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

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List of Abbreviations

7Q10	7-day consecutive lowest flow expected to occur every 10 years
BMP	Best Management Practice
BOD	Biochemical Oxygen Demand
CBOD	Carbonaceous Biochemical Oxygen Demand
CEAM	Center for Exposure Assessment Modeling
CBP	Chesapeake Bay Program
CWA	Clean Water Act
DMR	Discharge Monitoring Report
ECI	Eastern Correctional Institute
EPA	Environmental Protection Agency
EUTRO5	Eutrophication Module of WASP5
FA	Future Allocation
MREM	Manokin River Eutrophication Model
LA	Load Allocation
MDA	Maryland Department of Agriculture
MDE	Maryland Department of the Environment
MOS	Margin of Safety
NBOD	Nitrogenous Biochemical Oxygen Demand
NH3	Ammonia
NO23	Nitrate + Nitrite
NPDES	National Pollutant Discharge Elimination System
NPS	Non-point Source
ON	Organic Nitrogen
OP	Organic Phosphorus
PO4	Ortho-Phosphate
SOD	Sediment Oxygen Demand
TMDL	Total Maximum Daily Load
USGS	United States Geological Survey
WASP5	Water Quality Analysis Simulation Program 5
WLA	Waste Load Allocation
WQLS	Water Quality Limited Segment
WWTP	Waste Water Treatment Plant

PREFACE

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

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

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

EXECUTIVE SUMMARY

This document establishes Total Maximum Daily Loads (TMDLs) for nitrogen and biochemical oxygen demand (BOD) in the Manokin River. The Manokin River drains directly to the Chesapeake Bay, and is part of the Lower Eastern Shore Tributary Strategy Basin. The River is impaired by the nutrient nitrogen and BOD, which cause excessive algal blooms and exceedances of the dissolved oxygen standard.

The water quality goal of these TMDLs is to reduce high chlorophyll *a* concentrations (a surrogate for algal blooms), and maintain dissolved oxygen at levels whereby the designated uses for the Manokin River will be met. The TMDL was determined using the WASP5.1 water quality model. Total loading caps for nitrogen entering the Manokin River are established for both low-flow and average annual flow conditions. A total loading cap for BOD is established for low-flow conditions. As part of the TMDL process, 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 1,610 lb/month and the low-flow TMDL for BOD is 4,420 lb/month. These TMDLs apply during the period May 1 through October 31. The low-flow non-point source loads for the TMDLs are established as the estimated base-flow concentration times the base-flow. The low-flow point source loads make up the balance of the allocation.

The average annual TMDL for nitrogen is 353,680 lb/yr. Allowable loads have been allocated between point and non-point sources. The estimated average annual non-point source load for nitrogen is based on reduced year 2000 loadings. The average annual point source loads make up the balance of the allocation.

Four factors provide assurance that these TMDLs will be implemented. First, NPDES permits will play a major role in assuring implementation. Second, Maryland has several well-established programs that will be drawn upon, including Maryland's Tributary Strategies for Nutrient Reductions developed in accordance with the Chesapeake Bay Agreement. Third, Maryland's Water Quality Improvement Act of 1998 requires that nutrient management plans be implemented for all agricultural lands throughout Maryland. Finally, Maryland has adopted a watershed cycling strategy, which will assure that routine future monitoring and TMDL evaluations are conducted.

1.0 INTRODUCTION

Section 303(d)(1)(C) of the Federal Clean Water Act and the applicable federal regulations direct each State to develop a Total Maximum Daily Load (TMDL) for each impaired water quality limited segment (WQLS) on the Section 303(d) list, taking into account seasonal variations and a protective margin of safety (MOS) to account for uncertainty. A TMDL reflects the 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 includes a designated use for a particular body of water and the water quality criteria designed to protect that use. Designated uses include activities such as swimming, drinking water supply, and shellfish propagation and harvest. Water quality criteria consist of narrative statements and numeric values designed to protect the designated uses. Criteria may differ among waters with different designated uses.

The Manokin River was first identified on the 1996 303(d) list submitted to EPA by the Maryland Department of the Environment. The Manokin River was identified as being impaired by nutrients, due to signs of eutrophication, and low dissolved oxygen. Eutrophication, the over enrichment of aquatic systems by excessive inputs of nitrogen and phosphorus, was evidenced in the Manokin River by recurrent seasonal algal blooms. This document reveals that the impairment is principally due to nitrogen and biochemical oxygen demand (BOD) in the stream. For these reasons, this document establishes TMDLs for the nutrient nitrogen and for BOD in the Manokin River.

2.0 SETTING AND WATER QUALITY DESCRIPTION

2.1 General Setting and Source Assessment

The Manokin River is located in Somerset County, Maryland (Figure 1). It drains directly to the Chesapeake Bay roughly 4.5 miles due east of South Marsh Island. The River is approximately 15 miles in length, from its confluence with the Bay to the upper reaches of the headwaters. The Manokin River watershed has an area of approximately 52,351 acres or 81.8 square miles. The land uses in the watershed consist of: forest and other herbaceous land (35,890 acres, 64%), mixed agricultural land (14,290 acres, 26%), urban land (2,170 acres, 4%), and surface water (3,150 acres, 6%) (based on 1997 Maryland Office of Planning information 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.

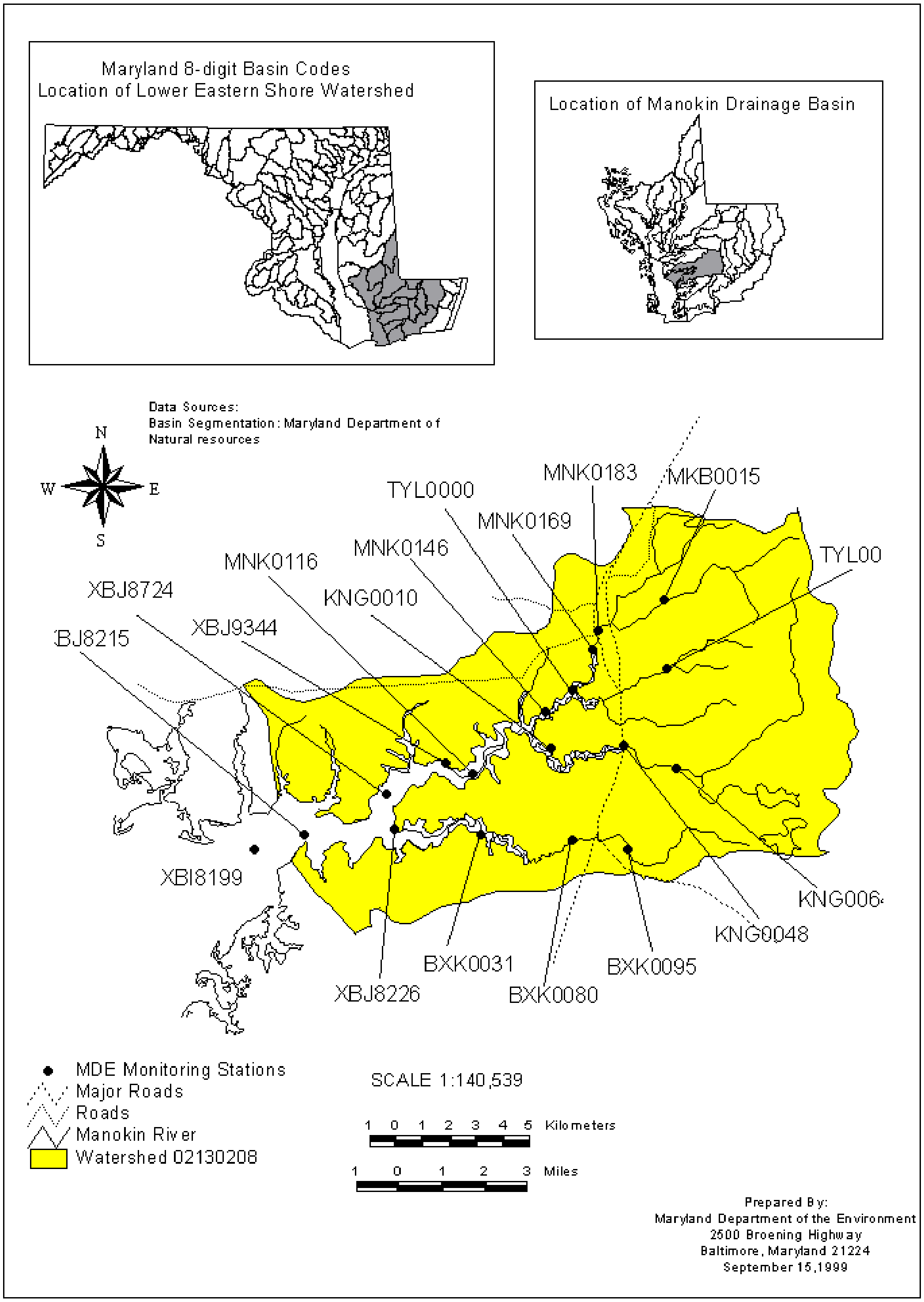

Figure 1: Location Map of the Manokin River Drainage Basin within Maryland

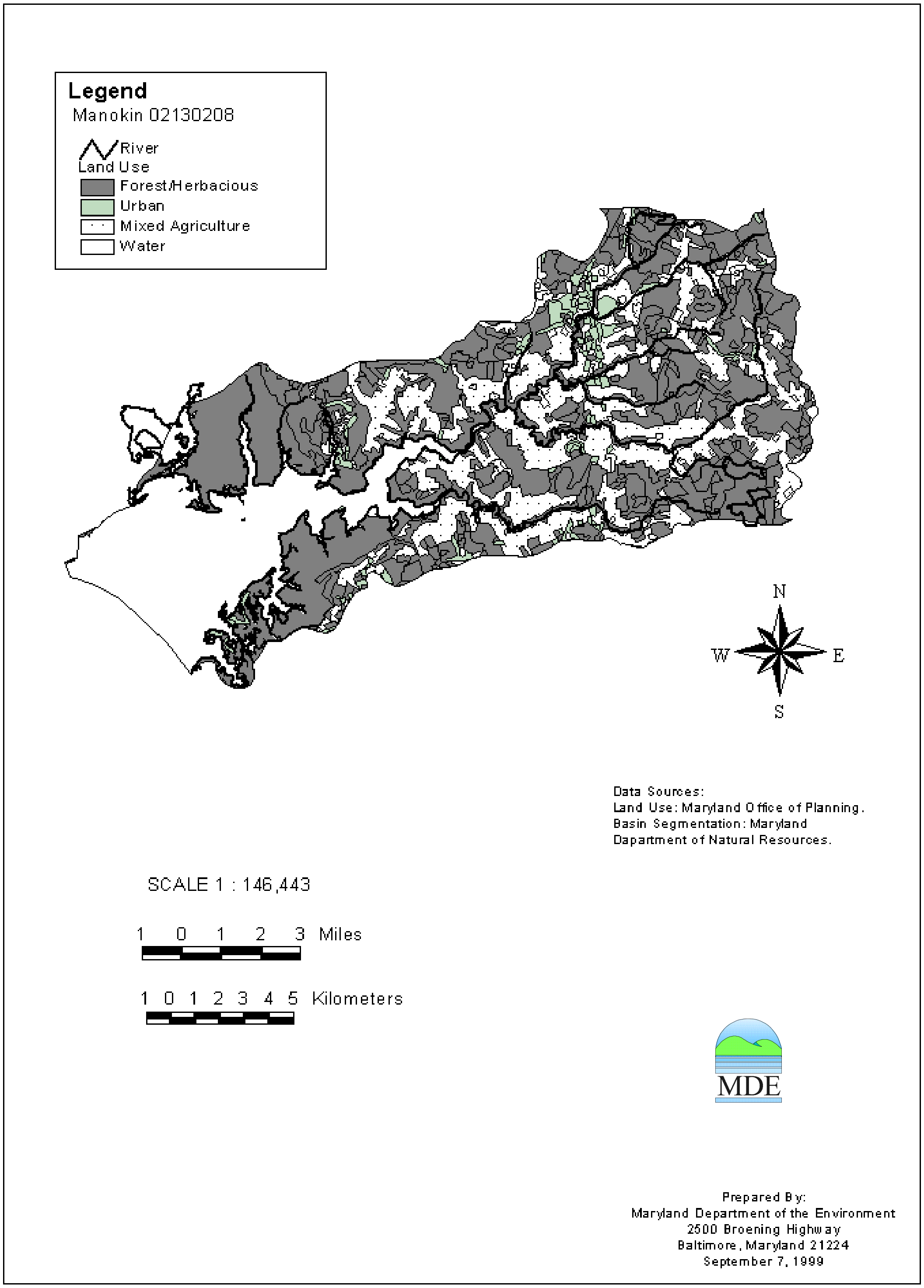

Figure 2: Predominant Land Use in the Manokin River Drainage Basin

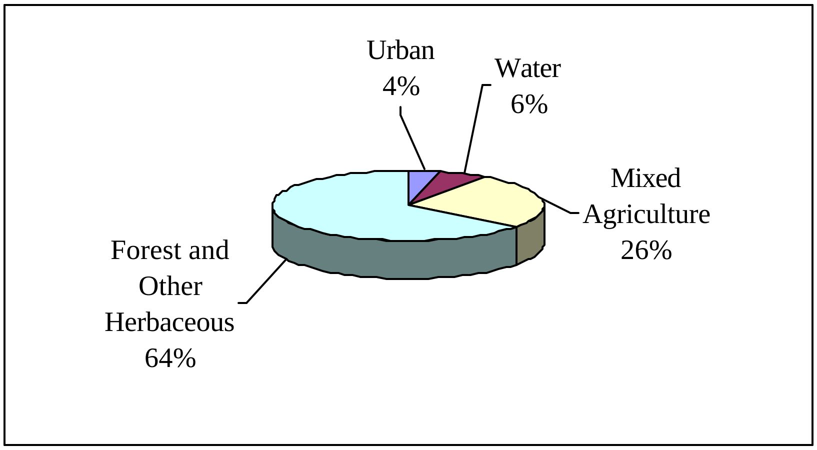

Figure 3: Estimated 1997 Land Use in the Manokin River Drainage Basin

Figure 4 shows the locations of the main tributaries to the Manokin River, the locations of the water quality sampling stations, and the locations of the three municipal wastewater treatment plants (WWTPs) within the basin. The headwaters of the Manokin River drain primarily forested and mixed agricultural land. In this area the practice of ditching to drain agricultural lands is very common. The headwater area contributes most of the fresh water flow to the River. The nearby Loretto Branch sub-watershed contributes high non-point source loads. The Town of Princess Anne, located approximately 11 miles upstream from the mouth on the mainstem, operates a WWTP that discharges to the River. The Kings Creek joins the Manokin River mainstem approximately 3 miles below the Town of Princess Anne. At this location the channel is very narrow, the river velocities are very high and the depth increases to as much as 15 feet. The Eastern Correctional Institute (ECI) WWTP discharges to the mainstem below the confluence with Kings Creek. The Back Creek joins the mainstem where it becomes broad and the depth decreases to about 6 feet. There is a small WWTP, Goose Creek Food Store, located near the headwaters of Back Creek. At the confluence with St. Peters Creek, the Manokin River doubles in breadth creating a bay-like river mouth, surrounded by marshland.

In the Manokin River watershed, the estimated average annual nitrogen load is 403,790 lb/yr, and the average annual phosphorus load is 27,052 lb/yr, for the year 2000. The relative distribution of these loads is shown in Figure 5. The non-point source loads were determined by calculating and summing all individual land use areas and multiplying by a corresponding land use loading coefficient. The land use information was based on 1997 Maryland Office of Planning data, with crop acres refined using 1997 Farm Service Agency data. The loading coefficients were based on the results of the Chesapeake Bay Model (U.S. EPA, 1996), which was a continuous simulation model. The Chesapeake Bay Program nutrient loading rates account for atmospheric deposition, loads from septic tanks, and loads coming from urban development, agriculture, and forest land. The average annual total nitrogen load coming from non-point sources is 384,520 lb/yr, and the average annual non-point source total phosphorus load is 26,620 lb/yr.

The point source flows and concentrations came from the discharge monitoring reports stored in MDE's point source database. The total nitrogen load from point sources in 1998 is 19,270 lb/yr, and the total phosphorus point source load is 432 lb/yr. The year 1998 is used as a base-line because this is the year for which water quality data was collected to support the calibration of the model.

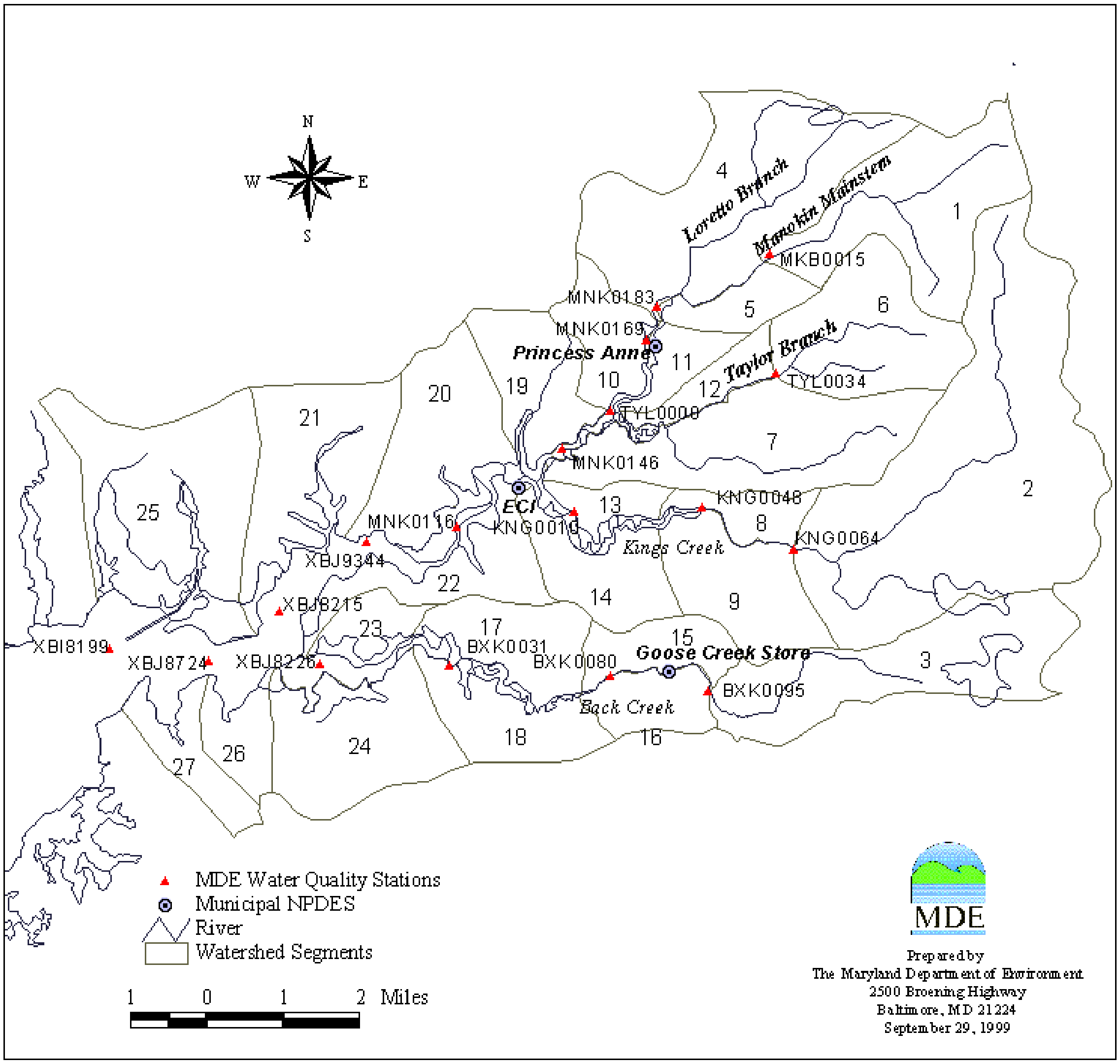

Figure 4: Manokin River Basin Map Showing Locations of Important Features

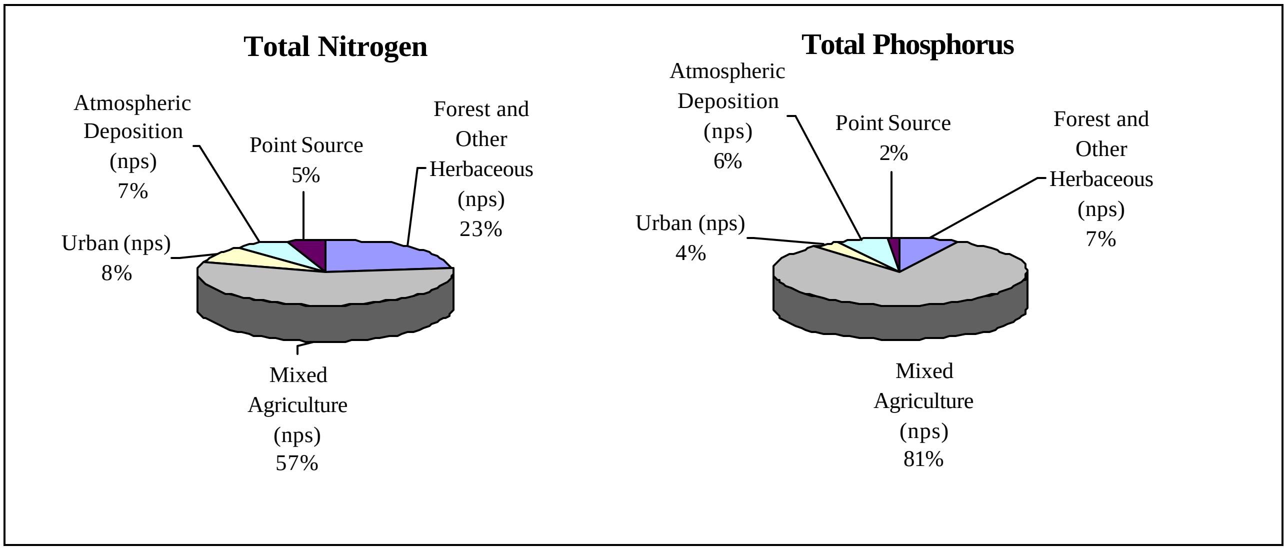

Figure 5: Average Annual Nitrogen and Phosphorus Point and Non-point Source Loadings

2.2 Water Quality Characterization

The Manokin River above the confluence with Kings Creek is Designated Use I, which must support water contact recreation, fishing, protection of aquatic life and wildlife, and agricultural and industrial water supply. The water quality criteria applicable to Use I waters provide that the dissolved oxygen concentration may not be less than 5 mg/l at any time. The portion of the River below the confluence with Kings Creek is Designated Use II. Designated Use II waters are protected for all uses identified for Use I waters and are also protected for shellfish harvesting (oysters, softshell clams, hardshell clams, and brackish water clams), where there are actual or potential areas for shellfish propagation, storage, and gathering for market purposes. A dissolved oxygen criterion of 5 mg/l applies in Use II waters, as well. The complete details of all designated water uses can be found in the *Code of Maryland Regulations, Section 26.08.02*.

The water quality of five physical parameters, dissolved oxygen, BOD, chlorophyll *a*, dissolved inorganic nitrogen, and dissolved inorganic phosphorus were examined to determine the extent of the impairment in the Manokin River. Six water quality surveys were conducted by MDE in the Manokin River watershed in February, March (2), July, August, and September of 1998. Figure 4 identifies the locations of the stations sampled during each survey, and Table 1 presents the distance of each station from the mouth. The months of July, August, and September represent critical conditions in the Manokin River. This is because in these months there is less water flowing in the channel, higher concentrations of nutrients, and the water temperatures are usually warmer creating good conditions for algal growth. The data collected in February and March does not show any chlorophyll *a* or dissolved oxygen problems. The following graphs present data from the critical low-flow periods. The data are presented from left to right in downstream to upstream order, and the stations for the main branch and the tributaries are on different graphs.

Table 1: Location of Water Quality Stations

Water Quality Station	River Miles from the Mouth
Manokin Mainstem	
XBI8199	0.0
XBJ8215	1.7
XBJ8224	2.8
XBJ8226	3.4
XBJ9344	4.3
MNK0116	6.1
Eastern Correctional Institute WWTP	7.8
MNK0146	8.8
Princess Anne WWTP	11.1
MNK0169	11.3
MNK0183	11.7
MKB0015	14.0
Back Creek	
BXK0031	6.0
BXK0080	8.1
Westover Goose Creek Food Store WWTP	9.3
BXK0095	10.9
Kings Creek	
KNG0010	9.4
KNG0048	13.2
KNG0064	15.3

Dissolved oxygen concentrations along the longitudinal profile are depicted in Figure 6. As can be seen on the graph, both the Manokin mainstem and the tributaries have dissolved oxygen levels below the standard of 5.0 mg/l. In the mainstem, dissolved oxygen concentrations fall below the water quality standard towards the middle portion of the River. At stations MNK0116 and MNK0146 the dissolved oxygen concentration falls to 4.2 mg/l.

Figure 7 depicts the BOD concentrations for the mainstem and tributaries. The general trend in BOD concentrations is progressively higher values towards the headwaters. In Back Creek and Kings Creek there are also several high values of BOD.

Figure 8 presents a longitudinal profile of chlorophyll *a* data from the 1998 field surveys. As the data indicates, chlorophyll *a* concentrations in the lower tidal portion of the River are all below 50 µg/l. However, at the upper most stations in the mainstem, the levels are much greater ranging from 75 µg/l, to a maximum concentration of over 350 µg/l.

The dissolved inorganic nitrogen levels along the longitudinal profile are depicted in Figure 9. In the Manokin River, dissolved inorganic nitrogen levels are generally less than 0.05 mg/l. However, there are several points above 0.5 mg/l towards the headwaters and in Kings Creek.

Figure 10 presents a longitudinal profile of dissolved inorganic phosphorus. The values in the mainstem range from 0.01 mg/l at the mouth to 0.06 mg/l near the town of Princess Anne (station MNK0183), and back to 0.01 mg/l near the headwaters. The concentrations of the tributaries range from 0.01 mg/l to 0.12 mg/l.

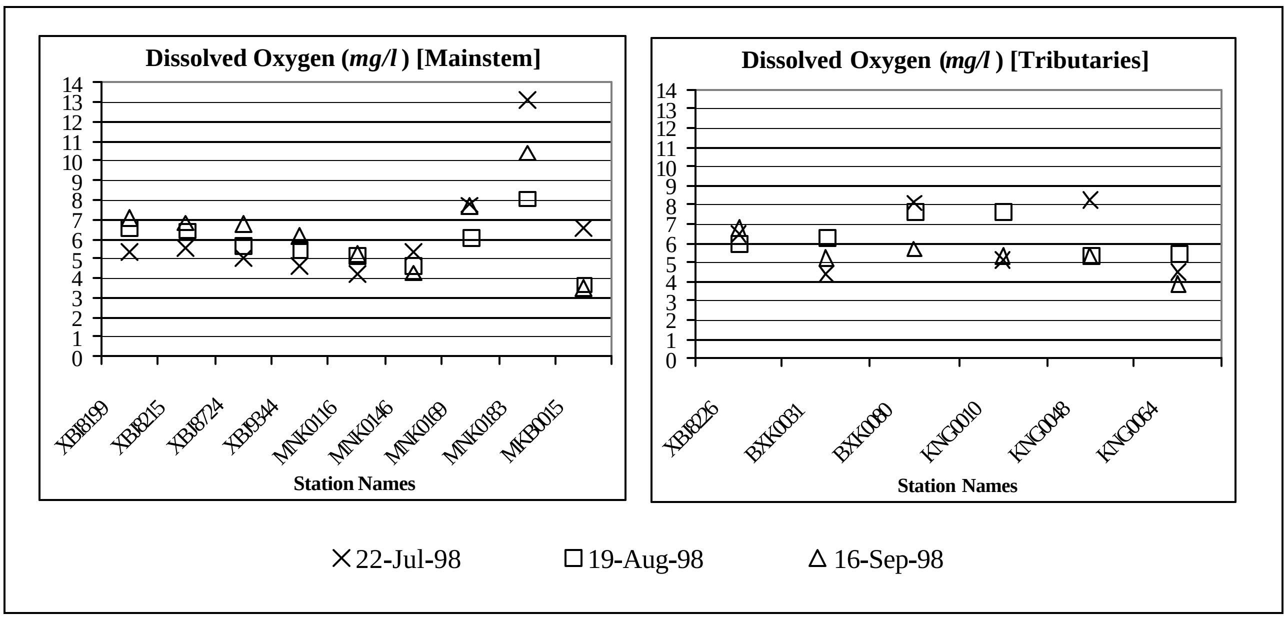

Figure 6: Longitudinal Profile of Dissolved Oxygen Data

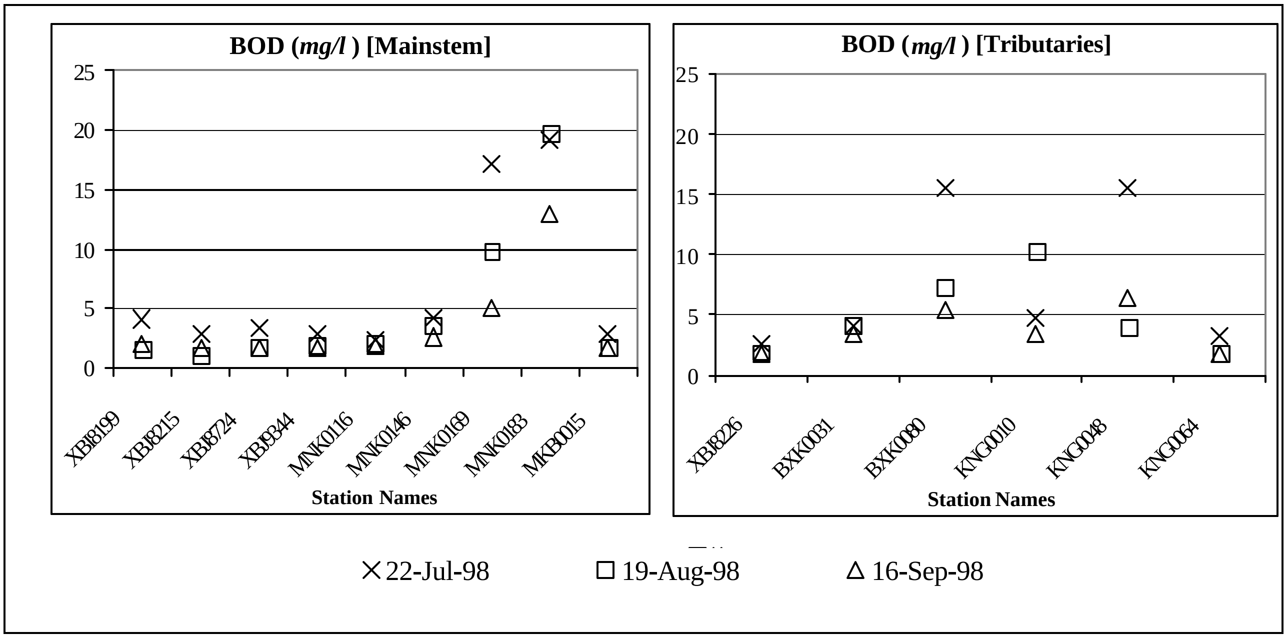

Figure 7: Longitudinal Profile of BOD Data

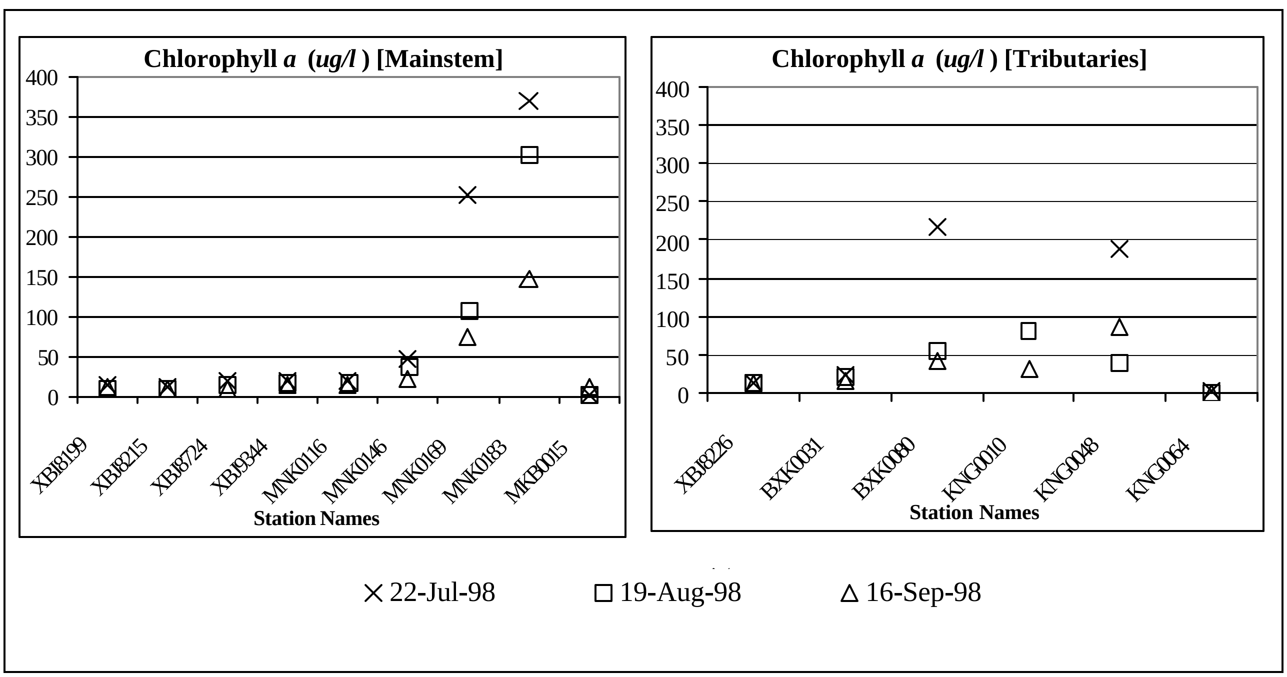

Figure 8: Longitudinal Profile of Chlorophyll *a* Data

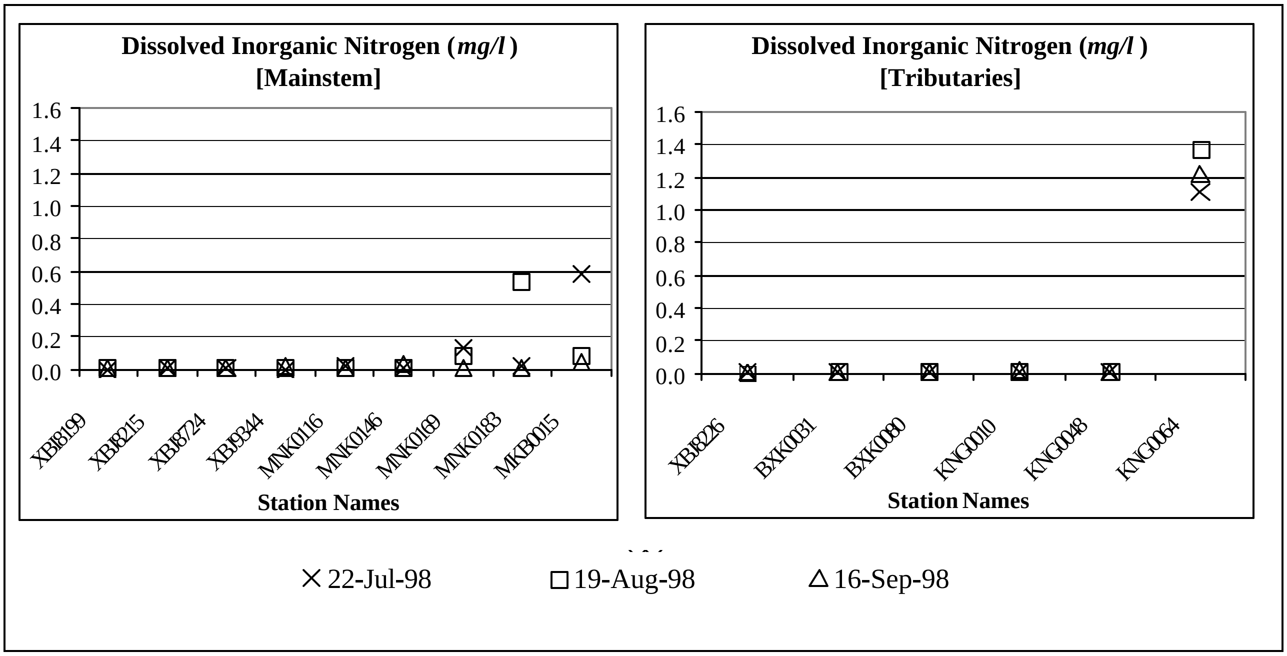

Figure 9: Longitudinal Profile of Inorganic Nitrogen Data

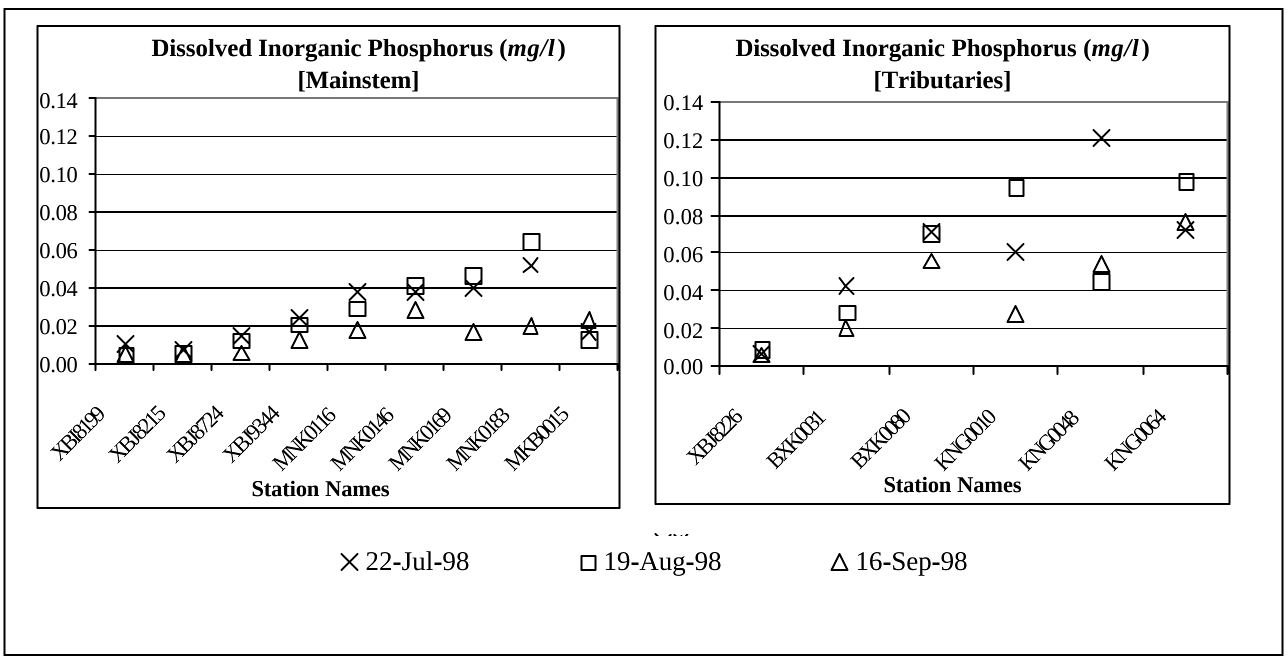

Figure 10: Longitudinal Profile of Inorganic Phosphorus Data

2.3 Water Quality Impairment

The Manokin River system is impaired by an overenrichment of nitrogen and excessive BOD loads. Nitrogen and phosphorus loadings from both point and non-point sources have resulted in higher than acceptable chlorophyll *a* concentrations and dissolved oxygen concentrations below the standard of 5.0 mg/l. High BOD concentrations have contributed to the low dissolved oxygen levels observed during the summer of 1998. Mean summertime concentrations of chlorophyll *a* in the upper reaches of the Manokin River range between 100-350 µg/l. Mean summertime concentrations of dissolved oxygen in the Manokin River range between 4.5 - 15 mg/l, with concentrations as low as 4.2 mg/l.

In the 1996 303(d) list, the cause of the impairment was presumed to be nutrients. However, as will be discussed in greater detail below, subsequent modeling has determined that nitrogen and BOD are the dominant causes of the higher than acceptable chlorophyll *a* concentrations and the low dissolved oxygen impairment.

3.0 TARGETED WATER QUALITY GOAL

The objective of the TMDLs for nitrogen and BOD for the Manokin River is to reduce inputs to a level that will ensure the maintenance of the dissolved oxygen standard and reduce the frequency and magnitude of algal blooms. Specifically, the TMDLs for nitrogen and BOD for the Manokin River are intended to:

1. Assure that a minimum dissolved oxygen level of 5.0 mg/l is maintained throughout the Manokin River system, and,

2. Reduce peak chlorophyll *a* levels (a surrogate for algal blooms) to below 50 µg/l.[1]

The dissolved oxygen level is based on specific numeric criteria for Use I & II waters set forth in the Code of Maryland Regulations 26.08.02. The chlorophyll *a* water quality goal is intended to assure the narrative water quality criteria for the designated uses in the Manokin River is attained (COMAR 26.08.02.03). And, the quantified threshold is based on 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).

1 MDE establishes permit limits based on maintaining chlorophyll *a* concentrations below a maximum level of 100µg/l, with an ideal goal of less than 50µg/l.

4.0 TOTAL MAXIMUM DAILY LOADS AND ALLOCATION

4.1 Overview

This section describes how the nitrogen and BOD TMDLs and total loading allocations for point sources and non-point sources were developed for the Manokin River. The first section describes the modeling framework for simulating nutrient loads, hydrology, and water quality responses. The second and third sections summarize the scenarios that were explored using the model. The assessment investigates water quality responses assuming different stream flow and nutrient loading conditions. The fourth and fifth sections present the modeling results in terms of TMDLs, and allocate the TMDLs between point sources and non-point sources. The sixth section explains the rationale for the margin of safety and a remaining future allocation. 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 Manokin River TMDLs was Water Quality Analysis Simulation Program version 5.1 (WASP5.1). This water quality simulation program provides a generalized framework for modeling contaminant fate and transport in surface waters and is based on the finite-segment approach (Di Toro *et al.*, 1983). WASP5.1 is supported and distributed by U.S. EPA's Center for Exposure Assessment Modeling (CEAM) in Athens, GA (Ambrose *et al.*, 1988). EUTRO5.1 is the component of WASP5.1 that simulates eutrophication, incorporating eight water quality constituents in the water column and the sediment bed.

The spatial domain of the Manokin River Eutrophication Model (MREM) extends from just above the confluence of the Manokin River and Broad Creek for about 13.4 miles along the mainstem of the Manokin River. The spatial domain also includes Back Creek and Kings Creek, and captures the flows and loads from Taylor Branch and Loretto Branch as well as other non-point source flows and loads.

There are three point source nutrient loads that discharge directly or indirectly into the Manokin River. The Princess Anne WWTP (NPDES permit number MD0020656) discharges directly into the mainstem near the Town of Princess Anne. The Eastern Correctional Institute WWTP (NPDES permit number MD0066613) also discharges directly into the mainstem approximately 3.4 miles downstream from the Princess Anne WWTP outfall. The Westover Goose Creek Food Store, formerly known as The English's Family Restaurant, (NPDES permit number MD0053104) is a small wastewater treatment plant (WWTP) which discharges into the upper reaches of Back Creek near Route 13.

Freshwater flows and non-point source loadings are taken into consideration by dividing the drainage basin into 27 sub-watersheds and assuming that these flows and loadings are direct inputs to the MREM.

The MREM inputs, including non-point source loads, were derived from existing data and results from previous modeling of water bodies within the Chesapeake Bay system. These are documented in Appendix A. The MREM was calibrated using the water quality monitoring data collected during March and July of 1998, and validated with data from February and August of 1998. The results of this calibration and validation are presented in Appendix A.

4.3 Scenario Descriptions

The model was applied to several different nutrient loading scenarios under various stream flow conditions to project the water quality response of the system. By modeling various stream flows, the scenarios simulate seasonality, which is a necessary element of the TMDL development process. Sensitivity analyses were performed to determine which nutrient (nitrogen, phosphorus, or both) was causing the impairment. The total point and non-point source nutrient loads were established to achieve the water quality goal of maintaining a dissolved oxygen concentration of 5.0 mg/l and reducing chlorophyll *a* concentrations to 50 µg/l.

The nutrient loading scenarios are grouped according to *critical conditions* and *future conditions*. The critical conditions represent the nutrient loads and water quality status in low-flow and average-flow conditions. The future conditions represent the system after there has been a reduction in nutrient loads to meet water quality standards. The future conditions also project the maximum allowable nutrient loads the system can incorporate without incurring an impairment. The future conditions include a margin of safety intended to account for estimation uncertainties in a manner that is environmentally conservative.

For both point and non-point sources, the concentrations of the nutrients nitrogen and phosphorus are modeled in their speciated forms. Nitrogen is simulated as ammonia (NH_3), nitrate and nitrite (NO23), and organic nitrogen (ON). Phosphorus is simulated as ortho-phosphate (PO_4) and organic phosphorus (OP). Ammonia, nitrate and nitrite, and ortho-phosphate represent the dissolved forms of nitrogen and phosphorus. The dissolved forms of nutrients are more readily available for biological processes such as algae growth, that can 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 protective of the water quality criteria in the River.

The first scenario represents the critical conditions of the stream at low-flow (0.16 cfs at the USGS gage), and warm water temperatures (above 70 ^{0}F). There is one United States Geological Survey (USGS) flow gage in the Manokin River watershed (01486000). The flow used in this scenario is the lowest 7-day average flow. The USGS flow was apportioned to the watersheds in Manokin River based on relative drainage area size. During low-flow, there is no freshwater flow from most of the sub-watersheds in the Manokin. Based on observations in the field, the following assumptions were made about flow; there was 100% of the relative USGS flow coming from the mainstem, Kings Creek, and Loretto Branch; there was 50% of the relative USGS flow coming from Back Creek and Taylor Branch; and there was no flow from other sub-watersheds. The total non-point source loads were computed using the July, August, and September 1998 base-flow field data, collected by MDE and DNR. The non-point source loads reflect atmospheric deposition, loads from septic tanks, and other non-point source loads coming off the land. The point source loads represent the maximum flows and estimated future maximum loads from all the WWTPs.

The second scenario represents the critical conditions of the stream at average-flow (4.6 cfs at the USGS gage). During average-flow it was assumed that all sub-watersheds were contributing flow and loads to the River. The total non-point source loads were calculated using the CBP loading rates, which represent edge-of-stream loads, for the year 2000 assuming BMP implementation at levels consistent with current progress, and include loads from atmospheric deposition, septic tanks, cropland, pasture, feedlots, forest, and urban land. Land use was calculated using 1997 MOP and adjusted with 1997 Farm Service Agency (FSA) crop acre data. The point source loads represent the maximum flows and estimated future maximum loads from all the WWTPs.

Sensitivity analyses were performed using the model to see if reductions in phosphorus had any effects on the chlorophyll *a* levels in the stream. The details of these sensitivity analyses can be found in Appendix A. The result was that the model showed that during low-flow conditions, the system was nitrogen limited and reductions in phosphorus had no effect on chlorophyll *a* concentrations. During average flow, the model showed very little change in chlorophyll *a* concentrations due to increases in phosphorus concentrations.

The third scenario represents the future conditions, for the case of low stream flow. The total non-point source flows were the same as for scenario 1. Non-point source loads were reduced from scenario 1. The controllable portion of the total nutrient load was estimated then reduced until there were no water quality violations in the river. The total controllable nitrogen load was reduced by 24%. The BOD load was reduced by 26%. The phosphorus load was not reduced. A 5% margin of safety (MOS) was also included in the non-point source load. Total point source loads for the summer low-flow future conditions made up the balance of the total allowable load. Details of this modeling activity are described further in the technical memorandum entitled "*Significant Nitrogen and Biochemical Oxygen Demand Point Sources and Non-point Sources in the Manokin River Watershed*" and Appendix A.

The fourth scenario represents future conditions, for the case of average stream flow. The flow at the USGS gage in the Manokin was the same as for scenario 2. Non-point source loads were reduced from scenario 2. The controllable portion of the total nutrient load was estimated then reduced until there were no water quality violations in the river. The total controllable nitrogen load was reduced by 33%. The phosphorus load was not reduced. For the case of average stream flow, it was not necessary to reduce the BOD load. A 3% margin of safety (MOS) was also included in the non-point source load. Total point source loads for the average annual future conditions made up the balance of the total allowable load. Details of this modeling activity are described further in the technical memorandum entitled *"Significant Nitrogen and Biochemical Oxygen Demand Point Sources and Non-point Sources in the Manokin River Watershed"* and Appendix A. The loads used in all the model scenario runs are shown in Table 2.

Table 2: Point and Non-point Source Loads Used in the Model Scenario Runs

Scenario	**Point Source**				**Nonpoint Source**				**Margin of Saftey**	
#	Flow	Nit.	Phos.	BOD_5	Flow	Nit.	Phos.	BOD_5	Nit.	BOD_5
	mgd	*lb/day*	*lb/day*	*lb/day*	*cfs*	*lb/day*	*lb/day*	*lb/day*	*lb/day*	*lb/day*
Scenario 1	1.7	42	4.5	113	0.98	11	1.2	44	0	0
Scenario 2	1.7	106	4.5	244	77	1053	73	1705	0	0
Scenario 3	1.7	46	4.5	113	0.98	8.6	1.2	33	0.43	1.6
Scenario 4	1.7	117	4.5	244	77	827	73	1705	25	0

4.4 Scenario Results

The MREM calculates the daily average dissolved oxygen concentrations in the stream. This is not necessarily protective of water quality when one considers the effects of diurnal dissolved oxygen variation due to photosynthesis and respiration of algae (See Appendix A for more details). The model can also output the minimum dissolved oxygen concentration, which is what will be used for all the model results in this section.

Critical Condition Scenarios:

1. *Low-flow:* Assumes low stream flow conditions. Assumes the 1998 low-flow non-point source loads, and maximum design flows and loads at all the WWTPs.

2. *Average Annual Flow:* Assumes average stream flow conditions. Assumes the 2000 average annual non-point source loads, and maximum design flows and loads at all the WWTPs.

The first scenario represents the critical condition for summer low-flow when water quality is impaired by low dissolved oxygen concentrations. The second scenario represents the critical conditions during average-flow. In both scenarios, the peak chlorophyll *a* levels are above the desired goal of 50 µg/l. The chlorophyll *a* results for scenarios one and two for the main branch can be seen in Figure 11. Model results for Back Creek and Kings Creek can be seen in Appendix A. Figure 11 also shows the dissolved oxygen and BOD concentrations for these scenarios. It can be seen that the dissolved oxygen level falls below the standard of 5 mg/l in scenario 1.

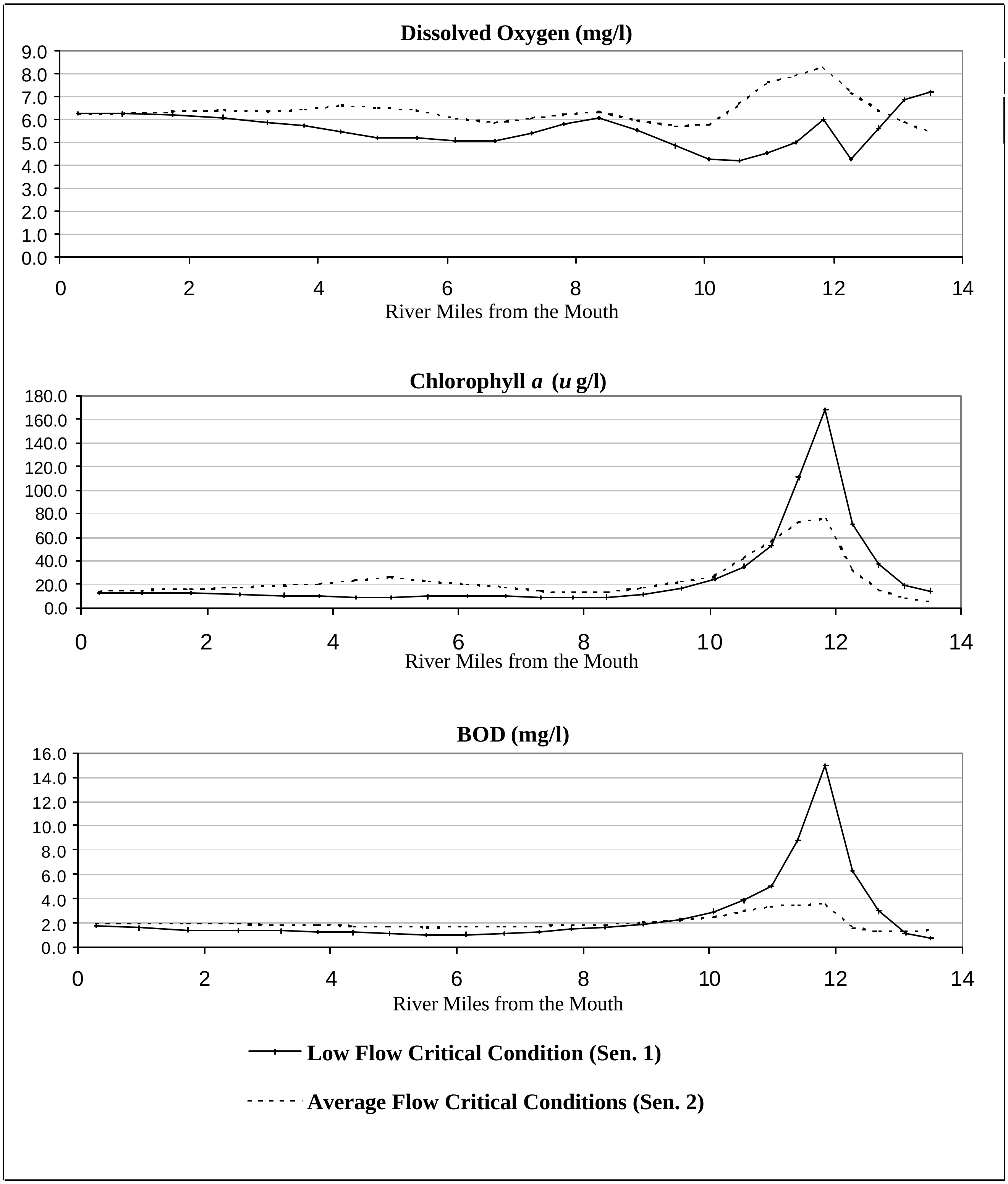

Figure 11: Model Results for the Critical Condition Scenarios for Chlorophyll *a*, Dissolved Oxygen, and BOD

Future Condition Scenarios:

3. *Low-flow:* Assumes low stream flow conditions. Assumes a total controllable nitrogen load reduction of 24%, no phosphorus load reduction , and a total BOD load reduction of 26% based on the 1998 base-flow non-point source loads, plus a 5% margin of safety. Assumes point source loads for the summer low-flow critical conditions make up the balance of the total allowable load.

4. *Average Annual Flow:* Assumes average stream flow conditions. Assumes a total controllable nitrogen load reduction of 33% and no phosphorus load reduction based on the 2000 average annual non-point source loads, plus a 3% margin of safety. Assumes point source loads for the average annual conditions make up the balance of the total allowable load.

The results of the third scenario indicate that, under summer low-flow conditions, the water quality target for dissolved oxygen and chlorophyll *a* is satisfied at all locations along the mainstem of the Manokin River. The fourth scenario shows that water quality standards for both chlorophyll *a* and dissolved oxygen are achieved along the entire length of the River during average-flow conditions. The results from scenarios 3 and 4 also showed that water quality is protected for the full length of the Manokin River and the two tributaries that were modeled. The results from these two scenarios can be seen in Figure 12, and complete results can be seen in Appendix A. These two scenarios provide the justification for the TMDL presented below.

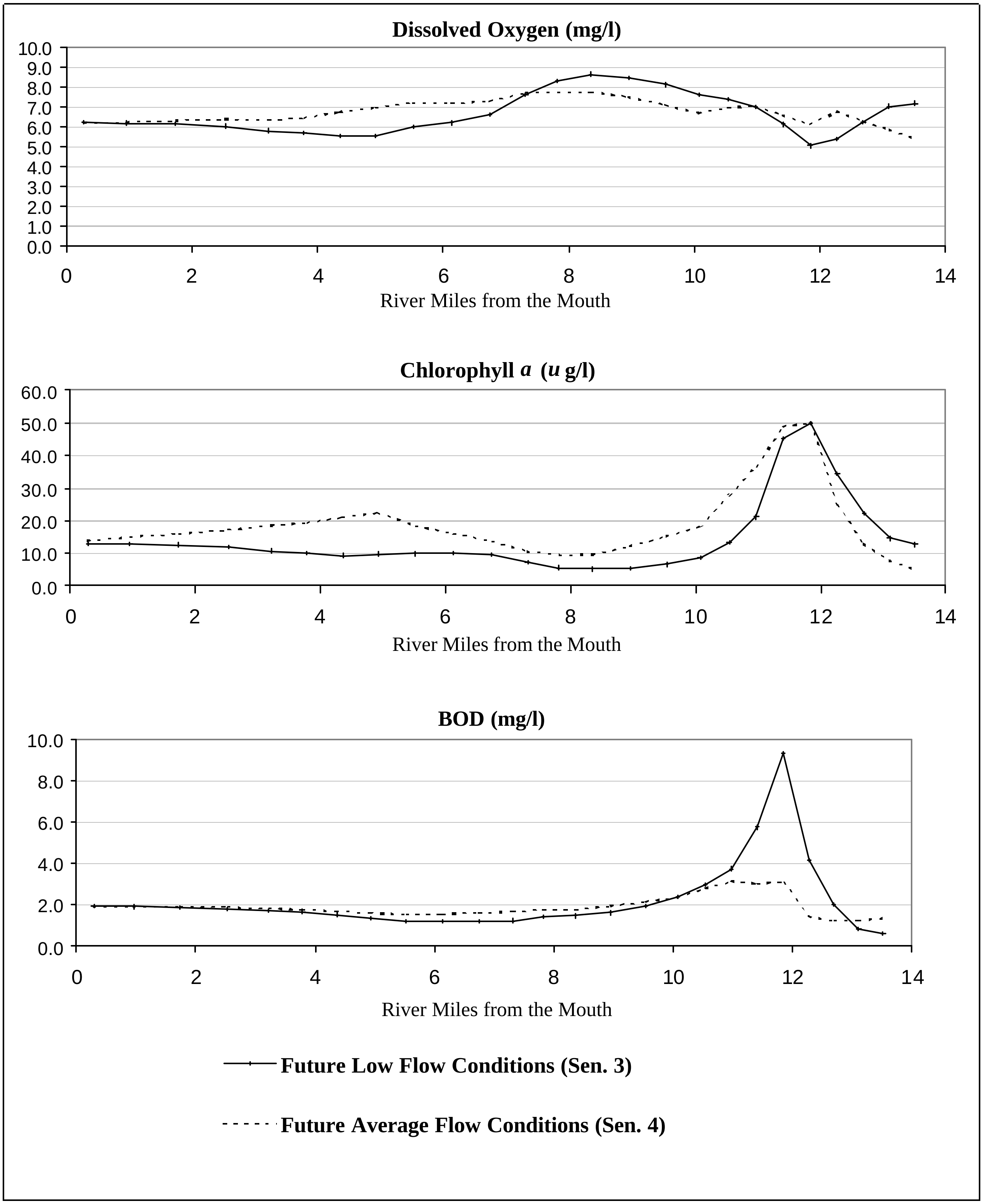

Figure 12: Model Results for Future Condition Scenarios for Chlorophyll *a*, Dissolved Oxygen, and BOD

4.5 TMDL Loading Caps

The critical period for excessive algal growth in Manokin River is during summer months for low-flow and average-flow conditions. During low-flow conditions the stream is poorly flushed, resulting in slow moving, warm water, which is susceptible to excessive algal growth, and low dissolved oxygen. During average-flow conditions, the increased non-point source nutrient loads can cause excessive algal growth. The model results for the third scenario indicate that, under critical low-flow conditions, the desired water quality goals are achieved. The low-flow TMDLs are stated in monthly terms because low-flow conditions occur for shorter periods of time.
For the summer months, May 1 through October 31, the following TMDLs apply:

NITROGEN TMDL **1,610 *lb/month***

BOD TMDL **4,420 *lb/month***

While the low-flow TMDLs presented above are designed to protect water quality during low-flow conditions, the Department recognizes that nutrients may reach the River in significant quantities during higher flow periods. The results of model scenario 2 have shown that during average-flow conditions, high chlorophyll *a* concentrations are still likely to result in diurnal low dissolved oxygen. Model scenario 4 showed that with the nutrient reductions expected in the basin, the water quality standards would be maintained for dissolved oxygen.
The resultant annual TMDL for nitrogen is:

NITROGEN TMDL **353,680 *lb/year***

4.6 Load Allocations Between Point Sources and Non-point Sources

The allocations described in this section demonstrate how the TMDLs can be implemented to achieve water quality standards in the Manokin River. Specifically, these allocations show that the sum of nutrient loadings to the Manokin River from existing point sources and non-point sources or anticipated changes in point sources and anticipated land uses can be maintained safely within the TMDLs established here.

The Clean Water Act and EPA regulations provide for flexibility in implementation of TMDLs, as long as the overall load is not exceeded. In the present case, individual waste load allocations ("WLAs"), i.e., effluent limitations for point sources, will be established through NPDES permits, which will be issued, reissued, or modified as appropriate on a watershed-wide basis. Load allocations ("LAs") to non-point sources set forth in this section represent best estimates of what loading rates will be in the year 2000 in light of existing land use and land use trends. They are not intended to impose restrictions on land use. MDE expressly reserves the right to allocate these TMDLs among different sources and land use categories in any manner that is reasonably calculated to achieve water quality standards.

Low-flow Allocations:

The nonpoint source loads of nitrogen and BOD simulated in the third scenario represent reductions from the critical condition scenario. Recall that the critical condition scenario loads were based on nutrient concentrations observed in summer 1998. These nonpoint source loads, based on observed concentrations, account for both "natural" and human-induced components and cannot be separated into specific source categories.

Point source load allocations for the summer low-flow critical conditions made up the balance of the total allowable load. This point source load allocation was adopted from results of model scenario 3. All significant point sources are addressed by this allocation and are described further in the technical memorandum entitled *"Significant Nitrogen and Biochemical Oxygen Demand Point Sources and Non-point Sources in the Manokin River Watershed."* The non-point source and point source nitrogen, and BOD allocations for summer critical low-flow conditions are shown in Table 3.

Table 3: Point Source and Non-point Source Summer Low-flow Load Allocations

	Total Nitrogen *(lb/month)*	**BOD (*lb/month)***
Non-point Source	260	980
Point Source	1,340	3,390

Annual Allocations:

The average annual non-point source nitrogen load allocations are represented as estimated year 2000 loads, with a 33% reduction in controllable nitrogen loads. The non-point 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 2000 loading rates from the Chesapeake Bay Model (U.S. EPA, 1996), and 1997 land use.

Point source load allocations for the annual flow conditions made up the balance of the total allowable load. This point source load allocation was adopted from results of model scenario 4. All significant point sources are addressed by this allocation and are described further in the technical memorandum entitled *Significant Nitrogen and Biochemical Oxygen Demand Point Sources and Non-point Sources in the Manokin River Watershed.* Table 4 shows the annual load allocations to point and non-point sources respectively for nitrogen.

Table 4: Point Source and Non-point Source Annual Load Allocations

	Total Nitrogen *(lb/year)*
Non-point Source	301,890
Point Source	42,730

4.7 Margins of Safety

A margin of safety (MOS) is required as part of a TMDL in recognition of the fact that there are many uncertainties in scientific and technical understanding of water quality in natural systems. Specifically, knowledge is incomplete regarding the exact nature and magnitude of pollutant loads from various sources and the specific impacts of those pollutants on the chemical and biological quality of complex, natural water bodies. The MOS is intended to account for such uncertainties in a manner that is conservative from the standpoint of environmental protection.

Based on EPA's guidance, the MOS can be achieved through one of 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 the design conditions for the WLA and the LA.

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 non-point source loads for nitrogen and BOD for the low-flow TMDL. Similarly, a 3% MOS was included in computing the average annual TMDLs. These explicit nitrogen and BOD margins of safety are summarized in Table 5.

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 approximately 50 µg/l. Further, the 50 µg/l chlorophyll *a* target is itself somewhat conservative. In the absence of other factors, a generally acceptable range of peak chlorophyll *a* concentrations is between 50 and 100 µg/l. For the present TMDLs, Maryland has elected to use the more conservative peak concentrations of 50 µg/l. Another implicit safety factor will be provided by the NPDES permits for the WWTPs, which are typically over-designed to account for the low-flow conditions.

Another MOS is that the fourth model scenario, for average-flow, was run under the assumption of summer temperature. When the water is warmer 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 75 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 represent a built in MOS because they allow more algal growth based higher loads that would not actually be seen in the summer.

Table 5: Margins of Safety for Low-Flow and Average-Flow TMDLs

	Total Nitrogen	**BOD**
Low-Flow	10 (*lb/month*)	50 (*lb/month*)
Average-flow	9,060 (*lb/year*)	-

4.8 Summary of Total Maximum Daily Loads

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

For Nitrogen (*lb/month*):

TMDL	=	LA	+	WLA	+	MOS
1,610	=	260	+	1,340	+	10

For BOD (*lb/month*):

TMDL	=	LA	+	WLA	+	MOS
4,420	=	980	+	3,390	+	50

The annual TMDL for Manokin River, equated with illustrative allocations, are:

For Nitrogen (*lb/yr*):

TMDL	=	LA	+	WLA	+	MOS
353,680	=	301,890	+	42,730	+	9,060

Where:

TMDL = Total Maximum Daily Load
LA = Non-point Source
WLA = Point Source
MOS = Margin of Safety
FA = Future Allocation

Average Daily Loads:

On average, the low-flow TMDLs will result in loads of approximately 54 lb/day of nitrogen, and 147 lb/day of BOD, and would be applicable to the period between May 1 and October 31. And, on average the annual TMDL when divided by 365 days will result in loads of approximately 968 lb/day of nitrogen.

5.0 ASSURANCE OF IMPLEMENTATION

This section provides the basis for reasonable assurances that the nitrogen and BOD TMDLs will be achieved and maintained. For both TMDLs, and especially the annual TMDL which involves more significant non-point source considerations, 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 WQIA requires that comprehensive and enforceable nutrient management plans be developed, approved and implemented for all agricultural lands throughout Maryland. This act specifically requires that these nutrient management plans be developed and implemented for nitrogen by 2002. Maryland’s CWAP has been developed in a coordinated manner with the State's 303(d) process. All Category I watersheds identified in Maryland's Unified Watershed Assessment process are totally coincident with the impaired waters list for 1996 and 1998 approved by EPA. The State has given a high-priority for funding assessment and restoration activities to these watersheds.

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

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

It is reasonable to expect that non-point source loads can be reduced during low-flow conditions. While the low-flow loads cannot be partitioned specifically into contributing sources, the sources themselves can be identified. These sources include dissolved forms of the impairing substances from groundwater, the effects of agricultural ditching and animals in the stream, and deposition of nutrients and organic matter to the stream bed from higher flow events. When these sources are controlled in combination, it is reasonable to achieve non-point source reductions of the magnitude identified by this TMDL allocation.

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

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APPENDIX A