenarios.

The baseline conditions are intended to provide a point of reference by which to compare the future scenarios that simulate 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. 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 "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. There are no permitted point sources in the watershed that discharge nutrients. As such, the baseline conditions often reflect a fixed potential future critical condition, which approximates a maximum future loading assuming no control actions.

<u>First Scenario</u>: The first scenario represents the baseline conditions of the stream at a simulated critical low flow in the creek. 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, and 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 August and September of 1999, which were also used in the calibration of the model. Water quality data collected in July 1999 was available (see figures 5-8 above) but was not used in the calibration of the model due to the unusual behavior of the creek as described above in Section 2.1. Also, flows and temperatures differ greatly between July and August-September 1999, which made the July data inappropriate to be included 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 all natural and human induced sources, including direct atmospheric deposition, loads from septic tanks, which are associated with creek baseflow during low flow conditions.

<u>Second Scenario</u>: The second scenario represents baseline conditions of the stream at average flow and an average annual loading rate. Summer water temperatures and solar radiation values are used as conservative assumptions. The total nonpoint source loads were calculated using an average of all the observed data MDE collected during 1999. These loads were computed as the product of the observed concentrations and the estimated average flow. The nutrient loads account for contributions from atmospheric deposition, septic tanks, cropland, pasture, feedlots, forest, and urban land. 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 as that used in the first scenario. This scenario simulates a reduction from the baseline conditions scenario controllable nonpoint source loads in the Worton Creek watershed. This reduction in nonpoint source loads includes a margin of safety computed as 5% of the NPS load allocation. 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 to 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. The scenario simulates a condition when the sunlight 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. This is considered to be part of the margin of safety.

This scenario simulates an estimated 35% reduction in controllable NPS loads of nitrogen and phosphorus in all subwatersheds of the Worton Creek 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 percentage reduction of organic matter settling to the bottom, computed as a function of the nutrient reduction. Details of nonpoint source load reductions are described further in the technical memorandum entitled "*Significant Nutrient Nonpoint Sources in the Worton Creek Watershed*". Further discussion of this scenario is provided in Appendix A.

4.4 Scenario Results

This section describes the results of the model scenarios outlined in the previous section. The WCEM 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.

Baseline Condition Loading Scenarios:

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

Results for the first scenario, representing the baseline condition for summer low flow, are summarized in Figure 9. Under these conditions, the peak chlorophyll *a* level is above the desired goal of 50 µg/l, reaching a peak value of about 81µg/l. DO concentrations are expected to fall below the minimum water quality criterion of 5.0 mg/l at the headwaters near the head of tide. The minimum DO concentrations in this zone are below 4.0 mg/l. Downstream concentrations, near the confluence with the Bay, are not expected to fall below the criterion.

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

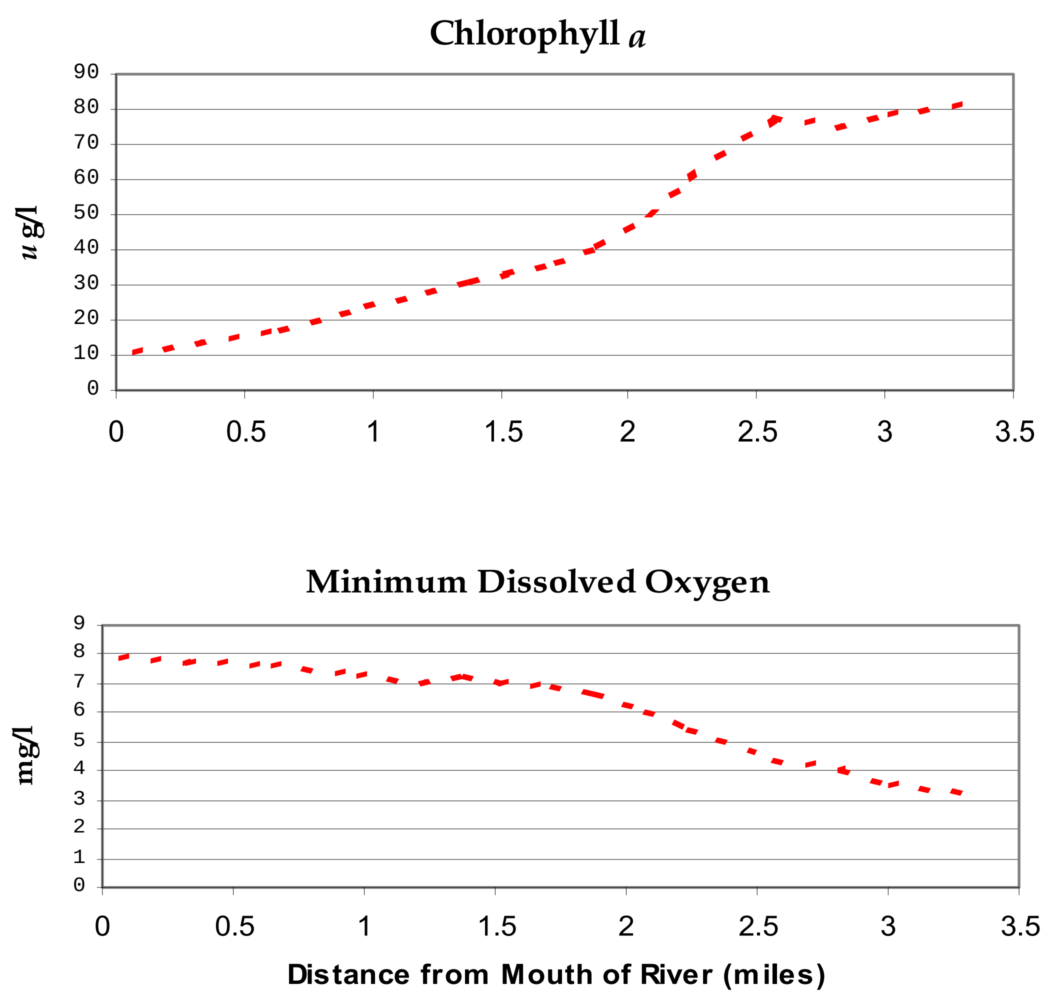

Figure 9: Model Results for the Low Flow Baseline Scenario for Chlorophyll *a* and Dissolved Oxygen (First Scenario)

Results for the second scenario, representing the baseline condition for the average stream flow and average loads, are summarized in Figure 10. Under these conditions, the chlorophyll *a* concentrations are also above the desired goal of 50 µg/l and DO concentrations remain above 5.0 mg/l throughout the length of the creek.

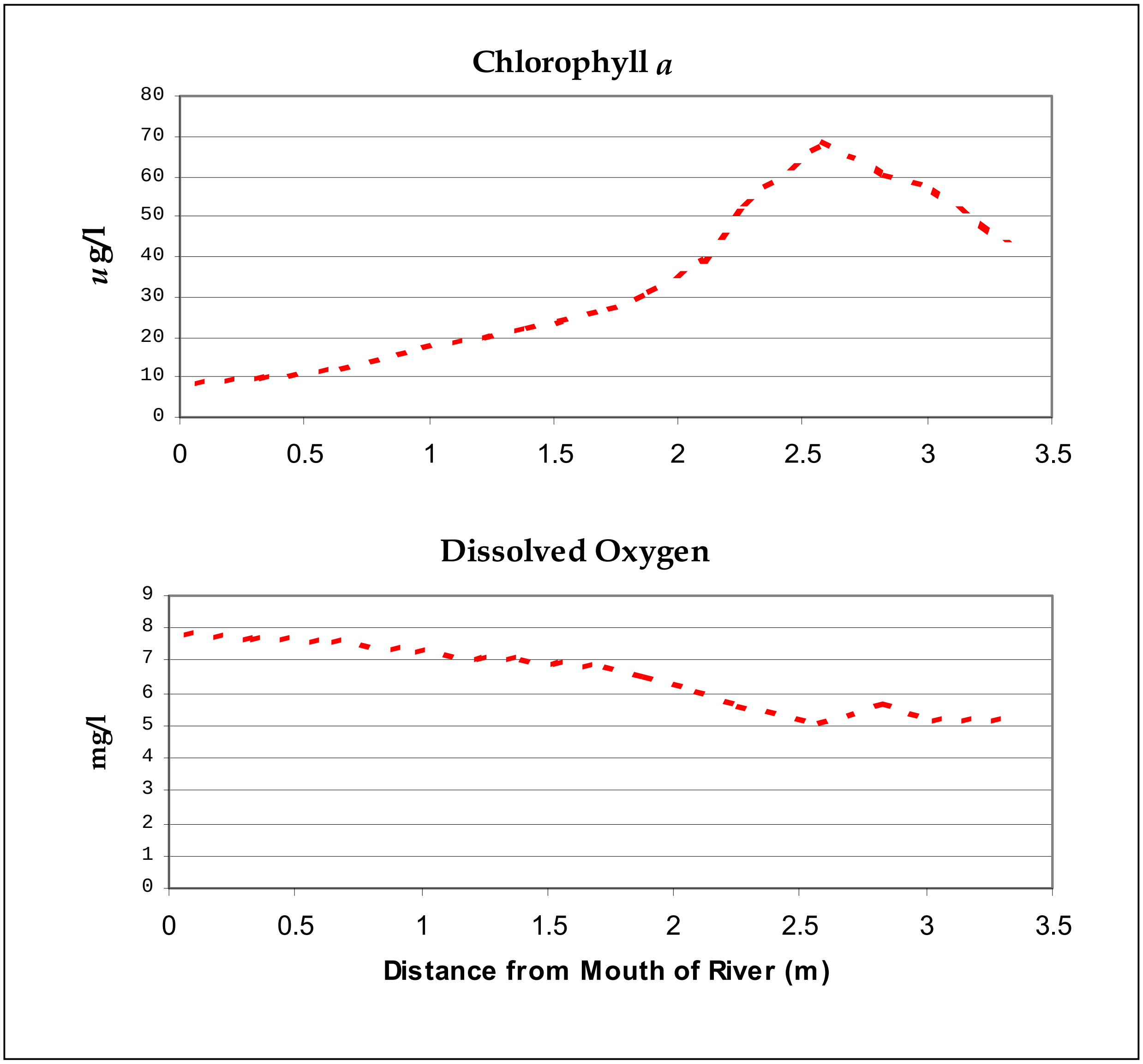

Figure 10: Model Results for the Average Flow Baseline Scenario for Chlorophyll *a* and Dissolved Oxygen (Second Scenario)

<u>Future Condition Scenarios:</u>

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

Results for the third scenario (dotted line), representing the maximum allowable loads for summer critical low flow, are summarized in comparison to the appropriate baseline scenario (solid line) in Figure 11. 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 Worton Creek. For dissolved oxygen (DO), the comparison shows that the DO along the length of the creek remains above the water quality criterion of 5.0 mg/l for the future condition scenario.

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

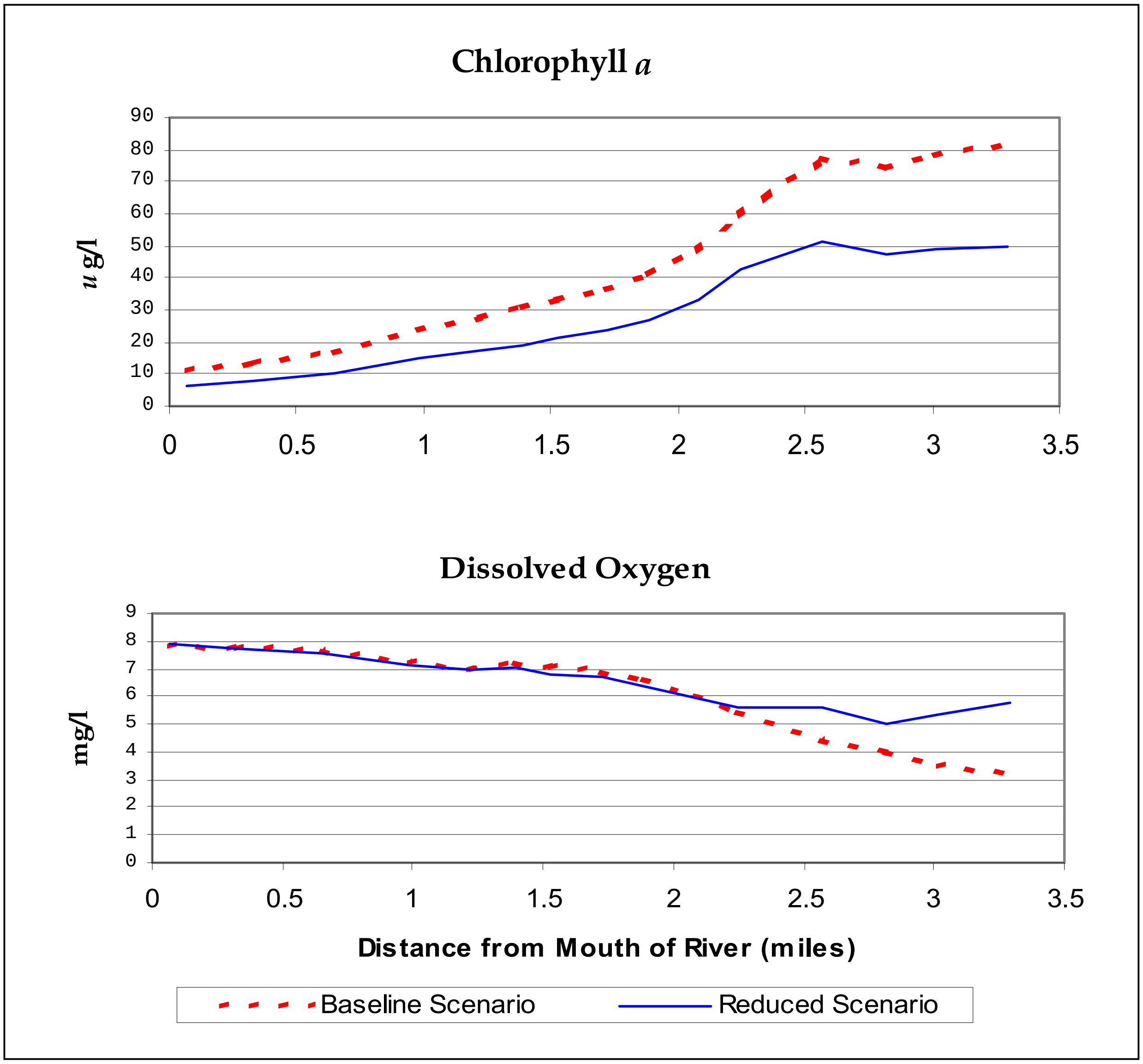

Figure 11: Model Results for the Low Flow Future Condition Scenario for Chlorophyll *a* and Dissolved Oxygen (Third Scenario)

Results for the fourth scenario (dotted line), representing the maximum allowable loads for average annual flow, are summarized in comparison to the appropriate baseline scenario (solid 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 Worton Creek. For dissolved oxygen (DO), the comparison shows that the DO along the length of the creek remains above the water quality criterion of 5.0 mg/l for both scenarios.

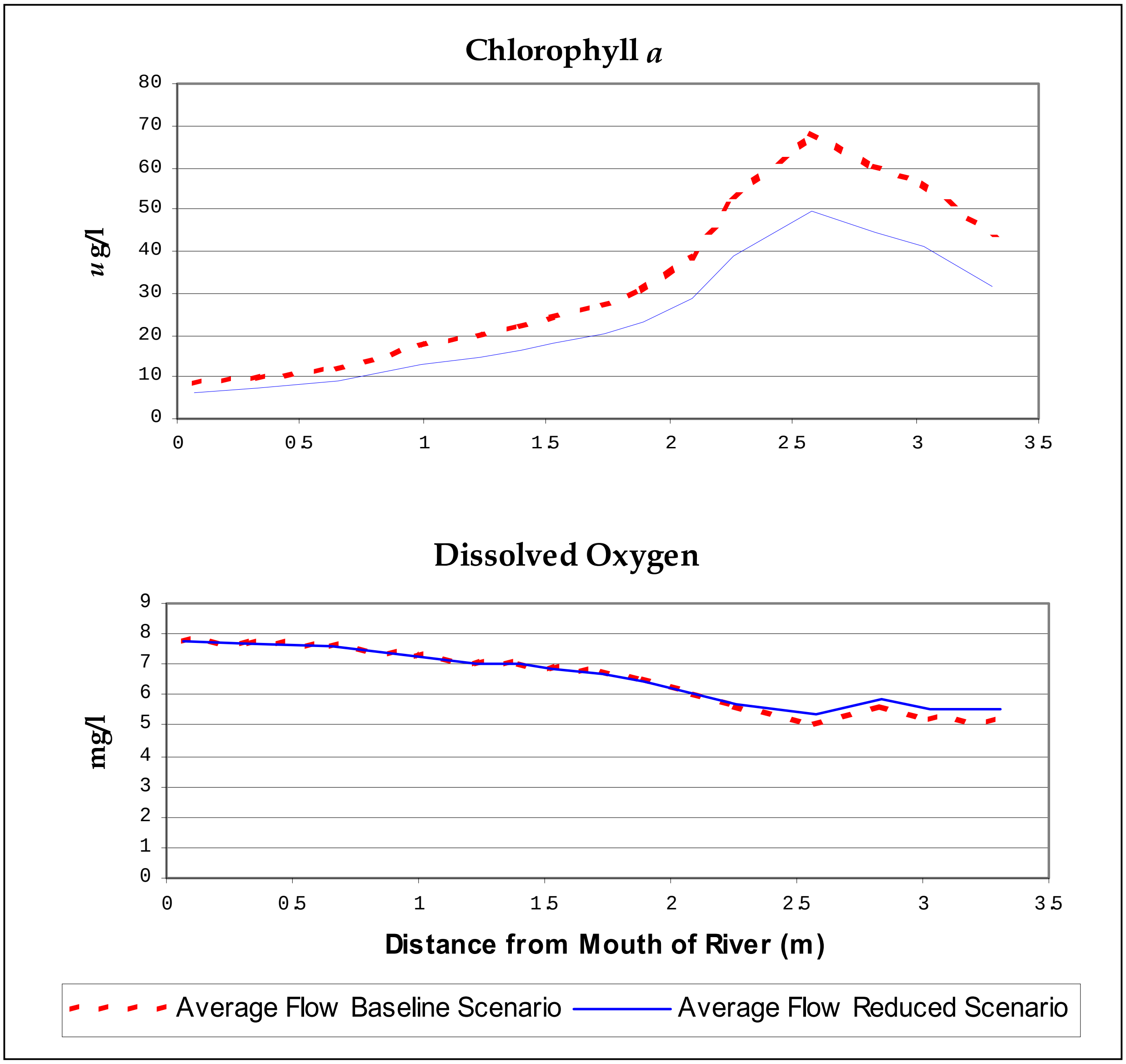

Figure 12: Model Results for the Average Annual Flow Future Condition Scenario for Chlorophyll *a* and Dissolved Oxygen (Fourth Scenario)

4.5 TMDL Loading Caps

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

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

Low Flow TMDLs:

NITROGEN TMDL	**351 *lbs/month***
PHOSPHORUS TMDL	**22 *lbs/month***

The average annual TMDLs for nitrogen and phosphorous are:

Average Annual TMDLs:

NITROGEN TMDL	**18,016 *lbs/year***
PHOSPHORUS TMDL	**1,382 *lbs/year***

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

4.6 Load Allocations Between Point Sources and Nonpoint Sources

The watershed that drains to Worton Creek has no permitted point source discharges of nutrients. Hence, for both the low flow and average annual TMDLs, the entire allocation, except for the margin of safety, is being made to nonpoint sources.

<u>Low Flow Allocations</u>:

The nonpoint source loads of nitrogen and phosphorus simulated in the third scenario represent a 40% reduction from the base-line scenario. Recall that the baseline scenario loads were based on nutrient concentrations observed in summer 1999. These nonpoint source loads, based on observed concentrations, account for both “natural” and human-induced components and cannot be separated into specific source categories.

There are no permitted point source discharges of nutrients in the watershed. Consequently, waste load allocations are set at zero. The nitrogen and phosphorus allocations for summer low flow conditions are presented in Table 2.

Table 2: Summer Low Flow Allocations

	Total Nitrogen *(lbs/month)*	**Total Phosphorus *(lbs/month)***
Nonpoint Source	351	22
Point Source	0	0

<u>Average Annual Allocations</u>:

The average annual nonpoint source nitrogen and phosphorus allocations are represented as the average of the data collected in 1999, with a 35% reduction in controllable nitrogen and phosphorus NPS loads in all subwatersheds of the Worton Creek watershed. The nonpoint source loads that were assumed in the model, account for both "natural" and human-induced components. As was discussed in the "Scenario Descriptions" section of this document, the loads were based on year 1999 MDE observed data.

There are no permitted point source discharges of nutrients in the watershed. Consequently, the waste load allocations are set to zero. The nitrogen and phosphorus allocations for the average annual TMDLs are shown in Table 3.

Table 3: Average Annual Flow Allocations

	Total Nitrogen *(lbs/yr)*	**Total Phosphorus *(lbs/yr)***
Nonpoint Source	18,016	1,382
Point Source	0	0

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 = WLA + LA + MOS). The second approach is to incorporate the MOS as conservative assumptions used in the TMDL analysis.

Maryland has incorporated margins of safety that combine these two approaches into these TMDLs. 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. Similarly, a 3% MOS was included in computing the average annual TMDLs. These explicit nitrogen and phosphorus margins of safety are summarized in Table 4.

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

	Nitrogen	**Phosphorus**
MOS Low Flow	18 lbs/month	1 lb/month
MOS Average Flow	540 lbs/yr	41 lbs/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 TMDLs, MDE has elected to use the more conservative peak concentrations of 50 µg/l.

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 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 TMDLs, applicable from May 1 – Oct. 31, for Worton Creek are as follow:

For Nitrogen (*lbs/month*):

TMDL	=	LA	+	WLA	+	MOS
351	=	333	+	0	+	18

For Phosphorus (*lbs/month*):

TMDL	=	LA	+	WLA	+	MOS
22	=	21	+	0	+	1

The average annual TMDLs for Worton Creek are as follow:

For Nitrogen (*lbs/yr*):

TMDL	=	LA	+	WLA	+	MOS
18,016	=	17,476	+	0	+	540

For Phosphorus (*lbs/yr*):

TMDL	=	LA	+	WLA	+	MOS
1,382	=	1,341	+	0	+	41

Where:

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

5.0 ASSURANCE OF IMPLEMENTATION

This section provides the basis for reasonable assurances that the nitrogen and phosphorus TMDLs will be achieved and maintained. For both TMDLs, Maryland has several well-established programs that will be drawn upon: the Water Quality Improvement Act of 1998 (WQIA), 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.

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 nutrient management plans be developed by December 2001 be implemented by December 2002 if chemical fertilizer is used, and by 2004-5 for those who use manure or organic sources. 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.

Maryland's CWAP has been developed in a coordinated manner with the State's 303(d) process. All Category I waters 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 higher 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 Eastern Shore Tributary Strategy Basin, which includes Worton Creek watershed. Maryland is in the forefront of implementing quantifiable nonpoint source controls through the Tributary Strategy efforts. This will help to assure that nutrient control activities are targeted to areas in which nutrient TMDLs have been established.

It is reasonable to expect that nonpoint 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 deposition of nutrients and organic matter to the streambed from higher flow events, septic systems failure and wildlife animal contribution. When these sources are controlled in combination, it is reasonable to achieve nonpoint 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 Worton Creek basin. In such case, load reductions from the Susquehanna, as part of the Chesapeake Bay Agreement, could have a significant positive effect on the Worton Creek water quality. Regardless of the uncertainty, nonpoint source reductions associated with the programs outlined above should be pursued aggressively to address the extensive enrichment of the Bay and Worton Creek and to off-set the increasing population pressure.

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 National Pollutant Discharge Elimination System (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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