Total Maximum Daily Loads of Carbonaceous Biochemical Oxygen Demand (CBOD) and Nitrogenous Biochemical Oxygen Demand (NBOD) for Antietam Creek Washington County, Maryland

FINAL

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LIST OF ABBREVIATIONS

7Q10	7-day consecutive lowest flow expected to occur every 10 years
BOD	Biochemical Oxygen Demand
CBOD	Carbonaceous Biochemical Oxygen Demand
CFR	Code of Federal Regulations
cfs	cubic feet per second
COMAR	Code of Maryland Regulations
CWA	Clean Water Act
CWAP	Clean Water Action Plan
DNR	Department of Natural Resources
DMR	Discharge Monitoring Report
EPA	Environmental Protection Agency
FA	Future Allocation
fps	feet per second
LA	Load Allocation
lbs/month	pounds per month
MD	State of Maryland
MDE	Maryland Department of the Environment
mg/l	milligrams per liter
MOS	Margin of Safety
NBOD	Nitrogenous Biochemical Oxygen Demand
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source
PA	Commonwealth of Pennsylvania
PS	Point Source
SOD	Sediment Oxygen Demand
TMDL	Total Maximum Daily Load
TKN	Total Kjeldahl Nitrogen
USGS	United States Geological Survey
WLA	Waste Load Allocation for point sources
WQIA	Water Quality Improvement Act
WQLS	Water Quality Limited Segment
WWTP	Waste Water Treatment Plant

EXECUTIVE SUMMARY

This document establishes Total Maximum Daily Loads (TMDLs) that addresses the control of pollutants affecting dissolved oxygen levels in Antietam Creek. The water quality goal of the TMDLs documented here is to establish allowable carbonaceous biochemical oxygen demand (CBOD) and nitrogenous biochemical oxygen demand (NBOD) inputs at a level that will ensure the maintenance of the dissolved oxygen standard.

Antietam Creek, a tributary of the Potomac River, is a free-flowing freshwater stream. As such, the TMDLs were developed using a mathematical model for free-flowing streams. CBOD and NBOD contributions from the nonpoint and point sources primarily affect the dissolved oxygen in the Antietam Creek; therefore, the model was used to determine allowable CBOD and NBOD loadings that will meet the dissolved oxygen standard. Load allocations were determined for distributing allowable loads between point and nonpoint sources. The model was also used to investigate seasonal variations in stream conditions and to establish margins of safety that are environmentally conservative.

The allocation of CBOD and NBOD for nonpoint sources was based on observed field values and the projected/estimated implementation of nutrient management plans, which will also achieve a reduction in CBOD and NBOD loads. The point source allocations were based on the current design and future projected flows and effluent limits for the Hagerstown Fiber Limited Partnership Wastewater Treatment Plant (WWTP), the Hagerstown Water Pollution Control Facility WWTP, the Funkstown WWTP, the Maryland Correctional Institution WWTP, and the Antietam WWTP. The overall objective of the TMDLs established in this document is to determine allowable CBOD and NBOD loads that are expected to result in meeting all water quality standards. The TMDLs for summer 7Q10 low-flow conditions in Antietam Creek are 135,186 lb/month for CBOD and 138,468 lb/month for NBOD. These TMDLs are seasonal and apply during the period from May 1 to October 31.

Several factors provide assurance that these TMDLs will be implemented. First, National Pollutant Discharge Elimination System (NPDES) permits will be written to be consistent with the load allocations in the TMDLs. Second, Maryland has adopted a watershed cycling strategy, which will ensure that future water quality monitoring and TMDL evaluations are routinely conducted. In addition, implementation of the nonpoint source CBOD and NBOD reductions in this watershed will be assured by two specific programs, the Water Quality Improvement Act of 1998 (WQIA) and the EPA-sponsored Clean Water Action Plan of 1998 (CWAP). Additionally, funds may be sought through the Maryland Agricultural Water Quality Cost-Share Program.

1.0 INTRODUCTION

The Clean Water Act (CWA) Section 303(d)(1)(C) and federal regulation 40 CFR §130.7(c)(1) direct each State to develop Total Maximum Daily Loads (TMDLs) 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 to account for uncertainty. A TMDL reflects the total pollutant loading of an impairing substance a waterbody can receive and still meet water quality standards.

Antietam Creek (02-14-05-02) was identified on the Maryland's 1996 list of WQLSs due to low dissolved oxygen (priority 14 listing), nutrients (low priority listing), and suspended sediment (low priority listing). This report documents the proposed establishment of TMDLs for CBOD and NBOD in Antietam Creek to maintain present and future dissolved oxygen concentrations.

The initial impairment decision did not include sampling data for for chlorophyll-a, which is a surrogate indicator of excess nutrients and eutrophication (i.e., the over-enrichment of an aquatic system by excessive inputs of nutrients leading to algal blooms); therefore, a nutrient TMDL may yet be developed if the results of chlorophyll-a sampling indicate the need to do so. The sediment impairment will be addressed at a later date.

TMDLs are established to achieve and maintain water quality standards. Water quality standards consist 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.

Antietam Creek is designated as Use IV-P water (recreational trout waters and public water supply) according to the Code of Maryland Regulations (COMAR) 26.08.02. The in-stream dissolved oxygen standard for Use IV-P water is 5.0 milligram per liter (mg/l) at any time. There are no numeric criteria for nutrients or suspended sediments.

Recent water quality data for Antietam Creek does not indicate a dissolved oxygen impairment; however, based on MDE's analysis, it is anticipated that future violations of the dissolved oxygen standard could occur if CBOD or NBOD are allowed to increase in Antietam Creek beyond the amount specified in this TMDL document. The Department's analysis demonstrates that the biochemical oxygen demand (BOD) loading in the stream affects the dissolved oxygen, and describes the development of TMDLs for CBOD and NBOD in Antietam Creek. Upon approval by the United States Environmental Protection Agency (EPA), these TMDLs will be reflected in the State's Continuing Planning Process. In the future, the established TMDLs will support regulatory and voluntary measures needed to protect water quality in Antietam Creek.

2.0 SETTING AND WATER QUALITY DESCRIPTION

2.1 General Setting and Source Assessment

Antietam Creek, a tributary of the Potomac River, located in Washington County, Maryland is a free flowing stream that originates in Pennsylvania and empties into Potomac River in Maryland. It is approximately 54 miles in length, with 17 miles in Pennsylvania and 37 miles in Maryland. The watershed of Antietam Creek (Figure 1) has an area of approximately 284 square miles out of which 181 square miles (64 percent of the area) are in Maryland. Refer to Figure 2 for land uses in the Antietam Creek watershed, and to Figure 3 for land uses in the Maryland portion of the watershed. The watershed's predominant land use (Figure 2) is agricultural, comprising 106,238 acres or 58 percent. Forest cover comprises 33,742 acres or 19 percent and urban areas comprise 23,114 acres or 13 percent. The agricultural land use in Maryland is approximately 65,920 acres and in Pennsylvania approximately 40,320 acres. The forest cover in Maryland is approximately 29,440 acres and in Pennsylvania approximately 4,352 acres. The urban area in Maryland is approximately 20,480 acres and in Pennsylvania approximately 3,200 acres.

In Maryland, Antietam Creek has a moderate streambed slope with estimated average stream velocities ranging from 0.56 to 0.76 feet per second (fps) during low-flow conditions. The watershed soils are typically classified as rocky consisting of carbonate and siliciclastic material**.** The streambeds are generally rocky.

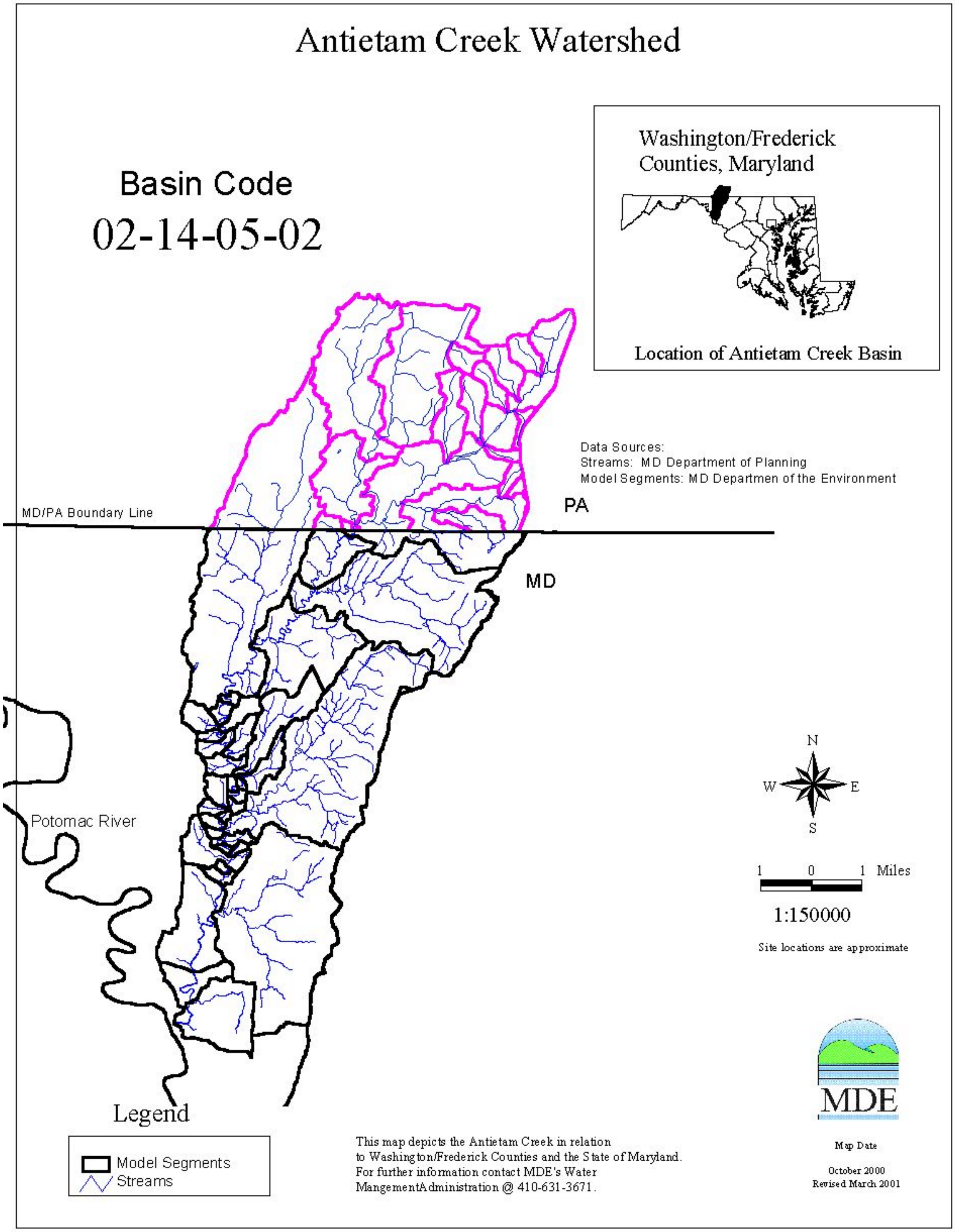


Figure 1. Watershed for the Antietam Creek

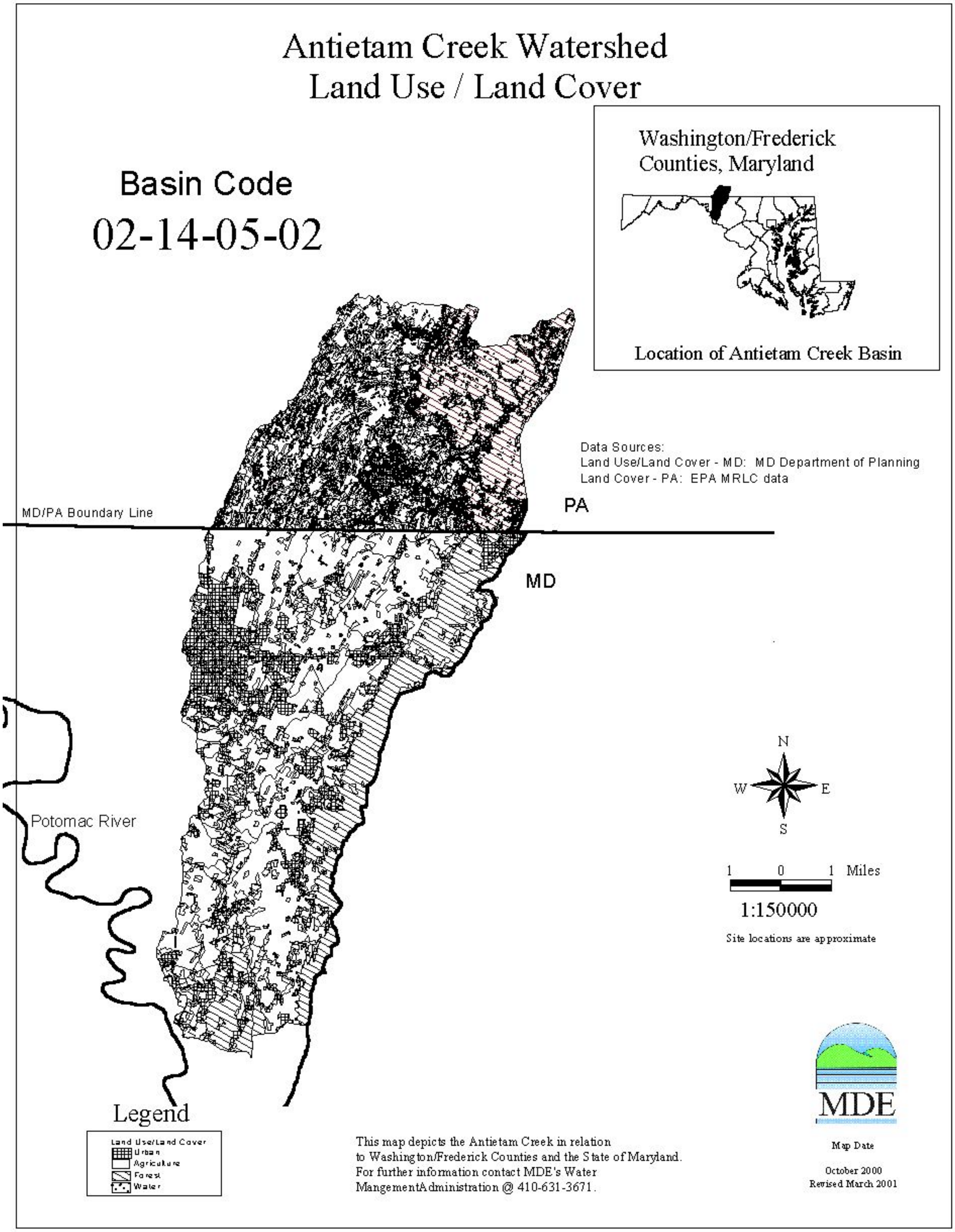


Figure 2. Land Use in the Antietam Creek Watershed

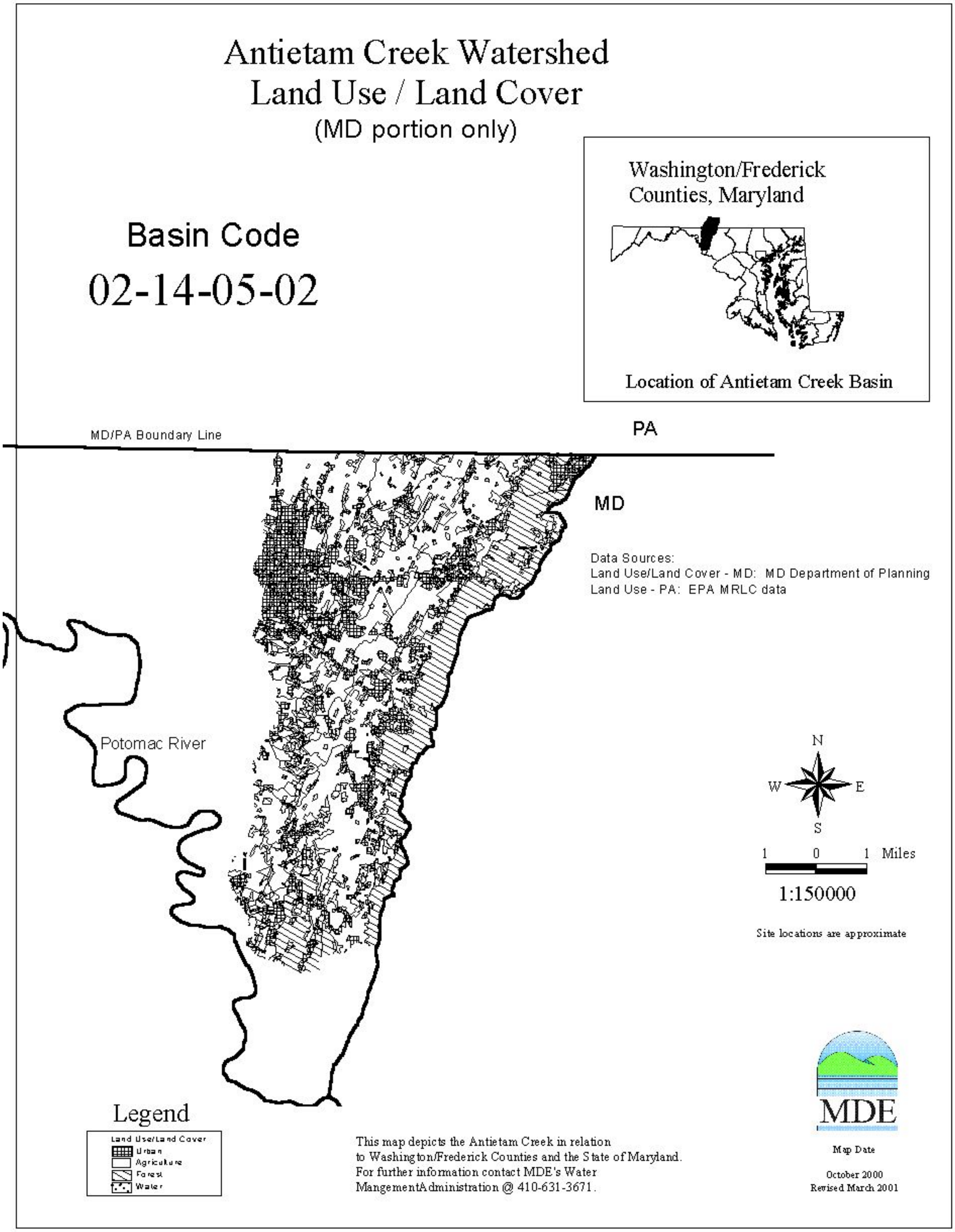


Figure 3. Land Uses in Maryland Portion of the Antietam Creek Watershed

2.2 Water Quality Characterization

Nineteen long-term historical water quality-sampling stations located on the Antietam Creek mainstem were used to characterize the existing water quality. Figure 4 shows the location of these 19 mainstem sampling stations, three sampling stations located along Antietam Creek's tributaries, and a United States Geological Survey (USGS) flow gage. Maryland Department of Natural Resources (DNR) and MDE since 1966 have collected water chemistry data at these stations. The water quality of three parameters, dissolved oxygen, total nitrogen, and total phosphorus collected at these stations were examined, for the period between May and July of the years 1996 and 1997.

Water quality parameters were measured along the mainstem of Antietam Creek during the 1996 and 1997 summer stream surveys at stations ANT0002, ANT0043, ANT0044, ANT0058, ANT0084, ANT0097, ANT0112, ANT0132, ANT0134, ANT0151, ANT0176, ANT0198, ANT0203, ANT0209, ANT0223, ANT0230, ANT0241, ANT0250, and ANT0366 (refer to Figure 4 for the station locations). Figures 5, 8, 11, 14, 17, 20 and 23 show dissolved oxygen concentrations. Figures 6, 12, 15, 18, 21, and 24 show total nitrogen concentrations. Figures 7, 10, 13, 16, 19, 22, and 25 show total phosphorus concentrations. Dissolved oxygen concentrations measured at these stations range from 6.0 - 13.0 mg/l. Total nitrogen concentrations measured at these stations range from 1.416 – 6.893 mg/l. Total phosphorus concentrations measured at these stations range from 0.016 – 0.669 mg/l. Refer to Appendix A for water quality data tables. These data demonstrate that Antietam Creek is meeting the numeric criteria for dissolved oxygen and is determined by the Department to have nutrient concentrations necessary to support its designated use.

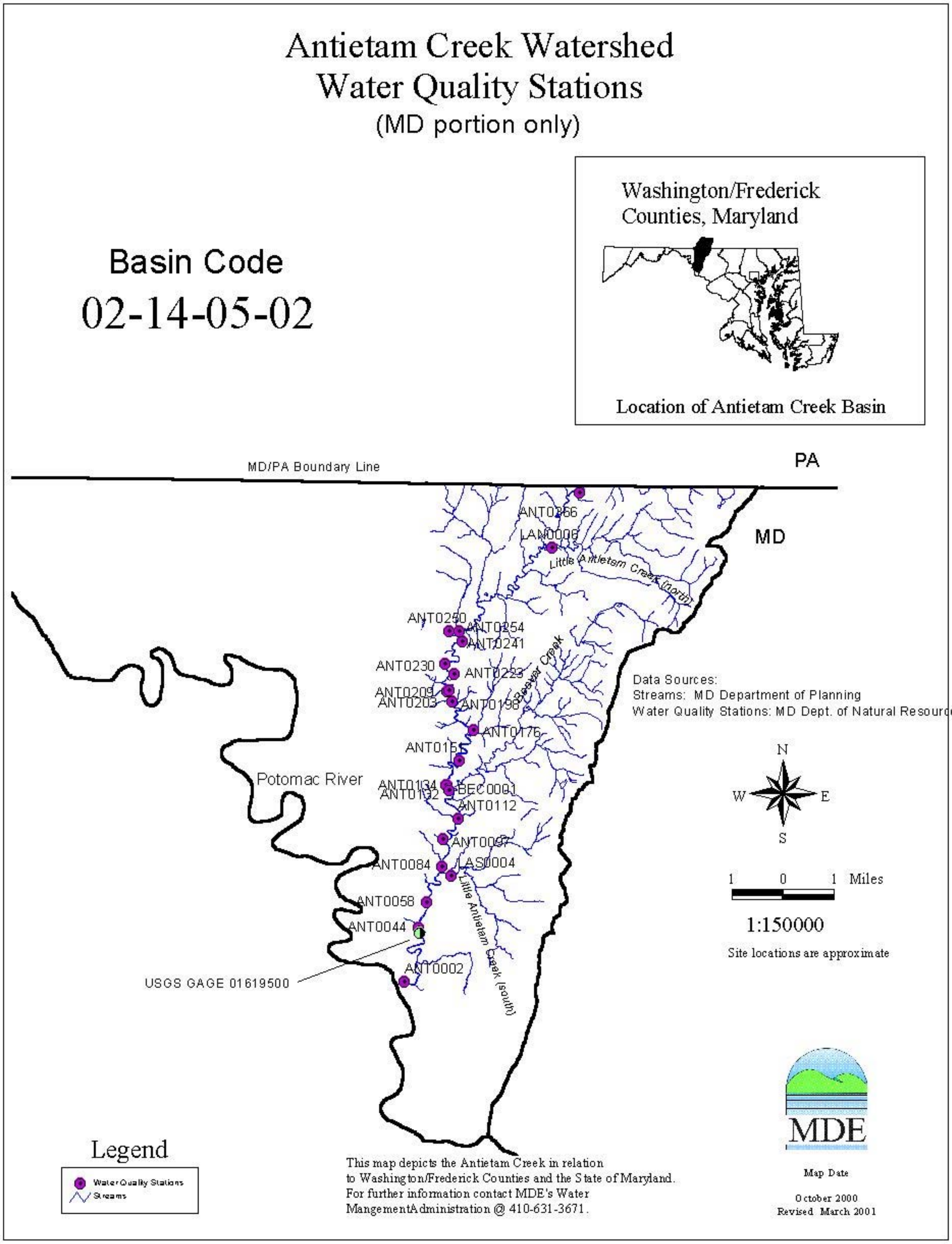


Figure 4. Water Quality Stations Location and Major Tributaries

Graphical Presentation of Water Quality Data Collected During May 1996 to July 1997:

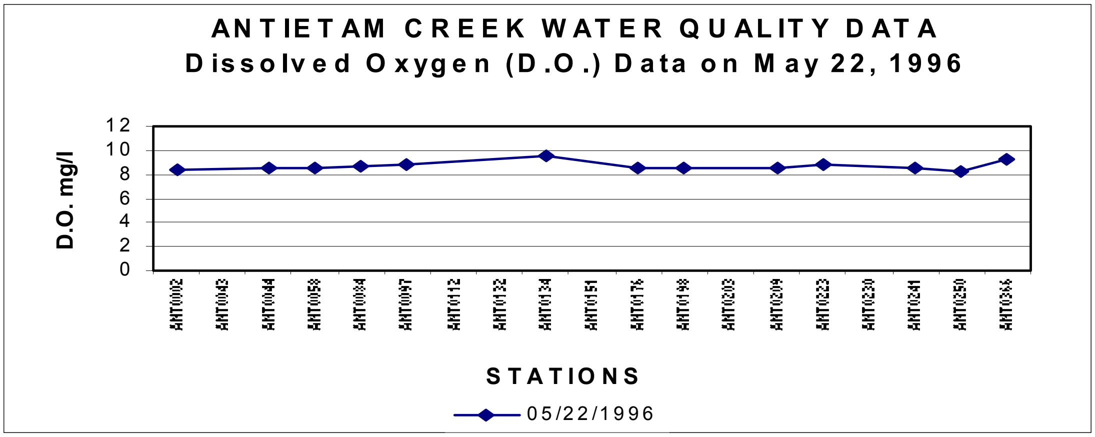


Figure 5. Graphical Presentation of the Water Quality Data

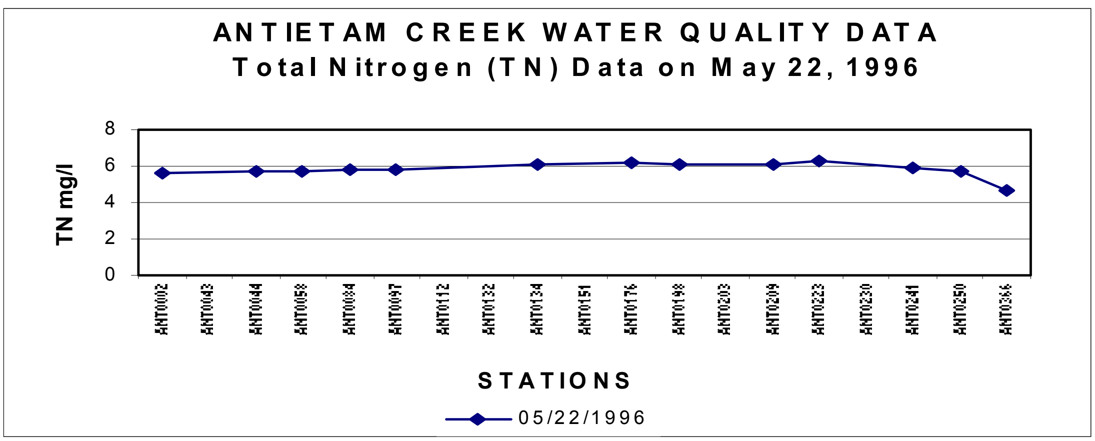


Figure 6. Graphical Presentation of the Water Quality Data

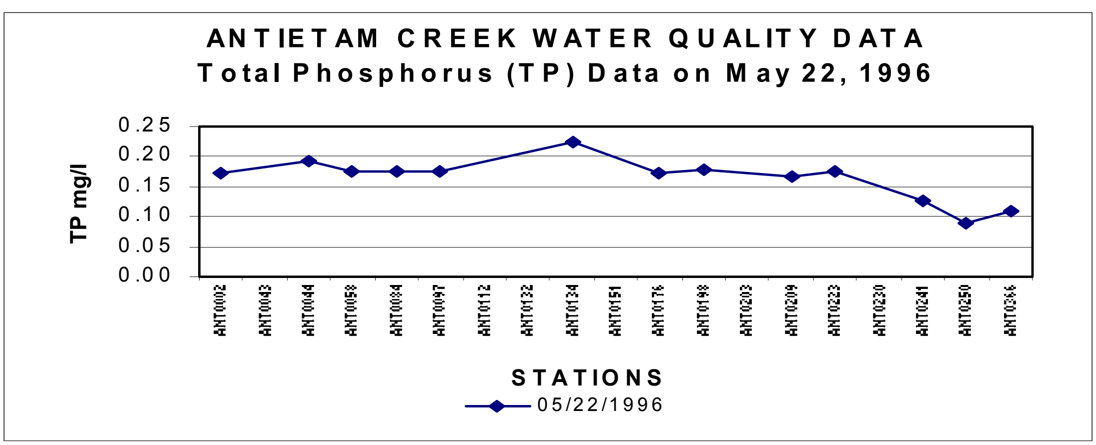
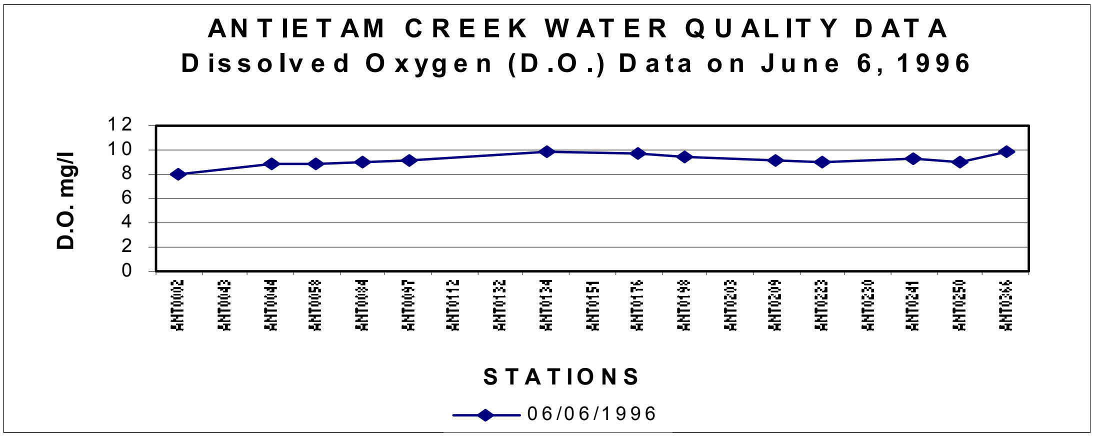


Figure 7. Graphical Presentation of the Water Quality Data

Graphical Presentation of Water Quality Data, Continued



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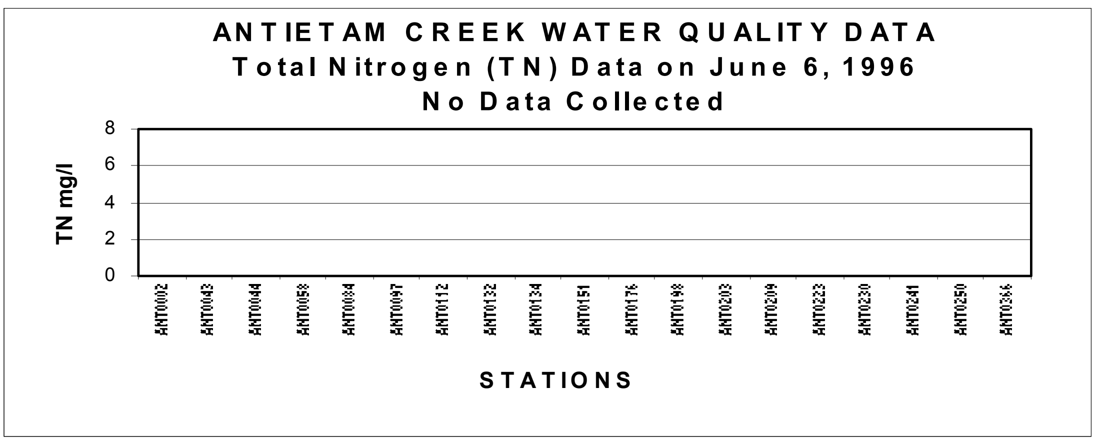


Figure 9. Graphical Presentation of the Water Quality Data

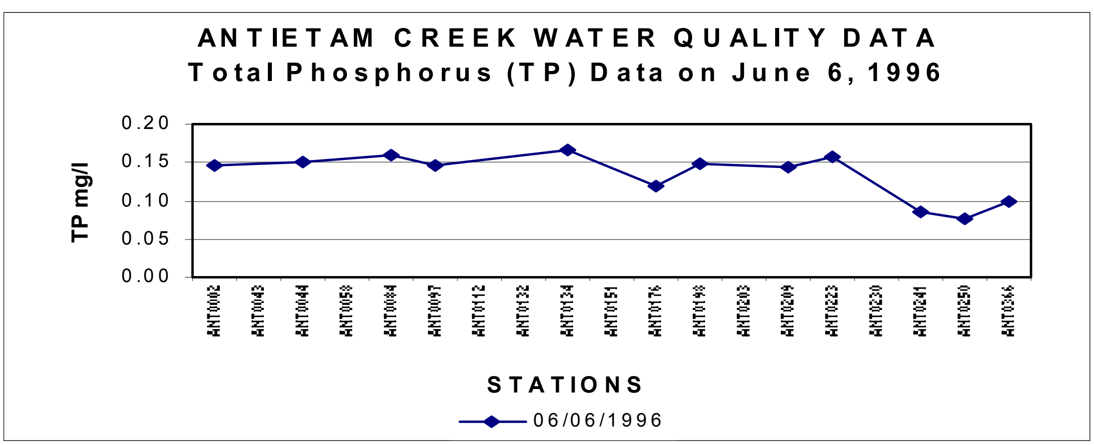
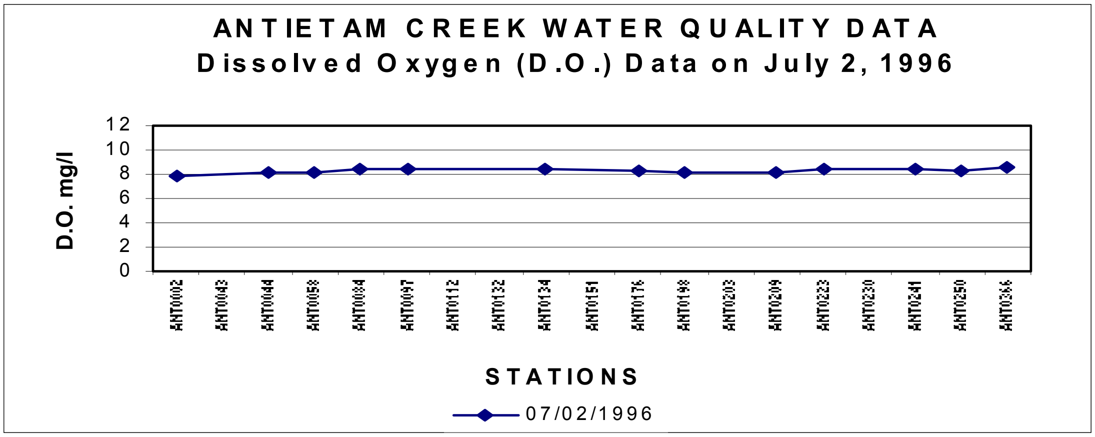


Figure 10. Graphical Presentation of the Water Quality Data

Graphical Presentation of Water Quality Data, Continued



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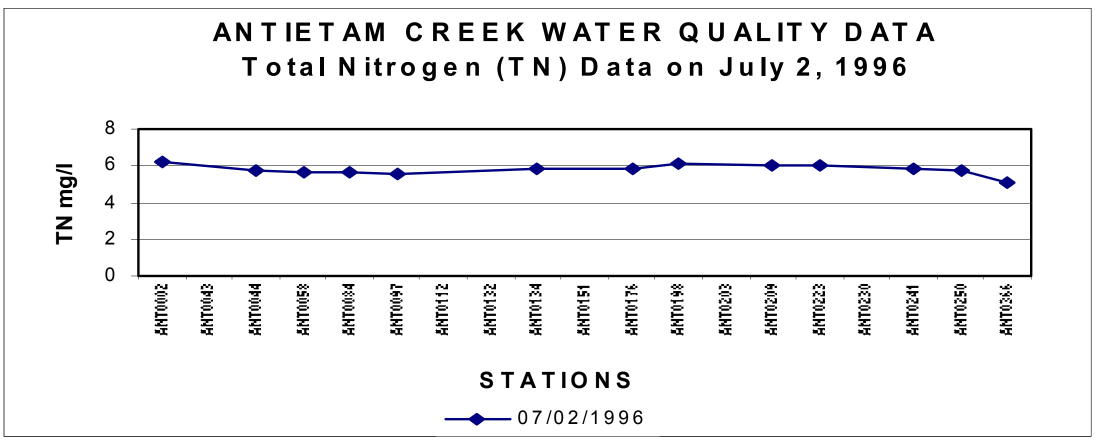

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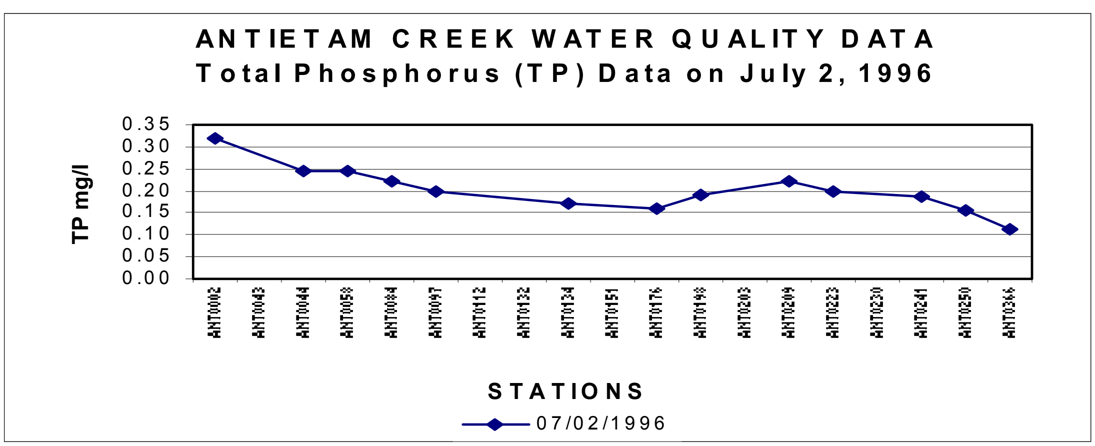
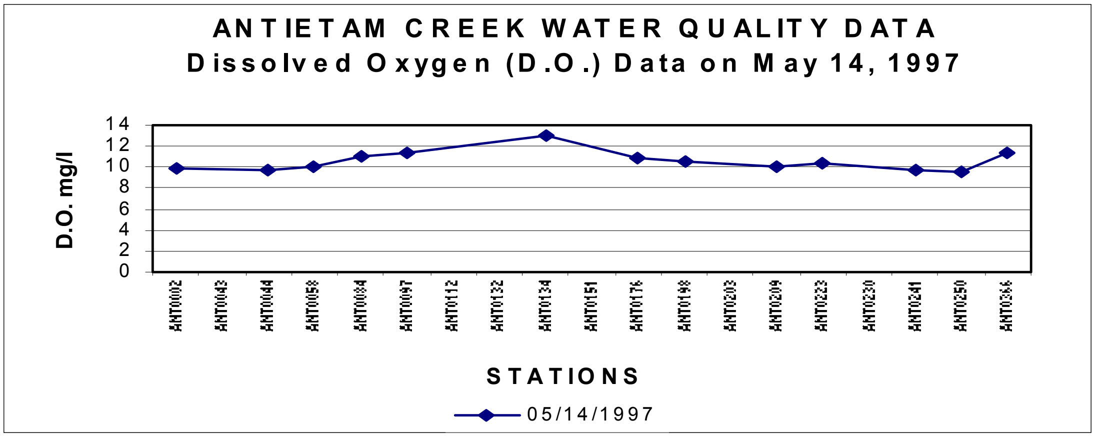


Figure 13. Graphical Presentation of the Water Quality Data

Graphical Presentation of Water Quality Data, Continued



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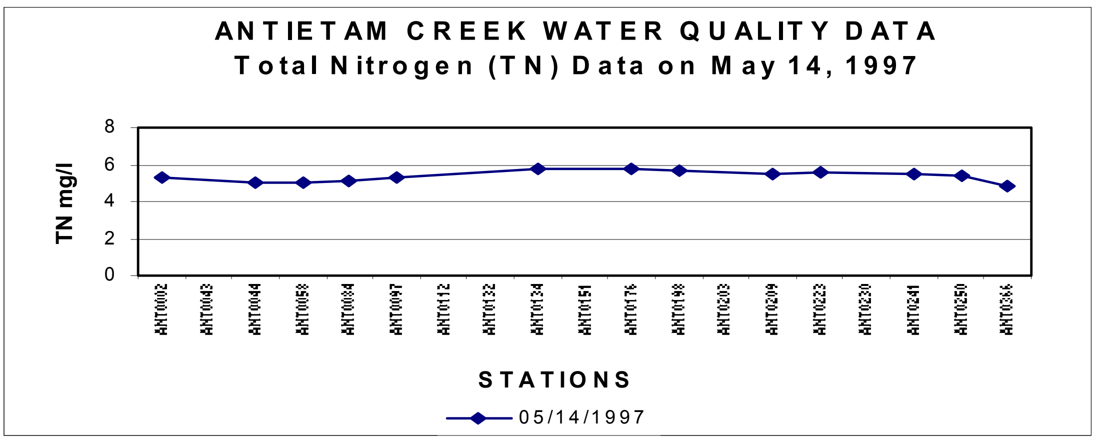

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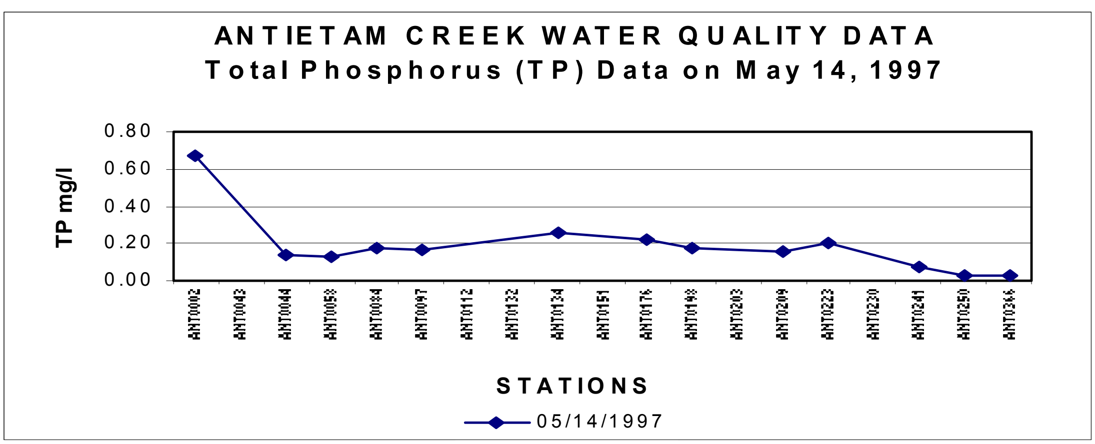
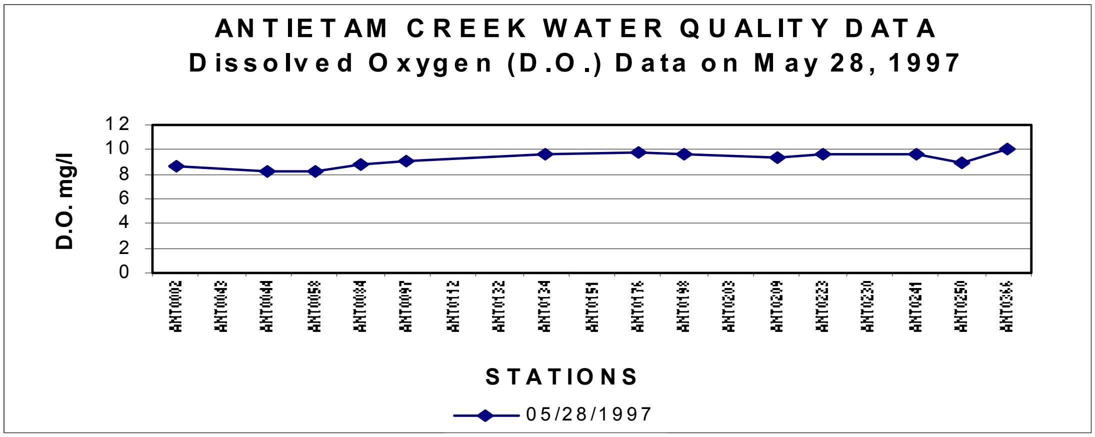


Figure 16. Graphical Presentation of the Water Quality Data

Graphical Presentation of Water Quality Data, Continued



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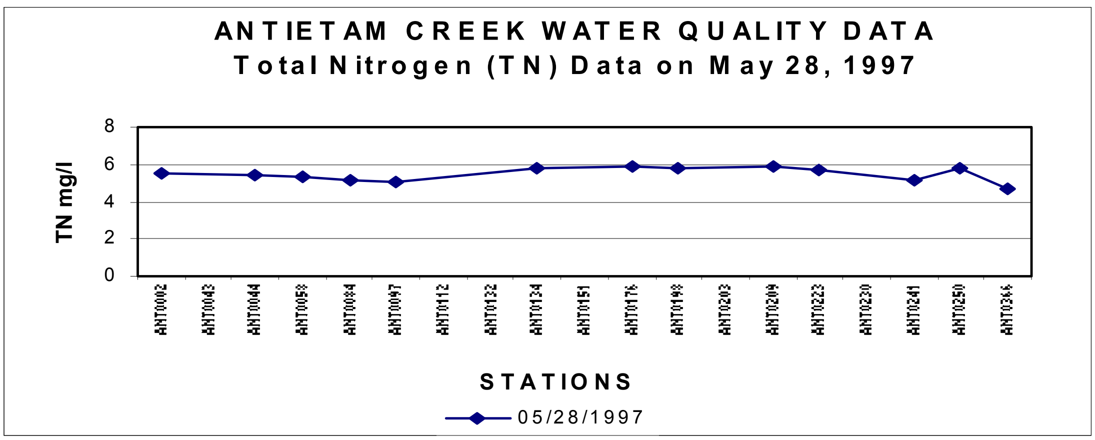

Figure 18. Graphical Presentation of the Water Quality Data

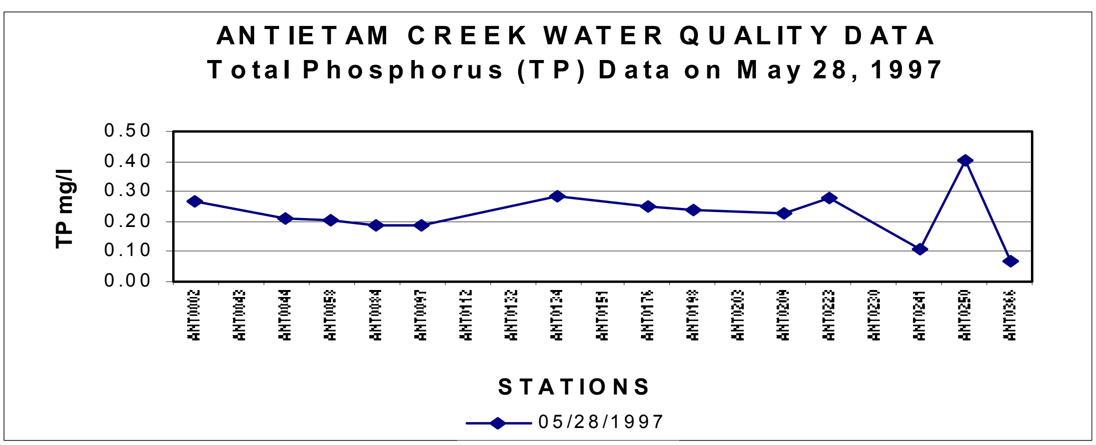

Figure 19. Graphical Presentation of the Water Quality Data

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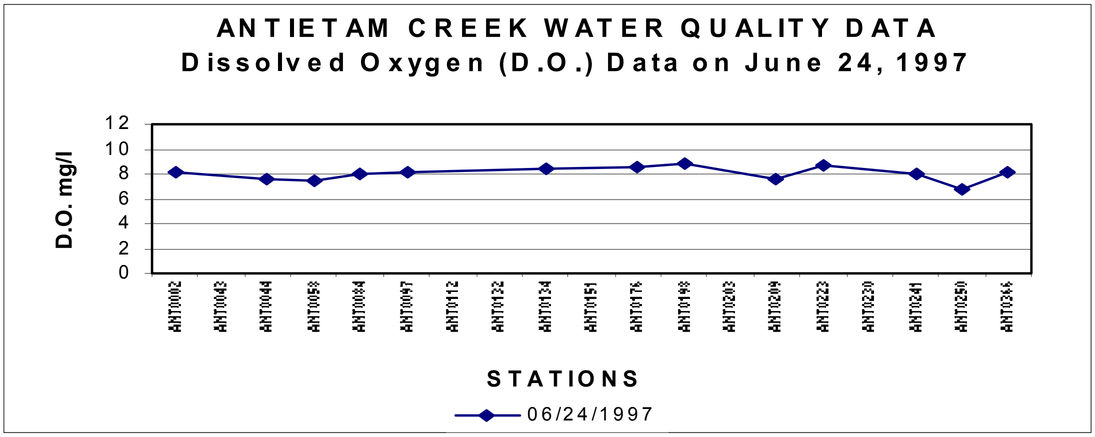

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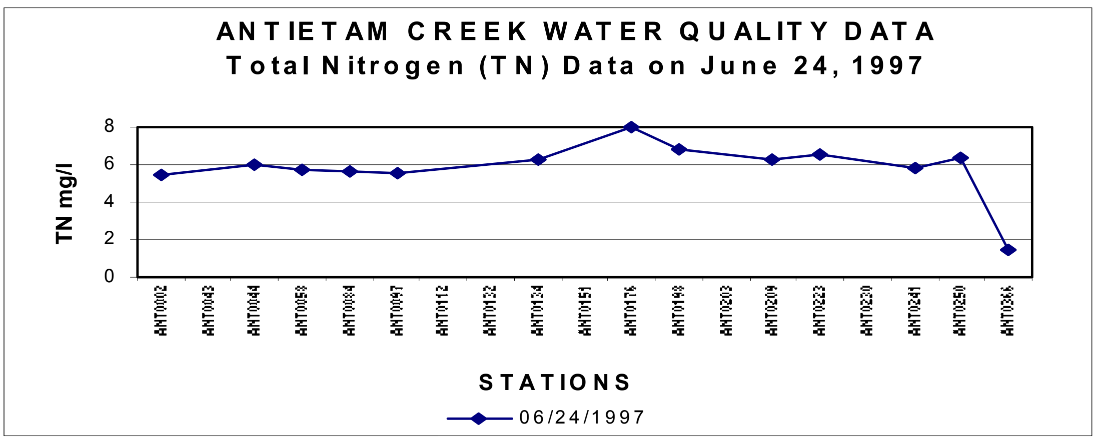

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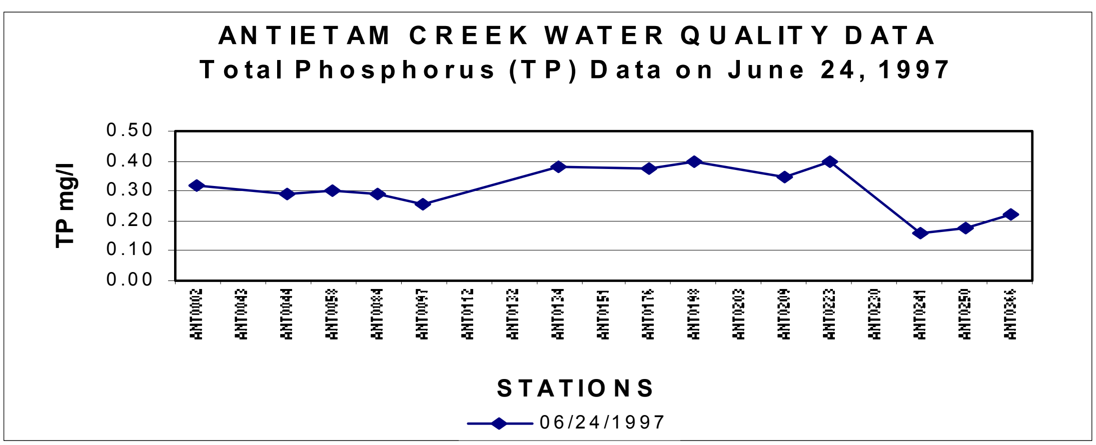

Figure 22. Graphical Presentation of the Water Quality Data

Graphical Presentation of Water Quality Data, Continued

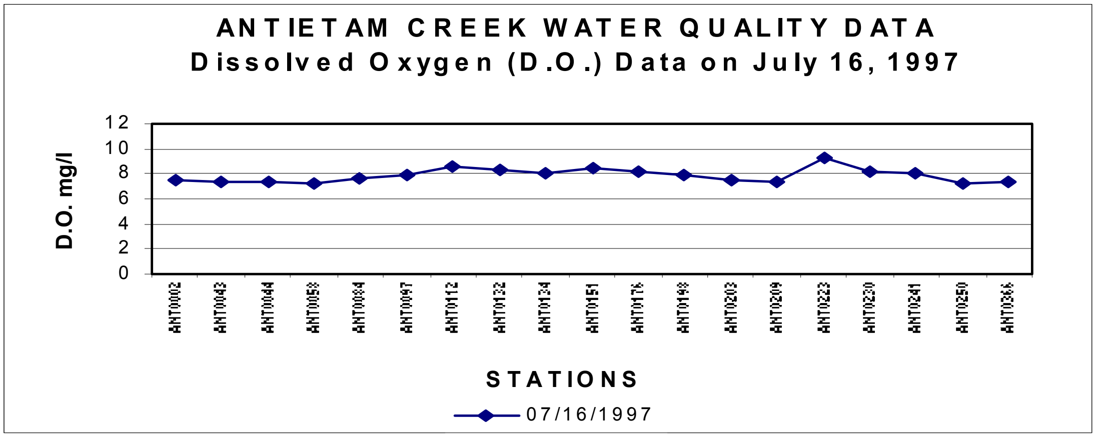

Figure 23. Graphical Presentation of the Water Quality Data

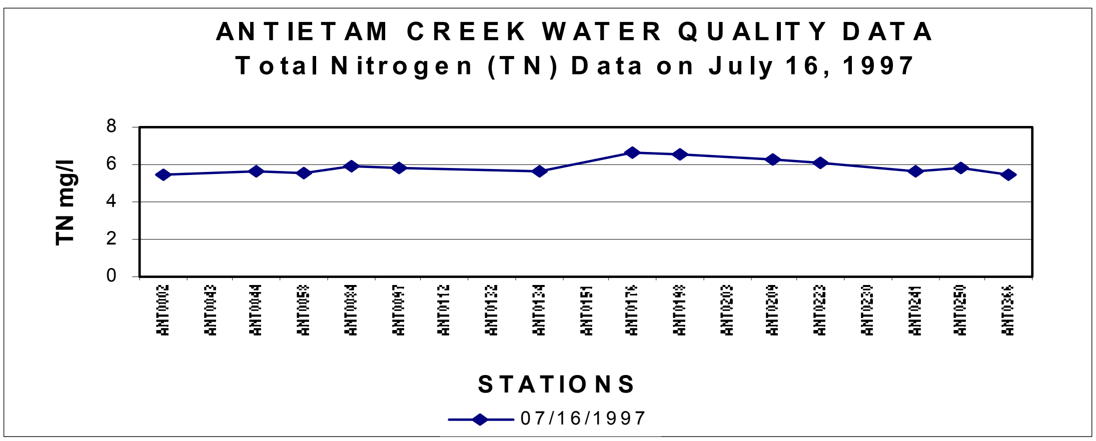

Figure 24. Graphical Presentation of the Water Quality Data

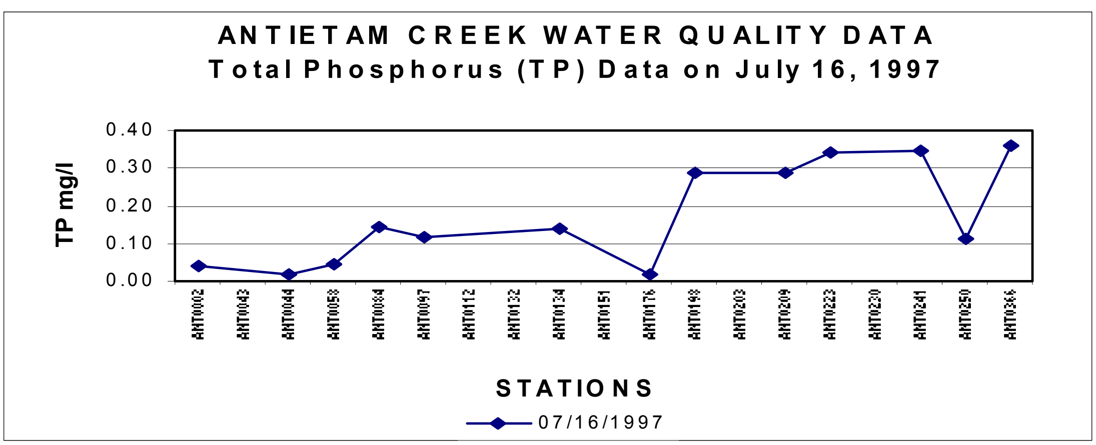

Figure 25. Graphical Presentation of the Water Quality Data

2.3 Water Quality Impairment

The development of these CBOD and NBOD TMDLs is intended to assure that the in-stream dissolved oxygen concentrations will remain above the minimum requirement for a Use IV-P designated body of water. Antietam Creek is designated as Use IV-P water according to COMAR 26.08.02. The in-stream dissolved oxygen standard for Use IV-P water is 5.0 mg/l minimum at any time. The observed water quality data does not show dissolved oxygen standard violations at the present time; therefore, the overall objective of the development of these TMDLs for Antietam Creek is to determine the maximum allowable BOD input from point and nonpoint sources that will allow for the maintenance of dissolved oxygen standards.

BOD is a composite term that describes the consumption of oxygen through the oxidation of carbon and nitrogen by bacteria in the water. The sources of BOD include both point and nonpoint source loads. The significant point sources addressed in this TMDL document are the Hagerstown Fiber Limited Partnership Wastewater Treatment Plant (WWTP), the Hagerstown Water Pollution Control Facility WWTP, the Funkstown WWTP, the Maryland Correctional Institution WWTP and the Antietam WWTP. During low flow and average high flow conditions, both point and nonpoint sources contribute significant BOD loads to the system.

The nonpoint source loads of BOD enter the system at the upstream boundary located at water quality modeling point 32 and the downstream tributaries of Little Antietam Creek (north), Beaver Creek, and Little Antietam Creek (south). The nonpoint source loads are based on the in-stream water quality monitoring data. Because the low-flow loading estimations are based on observed data, they account for all human and natural sources.

Combined Sources from Pennsylvania

The majority of combined (nonpoint and point sources) load contributions from Pennsylvania enter Antietam Creek at model segment 32 at the Maryland/Pennsylvania boundary line. Additional loads enter at model segments 33 and 36.

Nonpoint Sources in Maryland

Nonpoint source contribution to the Antietam Creek in Maryland, is represented by tributary concentrations in model segments. The nonpoint source values used in this document are from water quality data collected for the Antietam Creek at several stations during the 1996 and 1997 summer stream surveys. Refer to Appendix A for the water quality data summary.

Point Sources in Maryland

The wastewater treatment plant discharges represent the point source contribution. There are five facilities discharging directly to the Antietam Creek that contribute significant loads. Refer to Figure 27 for facilities locations. The Hagerstown Water Pollution Control Plant is the most significant discharger of effluent to the Antietam Creek. The nearby Hagerstown Fiber Limited Partnership Plant, when in operation, is the second most significant discharger of effluent. Combined discharge from other three facilities represents 16 percent of the total point source load. Refer to Appendix A for details.

The other wastewater treatment plants in the Maryland portion of the watershed are Boonsboro WWTP, Brooklane Psychiatric Center WWTP, Fahrney-Keedy Memorial Home WWTP, Greenbriar State Park WWTP, Highland View Academy WWTP, Hunter Hill Apartments WWTP, and Smithsburg WWTP. With relatively small outputs, discharges from these facilities were included in the tributary loads. These discharges, when combined, represent 10 percent of the total point source load in the Maryland portion of the watershed.

In addition to accounting for the sources of BOD, the processes that deplete dissolved oxygen were also considered. These processes include those that consume oxygen (sinks) as well as those that generate oxygen (sources). These processes and some additional factors are presented in Figure 26. As mentioned before, BOD reflects the amount of oxygen consumed through two processes: CBOD and NBOD. CBOD is the reduction of organic carbon material to its lowest energy state, carbon dioxide (CO_2), through the metabolic action of microorganisms (principally bacteria). NBOD is the term for the oxygen required for nitrification, which is the biological oxidation of ammonia to nitrate. The BOD values seen throughout this document represent the amount of oxygen consumed by the oxidation of carbonaceous and nitrogenous waste materials over a 5-day period, at 20 °C. This is referred to as a 5-day, 20 °C BOD and is the standard reference value utilized internationally by both design engineers and regulatory agencies. The 5-day BOD represents primarily consumption of carbonaceous material and minimal nitrogenous material. The ultimate BOD represents the total oxygen consumed by carbonaceous and nitrogenous material over an unlimited length of time.

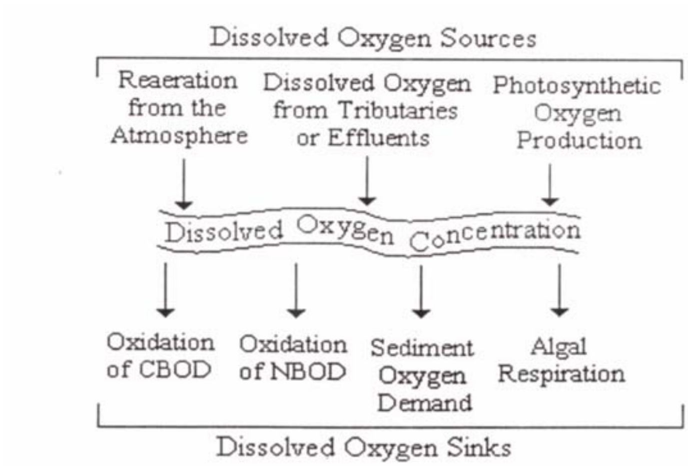

Figure 26. Sources and Sinks for Dissolved Oxygen in the Antietam Creek

Another factor influencing dissolved oxygen concentrations is the sediment oxygen demand (SOD). As with BOD, SOD is a combination of several processes. Primarily, it is the aerobic decay of organic materials that settle to the bottom of the stream; however, SOD is usually considered negligible in free-flowing streams like Antietam Creek because frequent scouring during storm events usually prevents long-term accumulation of organic materials. All of the dissolved oxygen sources and sinks make up the dissolved oxygen balance.

Antietam Creek appeared on the 1996 303(d) list, due to a presumed nutrient impairment. The total nitrogen and total phosphorus concentrations observed during the summer months and averaged across all mainstem stations are 5.69 mg/l and 0.2 mg/l, respectively. Generally, nutrient levels are of concern in slow moving waterbodies such as lakes and estuaries having low velocities and long travel times. Low velocities and excess nutrients can encourage the growth of undesirable levels of algae. Algal growth can be a significant factor in dissolved oxygen levels, due to photosynthetic oxygen production and oxygen consumption through respiration by the algae. Evidence of undesirable levels of algae is normally supported by large diurnal variations in dissolved oxygen concentrations. Further sampling is needed to determine whether nutrients may contribute to future low dissolved oxygen concentrations in Antietam Creek. An examination of dissolved oxygen data and subsequent modeling does not currently support a conclusion that algae is a significant factor influencing dissolved oxygen concentration in Antietam Creek.

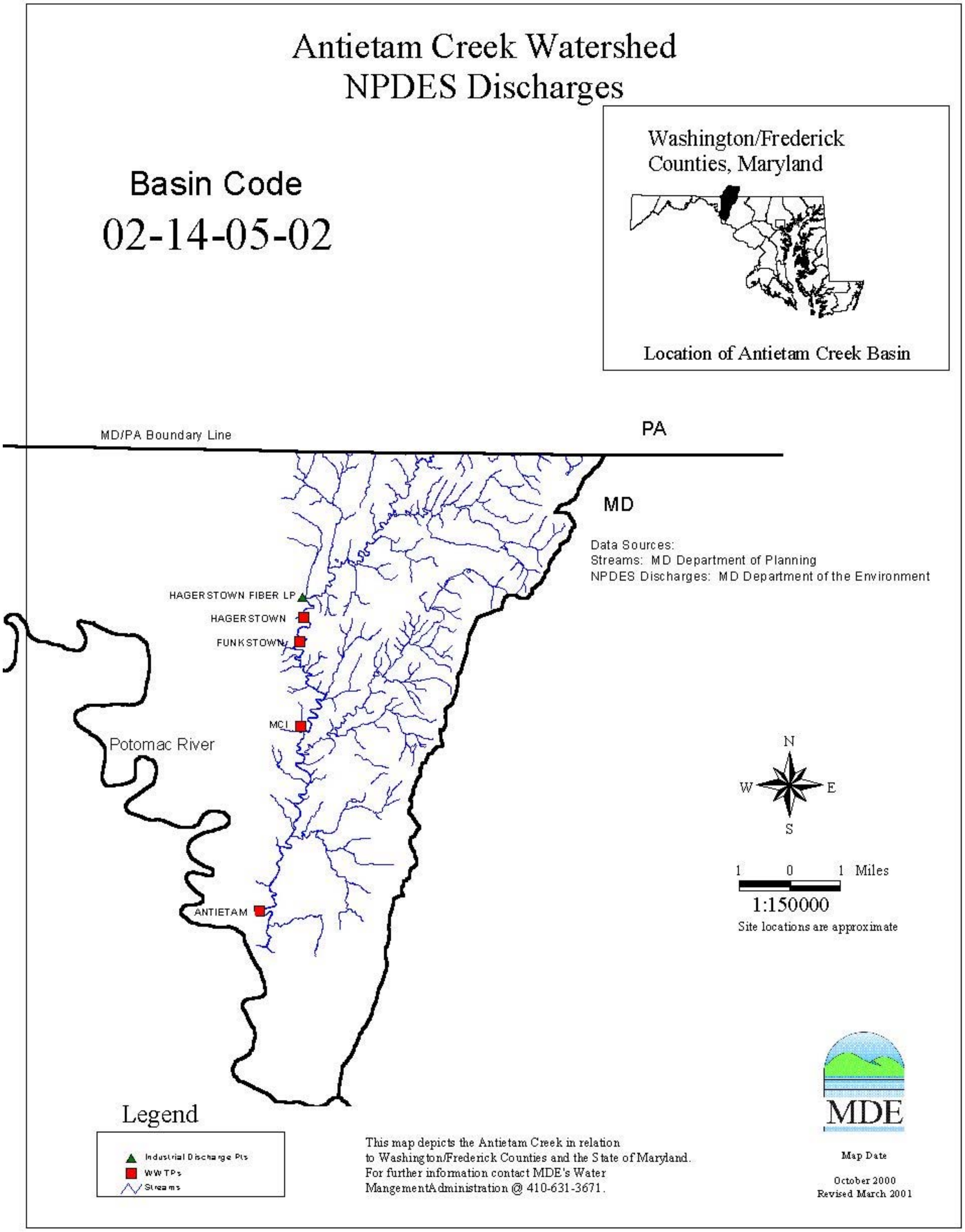

Figure 27. WWTPs Discharging to the Antietam Creek in Maryland

3.0 TARGETED WATER QUALITY GOAL

The minimum dissolved oxygen concentration observed over all stations during the summer stream surveys of 1996 and 1997 was 7.2 mg/l. The water quality data does not show dissolved oxygen standard violations at the present time. The overall objective of the development of these TMDLs in the Maryland portion of the Antietam Creek is to determine the maximum allowable BOD inputs from point and nonpoint sources that will allow for the maintenance of dissolved oxygen standards. BOD loads in the basin are expected to increase in the future, thus development of TMDLs for CBOD and NBOD is intended to assure that dissolved oxygen concentrations remain above a minimum of 5.0 mg/l in the Maryland portion of the Antietam Creek. This dissolved oxygen goal is based on specific numeric criteria for Use IV-P waters in the COMAR 26.08.02.

4.0 TOTAL MAXIMUM DAILY LOADS AND ALLOCATION

4.1 Overview

This section describes how the TMDLs and load allocations for point and nonpoint sources were developed for the Maryland portion of the Antietam Creek. The first section describes the modeling framework, and simulation of the water quality constituents and hydrology. The second section summarizes the scenarios that were explored using the model. The third section presents modeling results in terms of the TMDLs, and a summary of the TMDL allocations between point sources and nonpoint sources. The fourth section explains the rationale for the margin of safety and remaining future allocation. Finally, the pieces of the equation are combined in a summary accounting of the TMDLs.

4.2 Description of Modeling Framework

The Antietam Creek is a relatively fast-flowing freshwater stream with characteristics of one-dimensional downstream load transport. The computational framework or model chosen for determining the TMDLs for the Maryland portion of the Antietam Creek is an in-house calibrated model developed for Antietam Creek. The model prepares input data and runs a free-flowing stream model based on the Streeter-Phelps equation. It is capable of simulating steady-state conditions, one-dimensional system and linear kinetic water quality problems related to BOD and dissolved oxygen. In 1993, Eder Associates Consulting Engineers, P.C. developed a computerized model program of the Antietam Creek water quality model for MDE's use based on the original in-house model. For these TMDLs, the model has been updated and re-calibrated. The Streeter-Phelps equation and other equations, as listed in Appendix A, for dissolved oxygen sag projections in the stream are incorporated in this model. The model can project net CBOD, NBOD and dissolved oxygen values in each modeling segment.

The spatial modeling domain represents the segment of the Maryland portion of the Antietam Creek watershed that was included in the model. It is approximately 37 miles long and extends from Maryland/Pennsylvania boundary line to the confluence with the Potomac River. This segment was divided into a total of 37 modeling segments. Station 32 represents the upper boundary of the model's spatial domain and Station 31 at the confluence with the Potomac River represents the lower boundary. This numbering scheme was in the original model of Antietam Creek and maintained for this analysis. Refer to Figures 28 and 29 for locations of the modeling segments as represented by model stations.

4.3 Other Input Data Information

The model requires input of background flow and/or tributary flow at modeling points. Velocity estimates from the USGS time of travel study of Antietam Creek are incorporated in the model. The summer low-flow condition, which represents seven consecutive days' lowest average flow expected to occur once every 10 years (7Q10), is incorporated in all model runs. The stream flow data collected at USGS Gaging Station 1619500 is used in the model. Refer to Figures 28 and 29 for the gaging station's location. The other inputs required to run the model are creek temperature and specific point source discharge loadings.

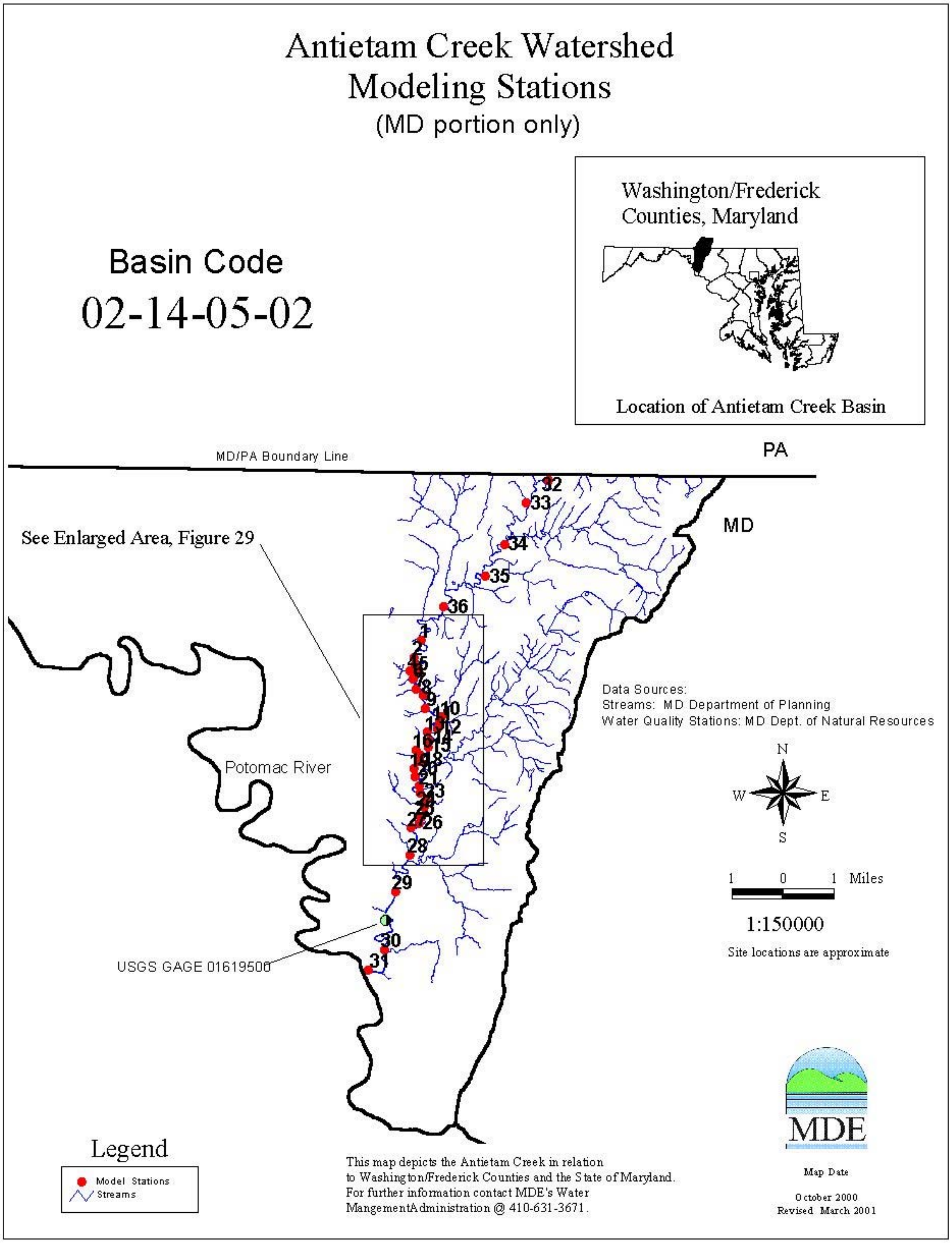

Figure 28. Location of Modeling Station Points

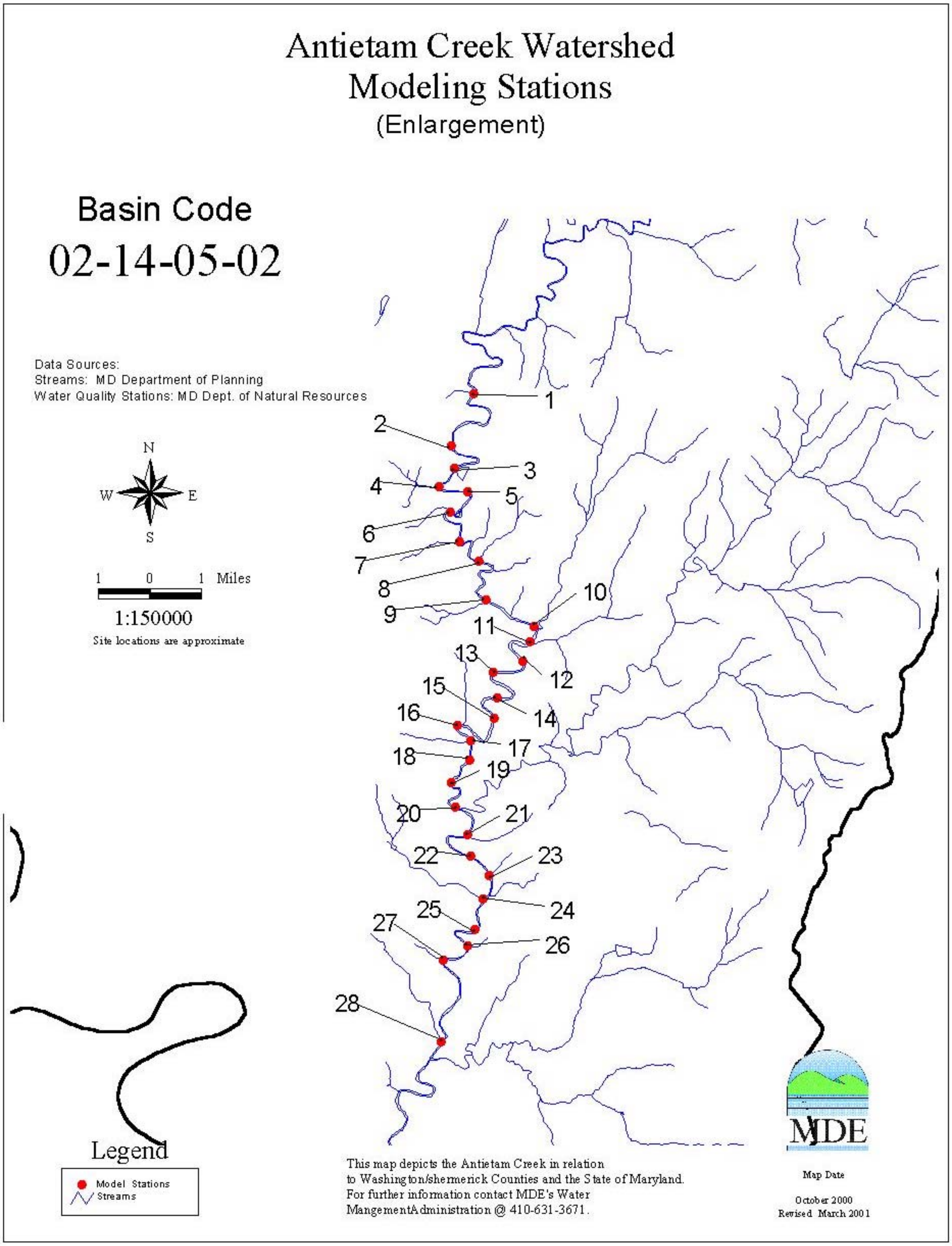

Figure 29. Location of Modeling Station Points, Enlarged Area

4.4 Calibration Run

The calibration run is performed to predict the BOD and dissolved oxygen of Antietam Creek that represents the existing water quality of the stream during the summer low-flow period. For freshwater streams, the summer months are critical due to expected low stream flow and expected high water temperatures. Average summer low-flow conditions were estimated using flow data for the months May to July at USGS gage 01619500 located on Antietam Creek near Sharpsburg. For the preliminary model run, the lowest gage stream flow observed during the summer stream surveys of 1996 and 1997 was used. The nonpoint source loads are the observed water quality concentrations in Antietam Creek watershed during the summer stream surveys of 1996 and 1997. The point source loads also were the observed effluent flows and concentrations during the summer stream surveys of 1996 and 1997 for the Hagerstown Fiber Limited Partnership WWTP, Hagerstown Water Pollution Control Plant WWTP, Funkstown WWTP, Maryland Correctional Institute WWTP, and Antietam WWTP.

4.5 TMDL Modeling Scenario Descriptions

Model Run 1 for Permitted Flows and WWTPs Effluent Limits

Model Run 1 reflects the permitted monthly average effluent limitations for the wastewater treatment plants listed above. The design flows were taken from the current Washington County Sewer and Sewer Plan. The CBOD, NBOD, dissolved oxygen and discharge flow values were taken from the NPDES permits for each of the facilities. The CBOD values were calculated by multiplying the 5-day BOD by 1.5. The NBOD values were calculated by multiplying the permit limits for either ammonia (NH_3) or Total Kjeldahl Nitrogen (TKN) by 4.6 (the permitted parameter differed among WWTPs; refer to Appendix A for permit limits). Other conditions including nonpoint source CBOD, NBOD, and dissolved oxygen values were kept the same as the preliminary run. Model Run 1 projects BOD and dissolved oxygen concentrations in Antietam Creek if future BOD loadings do not change from the current waste load allocations.

Model Run 2 for Allowable BOD TMDL Allocations

Model Run 2 estimates the total allowable BOD loads such that the dissolved oxygen concentrations in Antietam Creek do not fall below the State standard of 5.0 mg/l. This run predicts the daily average dissolved oxygen concentrations in the stream, which should be higher than the daily minimum dissolved oxygen concentrations that occur over a 24-hour period. Stream surveys prior to and including the 1996 and 1997 stream survey indicated a high dissolved oxygen concentration in stream model segments 06 to 14. As such, re-calibration of the model accounted for this. SOD is not considered for the dissolved oxygen calculations, due the fast-moving water and rocky streambed characteristics of Antietam Creek.

To compensate for the diurnal in-stream dissolved oxygen variations/depletions and to provide a margin of safety, a target dissolved oxygen of 5.5 mg/l minimum is considered in the model, rather than the dissolved oxygen standard of 5.0 mg/l. The model calculates dissolved oxygen by including oxidation of CBOD and NBOD matters and the reaeration process. The CBOD and NBOD loads were increased in proportion to the point and nonpoint sources that also include future allocations as well as the MOS to offset errors in modeling prediction and seasonal variations. The nonpoint and point source loads used for all model scenario runs are summarized in Table 1.

Table 1. Nonpoint and Point Source Flows Used in Model Scenario Runs

Model Scenario		Calibration	1	2
Nonpoint Source Loads				
CBOD	lbs/day	3,675	1,409	1,785
NBOD	lbs/day	2,307	1,008	1,310
Flow	cfs	140	64	64
Point Source Loads				
CBOD	lbs/day	146	2,168	2,566
NBOD	lbs/day	411	2,829	3,146
Flow	cfs	140	64	64
CBOD MOS	lbs/day	0.0	0.0	153
NBOD MOS	lbs/day	0.0	0.0	155

4.6 Model Results

Calibration Run

The calibration run results did not show any water quality problems related to dissolved oxygen and BOD. The results of the calibration run, as shown in Figure 30, show the dissolved oxygen concentration well above the State water quality standard of 5.0 mg/l.

Model Run 1

Model Run 1 represents the system during summer low flow critical conditions. A flow of 64 cubic feet per second (cfs) at USGS gage 01619500 on Antietam Creek was used to represent the 7Q10 flow. In Model Run 1, the point source loads were increased to include the permitted loads from the WWTPs mentioned in Section 6.3 while the nonpoint source concentrations were kept the same as the calibration run. The results of Model Run 1, as shown in Figure 30, show that in-stream dissolved oxygen levels in Antietam Creek remain above the State's water quality standard. Therefore, Antietam Creek has some assimilative capacity for more BOD loads expressed as future allocations.

Model Run 2

Model Run 2 used the 7Q10 flow of 64 cfs with increased loadings. In Model Run 2, the point and nonpoint source BOD loads (in conjunction with increased NH3 or TKN) were increased in proportion such that the in-stream dissolved levels remained above the State water quality standard and the model target dissolved oxygen value of 5.5 mg/l. The increased loads were distributed between future allocations and margin of safety. Results are shown on Figure 30.

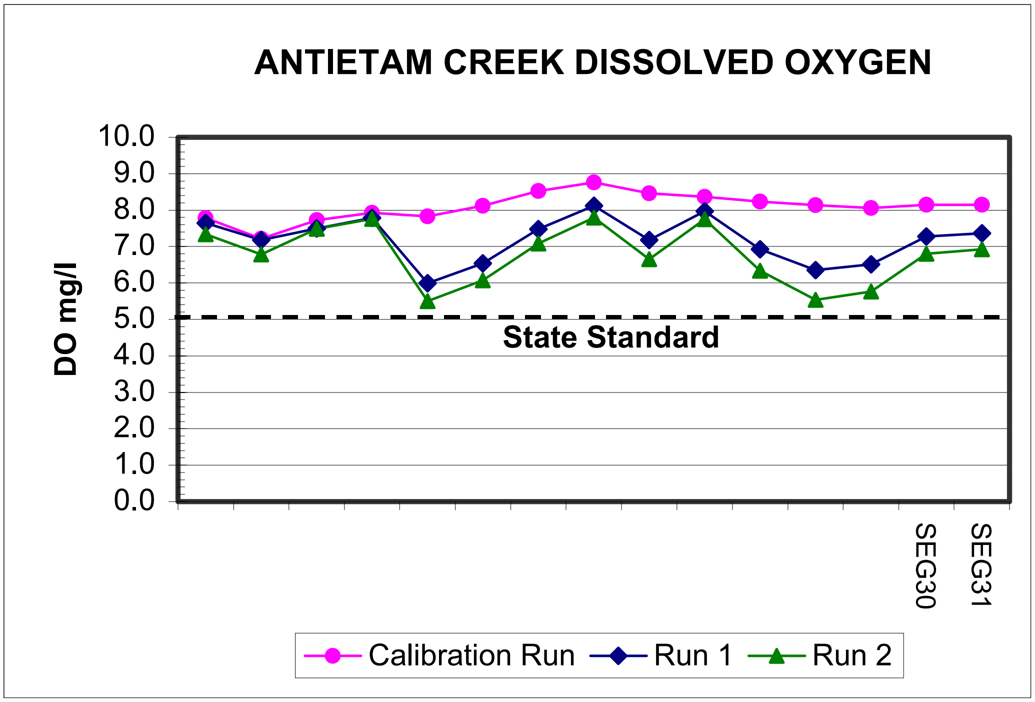

Figure 30. Model Results for Dissolved Oxygen

4.7 TMDL Loading Cap

The Antietam Creek in-stream concentration of dissolved oxygen is affected by the dilution of effluent discharges from point sources and the oxidation and reaeration process. During periods of high stream flow, more dilution is available. The summer months typically exhibit low stream flow, less dilution, and higher water temperatures which are critical conditions for a stream dissolved oxygen analysis. Model Run 2 shows that the dissolved oxygen standard is met with future allocation and a margin of safety. Thus, the modeling results indicate that under future projected conditions with the proposed CBOD and NBOD TMDLs, water quality standards are maintained at the critical summer low-flow conditions. Because 7Q10 and other critical conditions are only likely to occur during summer months, these TMDLs only apply from May 1 to October 31. Model Run 2 scenario represents the final TMDL loading scenario. The resultant TMDL loading for CBOD and NBOD is as follows:

CBOD TMDL (May 1 to October 31)	**135,186 lbs/month**
NBOD TMDL (May 1 to October 31)	**138,468 lbs/month**

4.8 Load Allocations Between Point Sources and Nonpoint Sources

Since Antietam Creek flows through Pennsylvania and Maryland, the TMDL load allocations for Pennsylvania and Maryland are described as follows:

Load Allocations for Pennsylvania

Water quality data from the summer stream surveys of 1996 and 1997 at the Maryland/Pennsylvania boundary line is used to estimate the in-stream concentrations of BOD and TKN in the background flow. These are representative values which are multiplied by the 7Q10 flow to produce the total CBOD and NBOD load allocations. These load allocations represent the combined point and nonpoint source contribution that will have to be evaluated, confirmed and agreed upon by Pennsylvania.

Load Allocations for Maryland

(a) Waste Load Allocations for Point Sources

The point source load allocations for CBOD and NBOD are represented as the projected monthly average loads from the Hagerstown Fiber Limited Partnership WWTP, the Hagerstown Water Pollution Control Plant, the Funkstown WWTP, the Maryland Correctional Institute WWTP, and the Antietam WWTP, assuming daily average design flow and monthly average BOD concentration limit. The total monthly load allocation was calculated by multiplying existing monthly averages of the daily limits from the permit limits multiplied by 30 days. To ensure that sampling variability issues are addressed, the limits will also require (as a minimum) the minimum sampling frequencies associated with the current permit limits. These load allocations are based on two understandings: 1) that the Hagerstown Fiber Limited Partnership WWTP will maintain an NH_3 limit of 1.0 mg/l as monthly average and a minimum dissolved oxygen limit of 7.0 mg/l and 2) that the Hagerstown Water Pollution Control Facility will continue to maintain a minimum dissolved oxygen limit of 8.0 mg/l at any time from May 1 to October 31. The other three facilities combined produce 33 percent of the CBOD load and 54 percent of the NBOD load. NPDES permit limits for the 5-day BOD, NH_3, and TKN at all facilities were developed to be protective of the dissolved oxygen standards of Antietam Creek. Refer to the Technical Memorandum entitled *"Significant CBOD and NBOD Point and Nonpoint Sources in Antietam Creek Watershed"* for details regarding the allocation of waste load among the five major point sources. These allocations demonstrate how these TMDLs could be implemented to acheive water quality standards; however, the State reserves the right to revise these allocations provided the allocations are consistent with the acheivement of the water quality standard.

(b) Load Allocations for Nonpoint Sources

The in-stream concentration of CBOD from nonpoint sources is estimated to range from 1.5 mg/l to 16.5 mg/l. The in-stream concentration of NBOD is estimated to range from 0.22 mg/l to 10.5 mg/l. These are representative values determined from several water quality stations located on Antietam Creek during the summer stream surveys of 1996 and 1997. The average observed CBOD and NBOD concentrations were used for the final TMDL loading scenario. These CBOD and NBOD concentrations were multiplied by 7Q10 flow of 64 cfs at the Maryland/Pennsylvania line, the upper boundary of the model's spatial domain, and by each tributary 7Q10 flow in Maryland to produce the nonpoint source load allocation for these TMDLs. The nonpoint source loads that were assumed in the model account for both "natural" and human-induced components. The total load allocation for nonpoint source CBOD is 42,264 lbs/month and for nonpoint source NBOD is 30,253 lbs/month. The point source and nonpoint source allocations for CBOD and NBOD are summarized in Table 2.

Table 2. Point Source and Nonpoint Source Load Allocations

State	Nonpoint Sources *lbs/month*		Point Sources *lbs/month*	
	CBOD	NBOD	CBOD	NBOD
Maryland	30,799	22,340	65,073	84,967
Pennsylvania	11,465 [a]	7,913	-	-
Total	**42,264**	**30,253**	**65,073**	**84,967**

[a] Though it is incorporated as a nonpoint source in TMDL allocation calculations, it represents the total (combined point source and nonpoint source) BOD load contributions from Pennsylvania at the Maryland/Pennsylvania boundary line.

The nonpoint source load allocations were calculated based on the 7Q10 low flow. It must be made clear that the above load allocations assume no runoff loads due to rainfall. To allocate loads at higher flows, a more detailed analysis of the in-stream concentrations of water quality constituents would have to be performed. This TMDL document only allocates loads during 7Q10 conditions. The nonpoint source load allocations may increase above those as stated in the TMDLs for flows higher than the 7Q10 flow.

4.9 Future Allocation and Margin of Safety

Future allocations represent surplus assimilative loading capacity that is either currently available, or projected to become available due to planned implementation of the environmental controls or other changes. The CBOD and NBOD concentrations at the upper boundary of the Antietam Creek modeling domain (i.e., the Maryland/Pennsylvania line) are estimated to be 4.1 mg/l and 3.5 mg/l, respectively. It was determined that an additional 1.3 mg/l CBOD and 1.1 mg/l NBOD could be introduced at the upper boundary of the model and the in-stream water quality would be met at all downstream locations. The CBOD future load allocations for nonpoint and point sources are estimated to be 11,301, lbs/month and 11,955 lbs/month, respectively. The NBOD future load allocations for nonpoint source and point sources are estimated to be 9,052 lbs/month and 9,528 lbs/month, respectively. Model Run 2 predicts that these additional CBOD and NBOD loads are allowable in Antietam Creek without violating the in-stream dissolved oxygen.

Margin of Safety (MOS)

TMDLs must include a MOS in recognition of the uncertainties in our scientific and technical understanding of the water quality in natural systems. Specifically, we cannot know 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 waterbodies. The MOS is intended to account for such uncertainties in a manner that is conservative from the standpoint of protection of the environment.

Based on the EPA guidelines, the MOS can be achieved through one of two approaches, either 1) reserve a portion of the loading capacity as a separate term in the TMDLs or 2) incorporate the MOS as part of the waste load allocations (WLAs) and computation of the load allocations (LAs) (EPA, 1991). The CBOD and NBOD TMDLs for Antietam Creek employ both of these approaches. In these TMDLs, a 4,593 lbs/month and 4,668 lbs/month loading capacity was set aside as the MOS for CBOD and NBOD, respectively. Model Run 2 incorporated a MOS for CBOD and NBOD at the tributary boundaries of the model and at each WWTP. The MOS at the tributary boundaries of the model was 5 percent of the total nonpoint future load allocation. The MOS at each WWTP was calculated as 25 percent of the difference between the weekly and monthly effluent permit limits. This is considered an appropriate MOS because it is unlikely that the WWTPs will go above their monthly limit more than a quarter of the time during a month. In addition to the set-aside CBOD and NBOD MOSs, the design conditions for the WLA, LA, and the future allocation (FA) computations include two implicit MOSs. First, the critical condition of the 7Q10 flow constitutes a worst case scenario because its use builds a conservative assumption into the TMDLs. Second, all the modeling was done using the NPDES monthly permit limits for effluent concentrations. The monthly limits are conservative because they represent an upper limit, which the WWTP will strive not to exceed to avoid paying a fine. In addition, the large FAs implicitly include a MOS for both the point and nonpoint sources. The future allocation and MOSs can be seen in Table 3.

Table 3. Future Allocation and Margin of Safety

State	Future Allocation				Margin of Safety			
	Nonpoint Sources *lbs/month*		Point Sources *lbs/month*		Nonpoint Sources *lbs/month*		Point Sources *lbs/month*	
	CBOD	NBOD	CBOD	NBOD	CBOD	NBOD	CBOD	NBOD
Maryland	10,136	6,104	11,955	9,528	1,540	1,117	2,480	3,155
Pennsylvania	1,165	2,948	-	-	573	396	-	-
TOTAL	**11,301**	**9,052**	**11,955**	**9,528**	**2,113**	**1,513**	**2,480**	**3,155**

4.10 Summary of Total Maximum Daily Load

The low-flow TMDLs, applicable from May 1 - October 31, for Antietam Creek, equated with illustrative allocations are:

For CBOD (lbs/month)

TMDL	=	LA	+	WLA	+	FA	+	MOS
135,186	=	42,264		65,073		23,256		4,593

For NBOD (lbs/month)

TMDL	=	LA	+	WLA	+	FA	+	MOS
138,468	=	30,253		84,967		18,580		4,668

Where:

LA = Load Allocation or Nonpoint Source
WLA = Waste Load Allocation or Point Source
FA = Future Allocation
MOS = Margin of Safety

5.0 ASSURANCE OF TMDL IMPLEMENTATION

This section provides the basis for reasonable assurances that the CBOD and NBOD TMDLs will be achieved and maintained. The certainty of implementation of the CBOD and NBOD in this watershed will be enhanced by two specific programs: the Water Quality Improvement Act of 1998 (WQIA) and the EPA-sponsored Clean Water Action Plan of 1998 (CWAP) and through enforceable NPDES permits for the wastewater dischargers in the basin.

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 phosphorus nutrient management plans be developed and implemented by 2004. Implementation of the nutrient management plan will also result in a reduction of nonpoint CBOD and NBOD loads.

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.

Enforceable NPDES permits that will be written for the wastewater dischargers in this basin provide confidence in assuring implementation of this TMDL. The implementation of point source CBOD and NBOD controls will be executed through the use of NPDES permits.

In addition, 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 these 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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